Master's degree thesis

LOG950 Logistics

Exploring the Potential of Blockchain-based Circular Supply Chains in the Textile Industry. A Case Study of H&M Group and Skogstad Sport.

Sivert Myrold

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Preface

This master thesis marks the end of the two-year Master of Science in Logistics program at Molde University College. The research for this thesis was carried out between January and May 2023.

First and foremost, I would like to extend my gratitude to my supervisor, Bjørn Jæger, for the guidance and support throughout the writing process. I appreciate our insightful discussions about the thesis and your continuous feedback on my work.

I would like to thank the case companies for participating in the research and their enthusiasm in answering my questions in the interviews and inquiries via mail. In addition, I want to thank Nikhil Varma for providing an expert opinion and answering any blockchain-related questions.

I am grateful to my classmates for all the good conversations during our lunch breaks and the numerous chess games in the library, which provided a much-needed break from the writing process and helped me stay motivated and gain new insights and perspectives on my research.

Sivert Myrold

22.05.2023

Abstract

As the second largest polluting industry in the world, the textile industry is experiencing increased stakeholder pressure to improve sustainability. Implementing the principles of the circular economy across all supply chain stages can help the industry become more sustainable. Blockchain technology is a potential enabler of such circular supply chains. Therefore, the purpose of this research was to explore the potential of blockchain technology as an enabler to move toward circular supply chains in the textile industry.

The research employed a qualitative research design with an explorative purpose. Using an embedded multiple case study, this research first mapped current measures taken in the textile industry to promote a circular economy and explored how circular supply chains can further improve circularity in the industry. Secondly, the research explored the potential of blockchain technology to see if its properties can match the needs of circular supply chains in the textile industry. Data was collected through semi-structures interviews with the case companies and the blockchain expert and secondary data sources.

This research found that there are significant opportunities for resource recovery in the textile industry and that current efforts to implement a circular economy are often siloed. An open loop system with closer collaboration across the supply chain and with cross-sector partners in secondary supply chains is needed to move toward more circular supply chains. However, the research concluded that a better technical solution is required to improve supply chain transparency and traceability to facilitate collaboration. This research suggests that a public blockchain is the best technical solution to enable circular supply chains in the textile industry. By removing the need for trust, a public blockchain increases transparency and traceability and allows textile companies to collaborate with unknown supply chain partners and cross-sector partners. This creates highly traceable products that enable circular material flows, improve resource recovery, and reduce textile waste and emissions. Successful implementation requires effective change management and all stakeholders to participate. However, a lack of regulations and standards and the high investment costs could make this challenging. Nevertheless, implementing blockchain-based circular supply chains can create economic, environmental, and social value across the textile industry, including reducing emissions and ensuring fair labor practices.

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1.0 Introduction

1.1 Background

The textile industry is the second largest polluting industry in the world. The industry's carbon emissions exceed those of all maritime transportation and international flights, resulting in significant social and environmental impacts throughout its supply chain (de Aguiar Hugo, de Nadae, and da Silva Lima 2021). The industry experience increased stakeholder pressure to improve sustainability (MIT 2022). As Brundtland (1987) defined, sustainability is "development that meets the needs of the present without compromising the ability of future generations to meet their needs." In March 2022, the European Commission presented the EU strategy for sustainable and circular textiles to address issues such as fast fashion, textile waste, the disposal of unsold textiles, and unethical labor practices (European Commission 2022). The circular economy (CE) offers a more sustainable alternative to the linear economy that follows a take-make-dispose model (Farooque et al. 2019). The CE represents a fundamental shift in economic systems, decoupling economic growth from the consumption of the earth's finite resources, and can make the textile industry more resilient and regenerative (Hofmann 2019). According to de Jesus and Mendonça (2018), technology innovation is an essential driver in facilitating the shift towards a CE. Technology also has a vital role in the EU strategy for sustainability and circular textile with their plan to make digital product passports (DPP) mandatory on all textile products sold in the EU by 2030. The DPP is a first-of-its-kind regulatory circularity tool to create transparency by collecting and storing product data throughout a product's life cycle and sharing it across the entire supply chain (WBCSD 2023).

Although CE can address issues such as fast fashion, textile waste, the disposal of unsold textiles, and unethical labor practices, the textile industry is dependent on levers and enablers to implement CE. Levers are tools and practices, such as supply chain management, that companies can leverage to implement CE. Enablers are factors, such as blockchain, that facilitate the implementation of levers (Bressanelli et al. 2021). To address these problems, this research aims to explore blockchain's potential as a CE enabler to move toward circular supply chains in the textile industry. Blockchain is a decentralized, distributed ledger technology (Crosby et al. 2016). Blockchain technology has generated a lot of interest in various business applications since the publication of Satoshi Nakamoto's white paper on Bitcoin in 2008 (Nakamoto 2008), especially applications for SCM (Crosby et al. 2016). However, since blockchain technology and the move toward circular supply chains are still in their early stages, this approach has a considerable amount of uncertainty. Therefore, this research will contribute to mapping current measures taken in the textile industry to promote CE and explore strategies for further improving circularity in the industry, especially the research will explore blockchain technology to see if its properties can match the needs of circular supply chains in the textile industry.

1.2 Research questions

There is both practical and scientific interest in researching CE in the textile industry because it offers a chance to solve current problems such as fast fashion, textile waste, the disposal of unsold textiles, and unethical labor practices. With the textile industry being the second largest polluting industry in the world and the proposed EU strategy for sustainable and circular textiles, there is also both practical and scientific interest in researching how the textile industry can move towards more circular supply chains. Therefore, the first research question is:

RQ1: How can the textile industry move towards more circular supply chains?

As mentioned in the previous section, the textile industry depends on levers and enablers to implement CE. The first research question explores circular supply chains as a CE lever. Therefore the second research question will explore an enabler that can facilitate the move towards more circular supply chains in the textile industry. Bressanelli et al. (2021) present a framework for researching CE, see Figure 1. The framework builds on three layers: (1) CE enablers that can facilitate the implementation of CE levers, (2) CE levers that support the implementation of CE, and (3) potential benefits that may be obtained from the adoption of CE enablers and levers, under the triple bottom line perspective of sustainability, i.e., economic, environmental, and social benefits.

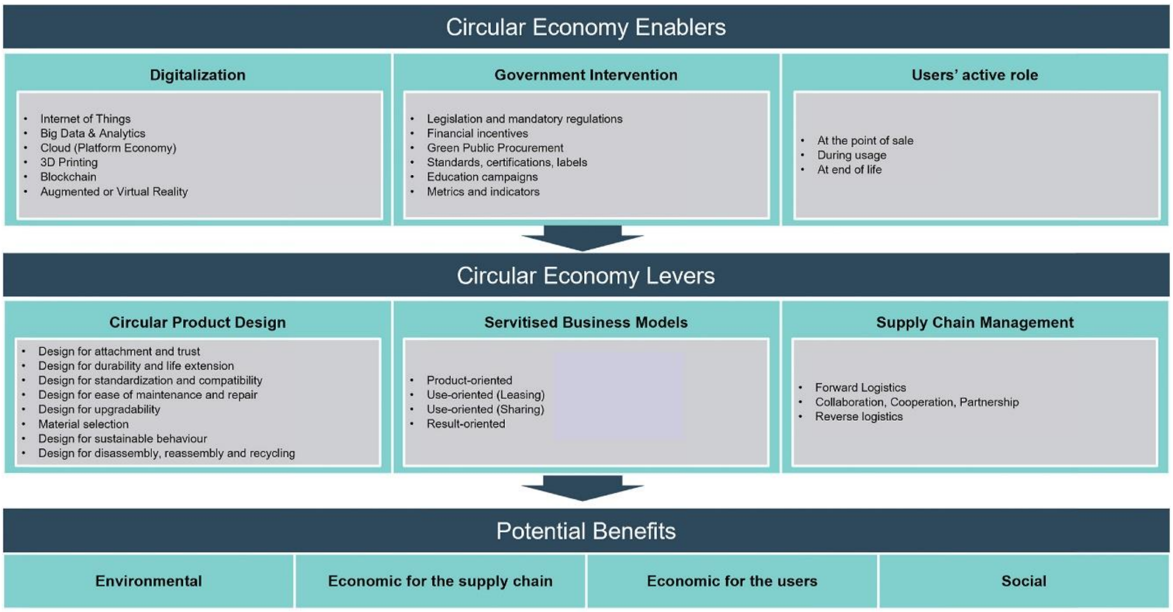

Figure 1. CE enablers, levers, and potential benefits (Bressanelli et al. 2021).

According to this research framework, one can move towards circular supply chains using CE enablers like blockchain to leverage supply chain collaboration and reverse logistics. Based on this framework, there is practical and scientific interest in exploring blockchain technology to see if its properties can match the needs of circular supply chains in the textile industry. Therefore, the second research question is:

RQ2: How can blockchain technology support circular supply chains in the textile industry?

1.3 Research methodology

The "Research onion" framework by Saunders, Lewis, and Thornhill (2016) serves as a basis for the methodology used in this research. A pragmatic research philosophy is employed. Therefore, the research acknowledges that there are numerous ways to interpret the world and conduct research (Saunders, Lewis, and Thornhill 2016). The approach to theory development is inductive. The research moves from collecting data from the case companies, H&M Group and Skogstad, to generalizing the findings in the textile industry. This research employs a qualitative research design with an explorative purpose. An embedded multiple case study is used to answer both research questions. The primary data collection strategy is semi-structured interviews with the case companies for RQ1 and RQ2 and the blockchain expert for RQ2. Secondary data is also collected to answer the research questions.

1.4 Structure of the thesis

The thesis is organized as follows. Chapter 2 provides a literature review on relevant topics, including supply chain management, circular economy, and blockchain technology. Chapter 3 provides a case description of the current state of the textile industry, the EU strategy for sustainable and circular textiles, and the case companies participating in this research. Chapter 4 provides the research methodology employed to address the research questions. The findings from the case study are presented in chapter 5. Chapter 6 discusses circular economy, circular supply chains and potential technical solutions, and blockchain-based circular supply chains in the textile industry. Finally, chapter 7 provides a research summary, limitations, and suggestions for further research.

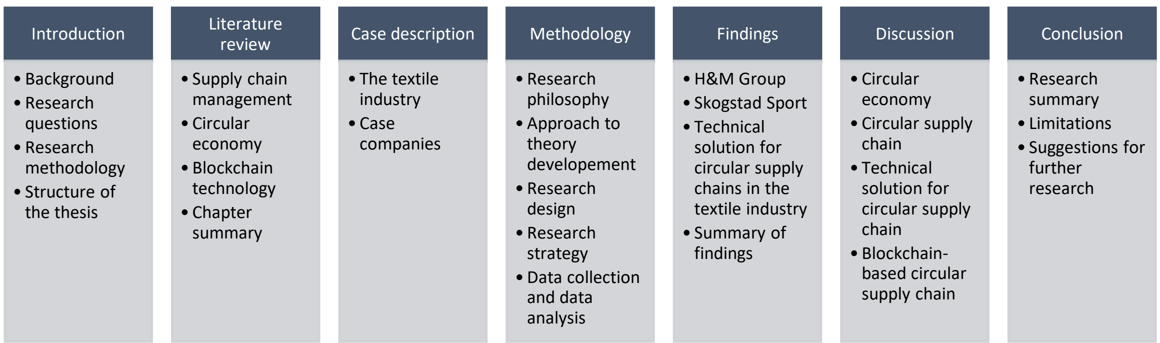

Figure 2. Structure of the thesis.

2.0 Literature review

2.1 Supply chain management

Supply chain management (SCM) is an essential part of most companies (CSCMP 2013). Harrison et al. (2019) define a supply chain as “a network of partners who collectively convert a basic commodity (upstream) into a finished product (downstream) that is valued by end-customers and who manage returns at each stage”. The analogy of the flow of water in a river is used to describe the positioning of partners in the supply chain. Those located closer to the source of raw materials are referred to as upstream partners, and those closer to the end customer are referred to as downstream partners. Each partner in the supply chain is responsible for a process that adds value to the product (Harrison et al. 2019). The traditional linear supply chain involves a primary flow of materials from raw material extraction through production and end-customer, and finally to disposal (Farooque et al. 2019). The focal firm is embedded in the supply chain and must coordinate its internal logistics with the other actors in the supply chain. The supply chain is structured into tiers, grouping supply chain partners based on their relationship with the focal firm. Tier one suppliers deliver directly to the focal firm, while tier two suppliers deliver to the tier one suppliers, and so forth (Harrison et al. 2019). An illustration of the supply chain is shown in Figure 3.

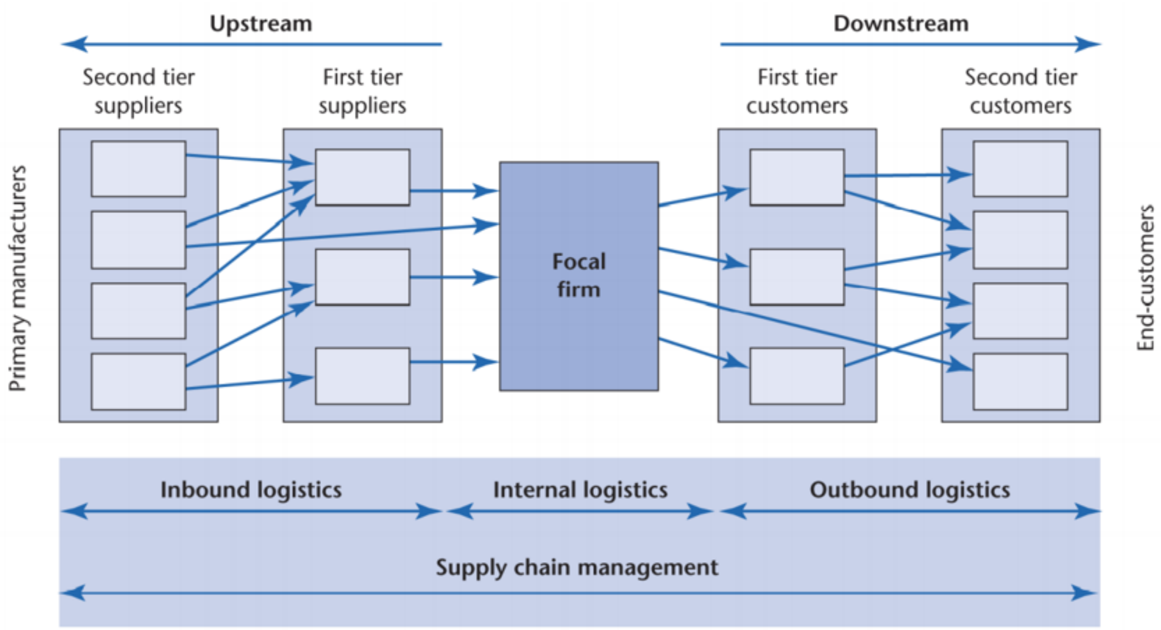

Figure 3. The supply chain (Harrison et al. 2019).

SCM is the end-to-end management of the entire supply chain, with the focus being on integrating the processes of the different supply chain partners (Harrison et al. 2019). SCM aims to ensure getting the right product, in the right quantity, in the right condition, at the right place, at the right time, to the right customer, and at the right price. The efficient completion of SCM processes such as planning, procurement, production, and distribution is crucial to provide high product availability and fulfilling customer demands (CSCMP 2013). The definition of SCM used in this research is adapted from the Council of Supply Chain Management Professionals: "SCM encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies" (CSCMP 2013).

2.1.1 Sustainability in supply chain management

According to the State of Supply Chain Sustainability 2022 report by MIT (2022), companies experience increasing stakeholder pressure to improve supply chain sustainability. Global supply chains can make a positive impact on our society. SCM professionals have the choice of who they choose to do business with, where they do business, and what and how they deliver (MIT 2022). The famous Brundtland (1987) report defined sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet their needs". The notion of incorporating sustainability into SCM is based on the triple bottom line (TBL) framework. The TBL framework evaluates supply chain performance based on the three pillars of sustainability, namely social, economic, and environmental. Companies should not only focus on maximizing profits, but also measure their social and environmental impact throughout their supply chains (Farooque et al. 2019).

MIT (2022) defines supply chain sustainability as "the management of environmental and social impacts within and across networks consisting of suppliers, manufacturers, distributors, and customers in line with the UN Sustainable Development Goals. This spans every phase of the supply chain, from raw material sourcing and extraction to product use and end of product life". Using the UN Sustainable Development Goals is a good way to understand how SCM can contribute to sustainability. While the three pillars of sustainability are a useful starting point, the UN Sustainable Development Goals provide a series of more specific goals for reaching sustainable development, see Figure 4. Companies’ supply chain activities impact several of these goals. Therefore these goals should impact the way companies manage their supply chains (Johnsen et al. 2019).

Figure 4. The UN Sustainable Development Goals (United Nations).

2.1.2 Transparency in supply chain management

Supply chain transparency is becoming increasingly important in SCM, especially in improving sustainability. This is because companies are facing increasing pressure from stakeholders such as governments, consumers, and NGOs to disclose more information about their supply chains. Failing to comply could have huge financial impacts and reputational damage to companies (Bateman and Bonanni 2019). Transparency in supply chains refers to the extent to which product-related data is accessible and commonly understood by all stakeholders within the supply chain. Traceability is an integral tool for achieving transparency in supply chains (Adhi Santharm and Ramanathan 2022). Therefore, tracking and tracing products in the supply chain is important in SCM. Technology, such as RFID, helps track supply and demand data across the supply chain. However, sustainability requires a higher level of traceability. As global supply chains become more complex, it is becoming harder for companies to maintain transparency and control over what their products actually contain. The 2013 horse meat scandal is a good example of this issue. Retailers such as Tesco and IKEA discovered that some of their products, labeled and sold as beef by their suppliers, contained horse meat. This scandal exposed the inability of companies to trace their products throughout their supply chains (Johnsen et al. 2019).

2.2 Circular economy

The circular economy (CE) offers the opportunity to address issues such as fast fashion, textile waste, the disposal of unsold textiles, and unethical labor practices in the textile industry. It represents a fundamental shift in economic systems, breaking the connection between economic activity and consumption of the earth's finite resources and making systems more resilient and regenerative (Murphy 2022). The CE is gaining momentum as a more sustainable alternative to the traditional linear economy based on the take-make-dispose model. CE is becoming a powerful driving force for sustainability and is being acknowledged as a key solution for organizations to significantly improve their environmental performance (Farooque et al. 2019). There are various definitions of the CE. However, in this research, I have chosen the definition provided by Geissdoerfer et al. (2017) based on their definition literature review stating that "The circular economy is a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (Geissdoerfer et al. 2017).

Several schools of thought inspire the concept of CE. The concept of CE was introduced by environmental economists Pearce and Turner (1989), building upon earlier work by ecological economist Boulding (1966). In his 1966 work, "Economics of the Coming Spaceship Earth", Boulding proposed the idea of the Earth as a "closed spaceship" with finite resources and proposed a circular system to maintain the sustainability of human life on Earth (Ghisellini, Cialani, and Ulgiati 2016).

The development of CE as an economic system has since been influenced by several theoretical closed-loop concepts, including industrial ecology, cradle-to-cradle, the performance economy, biomimicry, and the blue economy (Geissdoerfer et al. 2017). Industrial ecology utilizes the principles of natural ecosystems to design industrial systems that reduce their impact on the environment by closing energy and resource loops. Industrial ecology views the industrial system in concert with its surrounding systems and not in isolation (Andersen 2007). Cradle-to-cradle is a product design approach that aims to mimic natural systems by designing products that can be easily broken down and re-used or recycled as either biological nutrients for the environment or as raw materials for industry. This concept involves designing a closed-loop system where all materials are continuously cycled and regenerated with no waste (McDonough and Braungart 2010). The performance economy is a closed-loop economy focusing on reusing, repairing, and remanufacturing. It addresses the deficiencies of the industrial economy and calls for a change in economic thinking from 'doing things right' to 'doing the right things' (Stahel 2010). Biomimicry is the practice of observing and mimicking nature's strategies to solve design challenges. It involves studying organisms, biological processes, and ecosystems to inspire design solutions (Benyus 1997). The Blue Economy is an economic model where ecosystems are regenerated using a mindset of abundance and self-sufficiency by mimicking nature's methods and working in harmony with it (Pauli 2010).

2.2.1 The principles of circular economy

The CE is based on three principles: eliminating waste and pollution, keeping products and materials in use at their highest value, and regenerating natural systems (Murphy 2022).

2.2.1.1 Eliminating waste and pollution

Eliminating waste and pollution can be done before it even is created by focusing on the upstream design. The current linear economy has a take-make-dispose system. We take virgin materials, make products out of them, and deposit them at the landfill at the end of the product's life. This is not a sustainable system due to our resources being finite. The Ellen MacArthur Foundation (2019) emphasizes that the problem and the solution start with the design. Most products today are designed to be disposable. Waste is often perceived as an inevitable outcome in certain scenarios. However, it is a direct consequence of design choices. We introduced the concept of waste because there is no waste in nature. Our economy is filled with products that have been designed without considering their end-of-life consequences. Thus, to eliminate waste and pollution in CE, products should be designed to re-enter the economy at their end of life (Ellen MacArthur Foundation 2019).

2.2.1.2 Circulating products and materials at their highest value

The CE differentiates products' biological and technical cycles. The biological cycle involves returning the nutrients from biodegradable materials back to the biosphere (Ellen MacArthur Foundation 2019). In the technical cycle, products and materials are kept in circulation through means such as reuse, repair, remanufacture, and recycling. The most efficient way to preserve the value of products is through maintenance and reuse. Thus, the focus in the technical cycle is to keep products at their highest value as long as possible. At first, this could be done through business models based on sharing or resale, the next cycles of maintenance and repair. When a product reaches the end of its useful life, its components can be remanufactured. Any parts that cannot be remanufactured can be dismantled and recycled. Although recycling is the last resort, as it results in the loss of embedded value, it is crucial as it enables materials to remain in the economy and avoid ending up as waste. To circulate products and materials, products must be designed with their eventual circulation in mind. In our current economy, a lot of products cannot be circulated because they combine technical and biological materials (Ellen MacArthur Foundation 2019). The Ellen MacArthur Foundation (2019) has illustrated the biological and technical cycles in the butterfly diagram, see Figure 5.

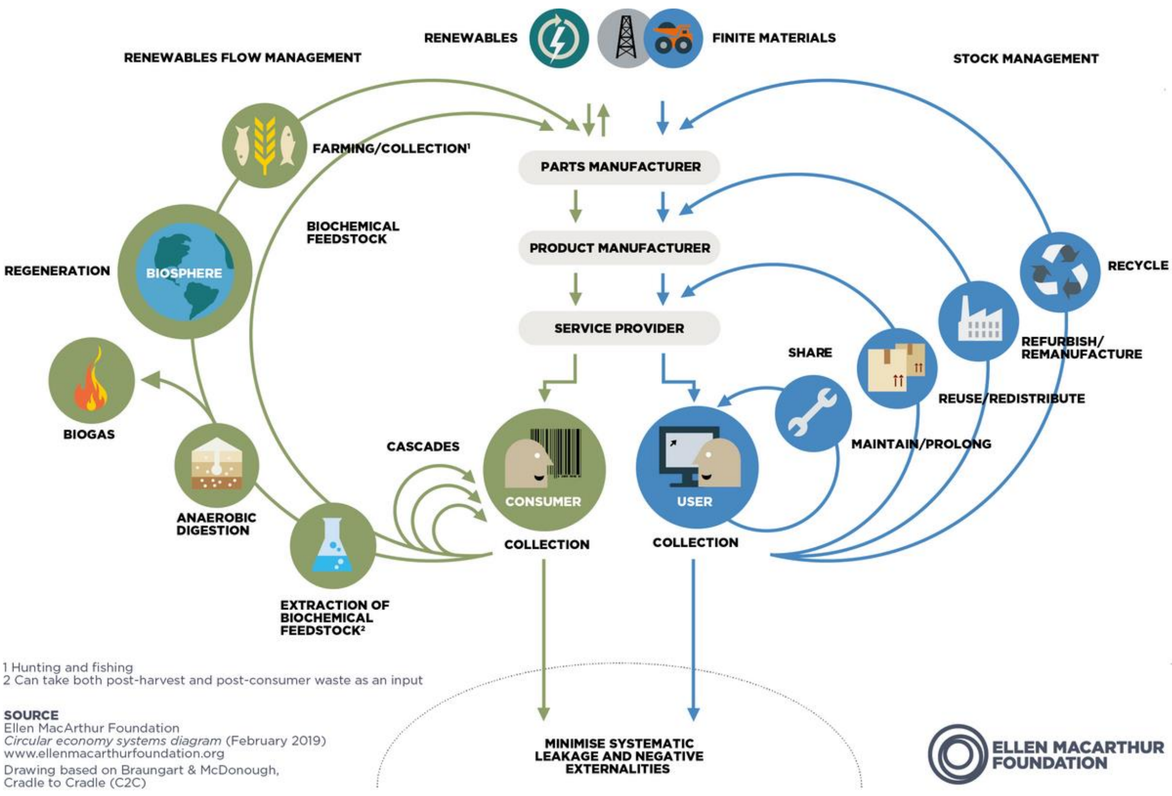

Figure 5. The butterfly diagram (Ellen MacArthur Foundation 2019)

2.2.1.3 Regenerate natural systems

The CE goes beyond just reducing negative impacts on the environment, and it actively works to improve it. The focus is on regenerating resources rather than exploiting them. By implementing farming practices that promote soil fertility and biodiversity and return biological materials to the earth, CE strives to build natural capital. A regenerative model emulates natural systems where waste does not exist. The CE aims to mimic nature's regenerative processes, thus providing a sustainable and regenerative system that benefits the environment. Retaining products and materials in use reduces the need for land to be used for obtaining virgin materials. As we gradually break the link between economic activity and material extraction by keeping materials in circulation, more land can be returned to nature, and rewilding can happen (Ellen MacArthur Foundation 2019).

2.2.2 Circular product design strategies

Designing products and services that promote material and energy recirculation is crucial in CE. The design process must embrace CE principles to impact the entire value chain (Farooque et al. 2019). The concepts of slowing, closing, and narrowing of resource loops are used to distinguish CE models from linear models according to how resources flow through a system. Slowing resource loops refers to the product life extension through design and service loops, resulting in a slower flow of materials. Closing resource loops involves recycling, closing the loop between post-use and production. Narrowing resource loops refers to reducing the number of resources that are used per product but does not address the cyclic use of products and materials (Bocken et al. 2016).

Extending the lifespan of products through design strategies can reduce resource usage because existing products do not require new resources to be produced. There are two major design strategies for slowing resource loops: designing long-life products and designing for product life extension. Designing long-life products involves enhancing both emotional and physical durability and reliability to extend the product's lifespan. Designing for product-life extension involves incorporating service loops like maintenance, repair, upgradability, standardization, disassembly, and reassembly (Bocken et al. 2016).

Design strategies for closing resource loops aim to promote circular flows of materials in product design and focus on the Cradle-to-Cradle design philosophy. The two main design strategies to close resource loops are "design for a technological cycle" and "design for a biological cycle" (Bocken et al. 2016). As presented in the previous section, the CE differentiates between the biological and technical cycles. The goal of designing for the technological cycle is to develop products so that their materials can be recycled into new materials or products. The difference between upcycling and downcycling is stressed in designing for the technological cycle. Downcycling is viewed as a linear progression of resources from production to waste, which does not align with circular design principles. Designing for the biological cycle aims to design products of consumption that are safe and healthy and can be biodegraded to provide food for natural systems (Bocken et al. 2016).

2.2.3 Circular business models

Business Models are simplified explanations of how an organization creates, delivers, and captures value for its stakeholders (Hofmann 2019). Circular business models (CBMs) are designed to create and capture value by slowing, closing, and narrowing material and energy loops. This approach shifts the focus from generating profit from product sales to making profit through the circular flow of resources, materials, and products. The goal of CBMs is to restructure existing markets by keeping products at their highest value as long as possible, reducing the need for virgin materials. Therefore, by adopting CBMs, companies can minimize negative environmental impacts while still creating value (Hofmann 2019).

2.2.3.1 Business model innovation

Implementing CBMs requires organizations to redesign and innovate their linear business models. Business model innovation (BMI) is a holistic approach to achieving change in organizations. Innovating and introducing new business models quickly and effectively can give organizations a competitive advantage. Geissdoerfer et al. (2020) define BMI as "the conceptualization and implementation of new business models that can comprise the development of entirely new business models, the diversification into additional business models, the acquisition of new business models, or the transformation from one business model to another. The transformation can affect the entire BM or individual or a combination of its value proposition, value creation and deliver, and value capture elements, the interrelations between the elements, and the value network".

2.2.3.2 Circular business models

Accentura (2014) proposed five underlying CBMs based on more than 120 case studies, see Figure 6. The five CMBs are 1) circular supplies, 2) resource recovery, 3) product life extension, 4) sharing platforms, and 5) product as a service and are briefly described in the following section:

The circular supplies business model focuses on using fully renewable, recyclable, or biodegradable resources as production inputs instead of virgin materials. It involves phasing out the use of scarce resources while reducing waste and increasing efficiency. This business model is best suited for organizations that work with scarce resources or have a significant environmental impact (Accentura 2014; Chong-Wen 2020).

The resource recovery business model focuses on recovering value from end-of-life products through recycling and upcycling. Utilizing new technologies, this business model aims to recover resources of equal or greater value than the initial input and repurpose them into new products or energy. This not only reduces waste but also maximizes the economic value of returned products, making it suitable for organizations that generate high volumes of by-products or can cost-effectively reclaim and reprocess waste materials (Accentura 2014).

Product life extension aims to extend the lifecycle of products. Values that would be wasted through discarded materials can be retained or even enhanced by reselling, repairing, or remanufacturing, generating more revenue, see Figure 6. By using this approach, organizations can keep their products at the highest value as long as possible, and product upgrades can be done more precisely, e.g., replacing a specific component instead of the entire product (Accentura 2014).

The Sharing Platform business model creates a platform for product users to collaborate and share resources such as excess capacity or underutilized assets. By sharing resources, waste can be reduced, and resource efficiency improved. This business model can be beneficial for organizations that have low utilization or ownership rates for their products and assets (Accentura 2014).

The Product as a Service model is an alternative to buying and owning products. Organizations provide a rental or pay-per-use arrangement for their products instead of selling the whole product. This model focuses on high performance over high sales volume, with revenue and cost reduction coming from the product's longevity, reusability, and shared usage (Accentura 2014; Chong-Wen 2020).

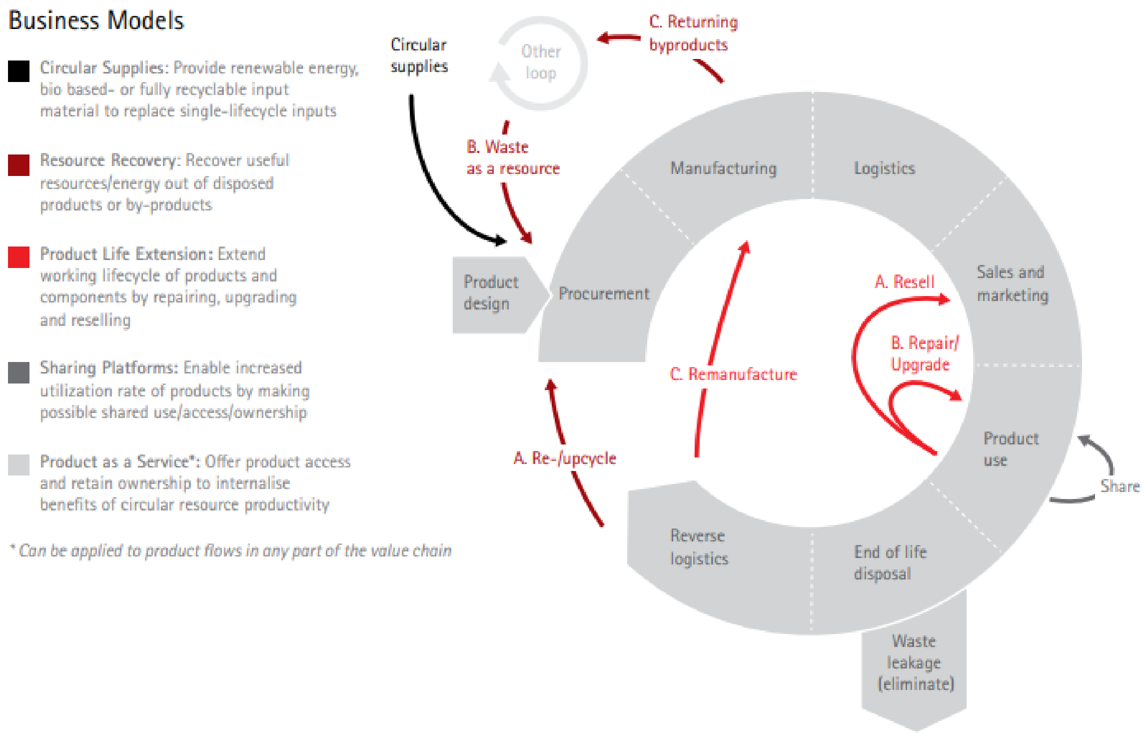

Figure 6.The five circular business models (Accentura 2014)

2.2.3.3 Why implement circular business models

According to Hofmann (2019), the reasons for implementing CBMs are to decouple economic growth from natural resource consumption and to enhance resilience. CBMs decouple economic growth from the utilization of natural resources by transitioning from linear business processes to circular value-creation practices, which leads to the idea of dematerialization, where companies move away from tangible products and instead offer services and capabilities. The shift towards immateriality is primarily driven by the reasoning that providing services could present new opportunities for growth while also decreasing absolute resource and energy consumption. Circular value propositions, such as leasing, rental, or performance contracting, can create new opportunities to connect with customers and build long-term relationships (Hofmann 2019). CMBs also lead to greater independence and autonomy from international commodity markets. This is because CBMs can help companies become more resilient and robust by using recycled materials or taking ownership of products through service-oriented and performance-oriented BMs, which can ensure operational reliability. This is important due to the increasing volatility of raw material prices, growing resource scarcity, and the potential risks of supply shortages and production inputs being affected by geopolitical and natural events (Hofmann 2019).

2.2.3.4 Core principles of integrating circular business models

According to Hofmann (2019), the adoption of new technologies such as blockchain, IoT, and big data can facilitate the implementation of new CBMs. These digital technologies allow organizations to convert autonomous products into smart, connected ones, enabling the implementation of product-service systems and reverse logistics. Sensors and tracking systems can facilitate real-time data collection, making it easier to monitor and manage products across the supply chain (Hofmann 2019). To establish successful collaborative CBMs, it is crucial for organizations to actively engage with all stakeholders. Stakeholders play a vital role in providing the resources necessary for value creation and are also greatly impacted by the CBM's activities. Thus, effective stakeholder management is key to successfully implementing CBMs (Hofmann 2019). The shift from linear to circular business models requires organizations to redesign their supply chains to prioritize collaboration and the creation of circular value. For this transition to be successful, the business models of the various supply chain actors must be compatible. Close relationships and communication are necessary to ensure sufficient volumes of products and materials both upstream and downstream in the supply chain (Hofmann 2019).

2.2.4 Circular supply chain management

Integrating CE principles into SCM is important for companies to remain competitive in today's socio-economic and environmental context (Batista et al. 2019). Circular SCM promotes sustainability by incorporating the principles of the CE throughout all stages and functions of the supply chain. This approach can be used for both manufactured products and service products. It involves collaboration with partners within and outside the industry to optimize the use of goods and materials. It presents a promising approach for supply chain managers to significantly improve resource efficiency and profitability while reducing negative environmental, social, and economic impacts (Farooque et al. 2019). Farooque et al. (2019) define circular SCM as "the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management, involving all stakeholders in a product/service lifecycle including parts/product manufacturers, service providers, consumers, and users".

Circular SCM aims to transition to circular supply chains. Implementing resource recovery processes within and between organizations brings an increased complexity to the design of a supply chain. Resource recovery in circular supply chains includes both reverse and forward flows of products, materials, and energy. A revers logistic approach to resource recovery is through a reverse flow of resources in the supply chain of a focal company, thus functioning as a closed-loop system. Forward flows of resources into secondary supply chains are a form of resource recovery in an open-loop system. Circular supply chains are a holistic approach and encompass all supply chain loops enabling maximum resource recovery (Batista et al. 2019). Farooque et al. (2019) illustrate in Figure 7 the contrast between a circular supply chain with a traditional linear supply chain and a closed-loop supply chain.

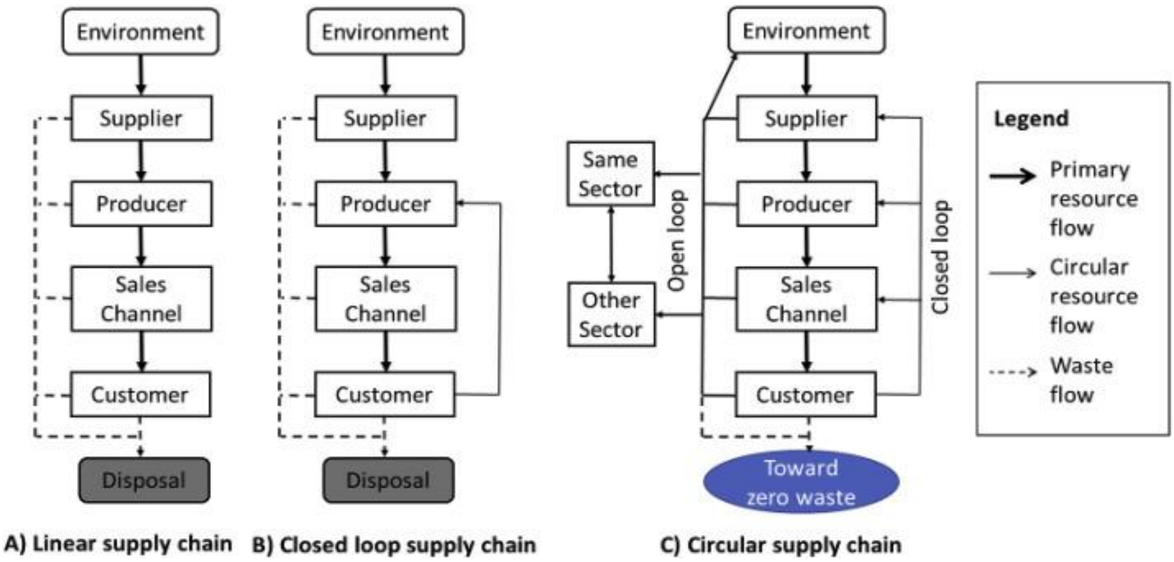

Figure 7. Linear, closed-loop, and circular supply chains (Farooque et al. 2019)

A linear supply chain extracts virgin materials and discards end-of-life products and waste from multiple stages of the supply chain. A closed-loop supply chain improves environmental performance with a reverse logistic approach by recovering value from goods and packaging materials and returning them to the producer. However, the extent of value recovery in a closed-loop supply chain is often limited, as it does not include secondary supply chains. It also generates substantial amounts of waste, as it is not always possible to reuse or recycle all materials within the same supply chain (Farooque et al. 2019).

Circular supply chains consist of a primary flow and several different circular resource flows. Primary resource flows refer to the forward flow of goods in linear supply chains. Circular resource flows refer to both the reverse and forward circular flow of products, materials, and energy, including by-products and waste (Farooque et al. 2019). In practice, the aim is to achieve zero waste by implementing system-wide innovations to recover value from what was previously considered waste (Farooque et al. 2019). However, recovered materials don't always add value within the same supply chain, so circular supply chains must collaborate with cross-sector partners in other industries to maximize the value recovered from waste by creating an open loop system. For example, used cooking oil from a food supply chain can be refined and used to produce biodiesel in a secondary supply chain (Farooque et al. 2019). Collaboration between actors across the supply chain and cross-sector partners is required to implement the different loops in a circular supply chain. Batista et al. (2019) argue that the relationships between all relevant stakeholders determine the efficiency of the circular supply chain. Thus, circular supply chains are enabled by close supply chain collaboration with partners within and outside the industry (Batista et al. 2019). Laws and regulations also play an important role, and can both facilitate and hinder the implementation of loops connecting circular supply chain actors (Batista et al. 2019).

2.2.5 Drivers and barriers in the shift toward a circular economy

Drivers are factors that enable and encourage the shift towards CE, while barriers are bottlenecks hindering the transition to CE (de Jesus and Mendonça 2018). A transition to CE is not a linear process aimed at achieving maximum profit. It is a dynamic, co-evolutionary, multi-actor process affecting economic development and social and environmental spheres. Thus, implementing CE requires increased involvement from stakeholders. Two approaches have emerged: a top-down approach driven by government policy and a bottom-up approach driven by enterprise and environmental organizations (Böhmecke-Schwafert, Wehinger, and Teigland 2022).

In their research, de Jesus and Mendonça (2018) identified two types of factors that influence the transition: "harder" factors, including technical and economic factors, and "softer" factors, including institutional and social factors. They found that the transition to a CE is mainly hindered by harder factors, including the lack of available technology and high investment costs. However, softer factors, such as effective public policies, consumer awareness of environmental issues, and demand for environmentally friendly products, drive the shift towards a CE (de Jesus and Mendonça 2018).

Technological factors are fundamental drivers in the shift towards CE, enabling resource optimization, re-manufacturing, and the regeneration of by-products for use in other processes. The sharing economy, empathized in the CE, also relies on technological advancements (de Jesus and Mendonça 2018). Innovation has the potential to enhance the quality of products, extend product lifecycles, facilitate the implementation of new circular business models, and support systemic integration (Böhmecke-Schwafert, Wehinger, and Teigland 2022). Technology innovation is an important driver in facilitating the recovery and reuse of materials. Dematerialization of products, which is an important aspect of CE, is also driven by technological innovation. Thus, the availability of technical solutions has become a significant barrier to shifting towards CE. These challenges include not only the existence of suitable technology (technological thresholds), but also technology gaps, such as those stemming from lags in processes and product development, invention and production, and a lack of adequately trained personnel (de Jesus and Mendonça 2018).

Financial drivers are important factors in the shift towards CE. With increasing levels of resource consumption, dependence, depletion, and volatility, the need to decouple revenues from material input and enhance resource efficiency has become a significant driver for companies to adopt circular business models. Significant financial barriers in the shift towards CE are related to high investment costs, as well as the difficulty in overcoming linear economic lock-ins. Despite the potential benefits, technical innovations that drive the CE have high initial investment costs and market uncertainty. For small and medium-sized enterprises (SMEs), the high investment costs are an even larger barrier in the transition to CE (de Jesus and Mendonça 2018).

In the textile industry, a significant financial barrier in its shift towards CE is that slow fashion cannot compete with fast fashion. A fundamental principle of circular fashion is to extend the lifespan of products to reduce consumption. However, the economic sustainability of slow fashion cannot compete with large-scale fast fashion companies, which benefit from economies of scale (de Aguiar Hugo, de Nadae, and da Silva Lima 2021). According to a study by de Aguiar Hugo, de Nadae, and da Silva Lima (2021), companies that prioritize slow fashion experience reduced profits and sales, as well as a significant reduction in inventory turnover.

Institutional and regulatory drivers are important for the transition to CE. The focus is on implementing public policies to tackle market failures while also creating a favorable environment for innovation and entrepreneurship. The government has a key role in promoting an institutional framework by revising existing laws, introducing new regulations, advocating for the use of innovative technologies, and organizing public education (de Jesus and Mendonça 2018). This is because sustainability is regarded as a collective good, and there are few incentives for private actors to partake in such transitional processes without institutional support and incentives. Policies like tax reduction on renewable resources and educational programs on CE can drive the transition to CE (Böhmecke-Schwafert, Wehinger, and Teigland 2022).

There are several social drivers of CE. Some of the most prominent are increasing consumer awareness of environmental issues, shift in customer preferences, and businesses recognizing the reputational benefits of transitioning to CE (de Jesus and Mendonça 2018). However, in their research, de Jesus and Mendonça (2018) found that customers' desire and acceptance of circular business models are only slowly increasing. Slow acceptance creates a barrier to the shift towards CE. According to de Aguiar Hugo, de Nadae, and da Silva Lima (2021), consumers prefer fast consumption of clothing, despite being aware of the environmental impact of their choices. Consumers are able to justify unsustainable clothing consumption because the negative impact is too far removed from them and thus not visible to them (de Aguiar Hugo, de Nadae, and da Silva Lima 2021).

2.3 Blockchain technology

Blockchain technology is a decentralized, distributed ledger technology that gained attention following the publication of Satoshi Nakamoto's white paper on Bitcoin in 2008 (Nakamoto 2008). Even though Bitcoin itself is highly controversial, the underlying blockchain technology has generated a lot of interest in various business applications, particularly in SCM. The distributed ledger functionality, coupled with the security of blockchain, makes it a very attractive technology (Crosby et al. 2016). Blockchain in SCM can improve supply chain performance through real-time information sharing, security, transparency, reliability, traceability, and visibility (Aslam et al. 2021). Furthermore, Murphy (2022) argues that blockchain technology can support the shift toward CE. However, the uncertainty regarding the future of blockchain remains high. On the one hand, some experts believe that blockchain is going to bring significant changes to companies, economies, and social systems, with a potential impact on par with the wheel and the internet (Kopyto et al. 2020). On the other hand, there are concerns about its real potential and various barriers that may hinder its widespread implementation, such as high energy consumption, scalability issues, lack of regulations, interoperability, lack of knowledge, and complex global supply chains (Kopyto et al. 2020). This section will explore what blockchain technology is, how it works, and its potential benefits and applications.

2.3.1 Distributed ledger technology

In the previous section I introduced blockchain technology as a decentralized, distributed ledger, but what is a distributed ledger? The appearance of ledgers can be tracked back thousands of years. In the current centralized ledger system, data records are authenticated by a trusted central authority. However, with the emergence of Bitcoin and blockchain technology, distributed ledger technology (DLT) started gaining traction (Lashkari and Musilek 2021). DLT is a database that is replicated across a peer-to-peer network of computers. This allows for decentralized record keeping and does not require a central authority to intermediate transactions (Li and Kassem 2021). Data is recorded on ledgers, and all participants or nodes in the decentralized network hold a copy of the ledger. Each node in the network can validate and add new transactions to the ledger, thus ensuring all copies remain synchronized (van Steen and Tanenbaum 2016). Blockchain is the most well-known type of DLT. However, blockchain is not interchangeable with DLT. In fact, blockchain should be viewed as a subset of DLT rather than an equivalent (Li and Kassem 2021).

2.3.2 Benefits of blockchain technology

Why should businesses adopt blockchain technology? Information is the driving force in any business. The faster it's received and the more accurate it is, the better. Blockchain technology offers an ideal solution for delivering information. The value of blockchain technology is its ability to simplify and enhance the accuracy of information flows (IBM). The decentralized design of Blockchains enhances data security. A complete copy of the blockchain is stored on every node within the network rather than a single central server (IBM). This distribution of information enhances transparency within the network, as data is visible to all participants (Kopyto et al. 2020). With blockchain, data is visible in real-time across the supply chain creating full transparency (IBM). Blockchains are immutable ledgers. When data has been recorded within a block, it cannot be altered or modified, which further enhances data security (Kopyto et al. 2020). The inalterability of blockchain data allows unrestricted traceability of transactions. This makes it possible to trace the origin of transactions and track the flow of information in the network. For example, in SCM, blockchain can be used to trace the origin of goods and ensure that they are sustainable and ethically sourced. Traceability data can also expose weaknesses in the supply chain (Kopyto et al. 2020).

Blockchain technology replaces trust with cryptographic proof. This eliminates the need for trusted third parties, such as financial institutions, enabling direct transactions between unknown and untrusted parties. The absence of intermediaries in blockchain transactions can reduce transaction costs and result in quicker, more efficient transactions (Kopyto et al. 2020). Transactions can also be automated with smart contracts, which will increase the efficiency and speed of the process even further (IBM).

2.3.3 How does blockchain work?

Mack (2021) describes blockchain as "everything you don't understand about technology, finance, and law mixed together". In a blockchain, transactions are recorded as blocks of data. These transactions show the movement of an asset that can be tangible (a product) or intangible (intellectual). These blocks of data are sorted chronologically into chains of blocks using cryptography (IBM). Blocks are given an exact timestamp when they are added to the chain, which confirms the time and sequence of transactions and creates a secure and irreversible timeline of data (Rolinck et al. 2021). This makes it very difficult to manipulate data when it has been recorded on the blockchain. Each block in the blockchain contains data, a hash value, and the hash of the previous block, see Figure 8. The hash value is the unique identifier of each block in the blockchain and can be thought of as the fingerprint of the block. The hash value is calculated when a block is created by using a hash function that converts an arbitrary amount of input data into an encrypted output of a fixed length. The hash value is nonreversible because a small change in inputs results in a totally different hash value. This makes it very easy to detect changes to a block. If the hash value of a block changes, it is no longer the same block (Wan 2020). Every block also contains the hash value of the previous block and is what chains the blocks together. By making every block chained to the previous block, the blockchain becomes more secure and immutable (Rolinck et al. 2021). If someone tries to change the input data in one block the hash value changes. This will make the next block and all following blocks invalid since they no longer contain a valid hash of the previous block (Wan 2020).

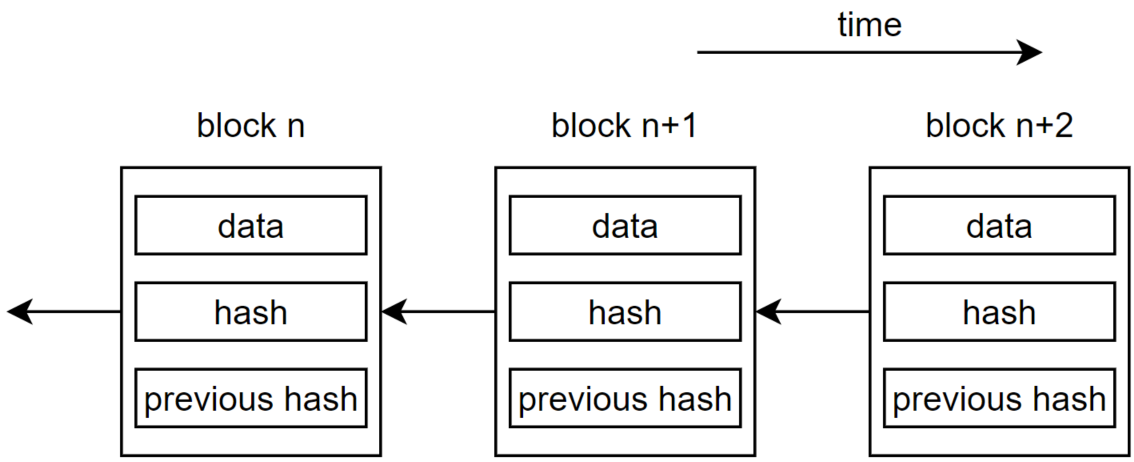

Figure 8. Simplified Blockchain data structure (He et al. 2018).

2.3.4 Consensus mechanism

Since blockchains are distributed ledgers without a central authority, a consensus mechanism is required. A consensus mechanism validates new blocks and maintains the security of the blockchain network. The consensus mechanism is one of the core components of blockchains and provides the technical infrastructure layer to reach consensus between nodes in the peer-to-peer network. There are many different types of consensus mechanisms, and which one is used decides the blockchain's performance, scalability, and security (He et al. 2018). In the next sections, I will present the most well-known, namely proof-of-work and proof-of-stake, to give an understanding of how such mechanisms work.

2.3.4.1 Proof-of-work

The most publicly proven consensus mechanism is proof-of-work. In proof-of-work, nodes compete against each other in mining new blocks. The nodes use their computing power to solve mathematical puzzles and validate transactions to generate blocks. By mining, nodes prove they have used enough computational resources and can be trusted. Proof-of-work assumes that honest nodes control a majority of CPU power. The mining process slows down the creation of new blocks to make tempering with the blockchain computationally impractical for one node. This is because if you temper with one block, you need to recalculate the proof-of-work for all following blocks (He et al. 2018). Proof-of-work is criticized for wasting vast amounts of computational power and energy by having all nodes compete against each other to mine new blocks. The energy consumption needed to run proof-of-work also creates disadvantages when it comes to scalability (He et al. 2018). Another issue with proof-of-work is the 51% attack. This refers to the possibility of nodes controlling more than 50% of the network's CPU power and starting to reverse verified transactions (He et al. 2018).

2.3.4.2 Proof-of-stake

Proof-of-stake aims to address the environmental and scalability problems of proof-of-work. Instead of having nodes compete against each other, proof-of-stake randomly selects nodes to validate the next block. To become a validating node, the node must deposit a certain number of tokens as a stake. One can think of this as a security deposit. The size of the stake determines the chances of a validating node being chosen to forge the next block (Saleh 2021). To avoid the "rich get richer" phenomenon, proof-of-stake also considers the time when choosing the next validating node. Thus, the selection of the next validating node is based on the number of tokens held by a node multiplied by the time it has been staked for. After a node has been selected and forged a new block, the duration of time the node's tokens have been staked for is reset. This is done to prevent nodes with large stakes from dominating the blockchain. With every node being able to verify transactions security increases since it is to the miners' benefit to maintain consensus and prevent the network from attacks. To some extent, this mitigates the possibility of a 51% attack (He et al. 2018).

2.3.5 Smart contracts

The emergence of blockchain technology in recent years has provided a platform for other concepts that have been suggested in the literature. Szabo (1997) introduced the concept of smart contracts, which are self-executing digital contracts. Compared to 20 years ago when they were first introduced, blockchains now make it easier to utilize smart contracts. IBM defines smart contracts as "digital contracts stored on a blockchain that is automatically executed when predetermined terms and conditions are met".

Smart contracts are used to automate the execution of a contract without the need for an intermediary. They work based on "if/when…then…" statements that are written into lines of code on the blockchain. When predetermined conditions are met and verified, the contract automatically executes the agreed-upon actions, and the transaction is recorded on the blockchain network. The execution of the contract is guaranteed by the underlying blockchain technology. The elimination of intermediaries reduced time delays and fees associated with their involvement (IBM). The “if/when…then…” statements represent how the business world operates and is the reason the use of smart contracts is one of the most adopted applications of blockchain technology. For example, a smart contract could be used in a SCM scenario to automatically release the payment for a shipment of goods once the delivery has been confirmed (Mack 2021).

2.3.6 Types of blockchains

There are three common types of blockchain networks, namely public, private, and consortium. Each of these types of blockchain networks serves a particular purpose, solves a specific problem, and has its own set of features.

2.3.6.1 Public blockchain

Public blockchains are non-restrictive, permissionless networks and are completely decentralized. Anyone with an internet connection can join the network and participate in consensus. All nodes can initiate transactions, validate blocks, and download a copy of the shared ledger. The nature of public blockchains makes privacy and data security an issue for organizations wanting to adopt blockchain technology. To validate new blocks and maintain the security in the network, public blockchains use consensus mechanisms such as proof of work and proof of stake to reach consensus in the entire network (Yang et al. 2020).

2.3.6.2 Private blockchain

Private blockchains are permissioned blockchains that are used in closed networks controlled by a single organization. The organization controls who are authorized to join the network and thus create higher privacy and data security. Fewer nodes in the network give private blockchains a higher processing rate of transactions. The reason is that with fewer nodes, the network reaches consensus faster and can process more transactions (Yang et al. 2020). Consensus mechanisms used in private blockchain networks include proof of authority and proof of elapsed time. Private blockchains are governed by a single authority and are considered more centralized. Therefore, private blockchains are often criticized for not being real blockchains (Wan 2020).

2.3.6.3 Consortium blockchain

Consortium blockchains are hybrid blockchain networks that combine public and private blockchain network features. These are permissioned blockchain networks monitored by a group of organizations. The group of organizations control who can join the network, and consensus is reached by a set of authorized nodes in a decentralized manner. By being a type of permissioned network, consortium blockchains also have a high transaction throughout but are more decentralized then private blockchains (Merlec et al. 2022). The data recorded in the blocks are not public and are only available to consortium members. Consortium networks thus have high privacy and data security. A consortium blockchain is a good option for a shared ledger for supply chain networks (Wan 2020).

2.3.7 Blockchain and Internet of Things (IoT)

The Internet of things (IoT) is a giant network of devices connected to the internet. IoT makes it possible for the digital world to meet the physical world and cooperate with each other. These devices collect and share data about how they are used and the environment in which they are operated. Data is gathered using sensors embedded in every physical device (He et al. 2018). The concept of linking computers and networks to monitor and control devices has been around for decades, but the term IoT was first used by British technology pioneer Kevin Ashton in 1999 (Ashton 2009). As of 2022, the number of IoT-connected devices globally was estimated at 13.14 billion and is projected to nearly triple by 2030 (Vailshery 2022).

IoT has been around for decades, but recent technological advancements have greatly enhanced its potential and capabilities. The availability of affordable and reliable sensors and the rise of blockchain technology have been crucial in this transformation. Blockchain has accelerated the adoption of IoT by bringing in the missing element of trust, which is essential for businesses to adopt the technology at a larger scale. IoT with blockchain can bring real trust to the data captured by sensors (Cuomo 2020). A SCM example of this is the transportation of goods. This complex process involves different parties with different priorities. An IoT-enabled blockchain can store and track data such as temperatures, positions, arrival times, and status of shipping containers, making it easier for all parties involved to trust the information and take necessary actions to move products quickly and efficiently (Cuomo 2020).

2.3.8 Do you even need Blockchain?

There are several decision models to evaluate whether blockchain is needed for a particular use case. In this research, the decision models proposed by Suichies (2015), see Figure 9, are being used. This model is based on an article by Greenspan (2015) on how to avoid pointless blockchain projects. In his article, Greenspan (2015) outlines several conditions that are needed to be fulfilled for it to make sense to use blockchain. These are incorporated into the decision model. The model considers whether the need for trust can be established through other means, weather the network is centralized or decentralized, and whether the use of a blockchain would bring additional benefits such as security, immutability, and transparency. The aim is to determine if a blockchain is actually needed or if a centralized database or other types of distributed database are sufficient. Furthermore, if a blockchain is needed, the model helps to determine the most appropriate blockchain type (Suichies 2015).

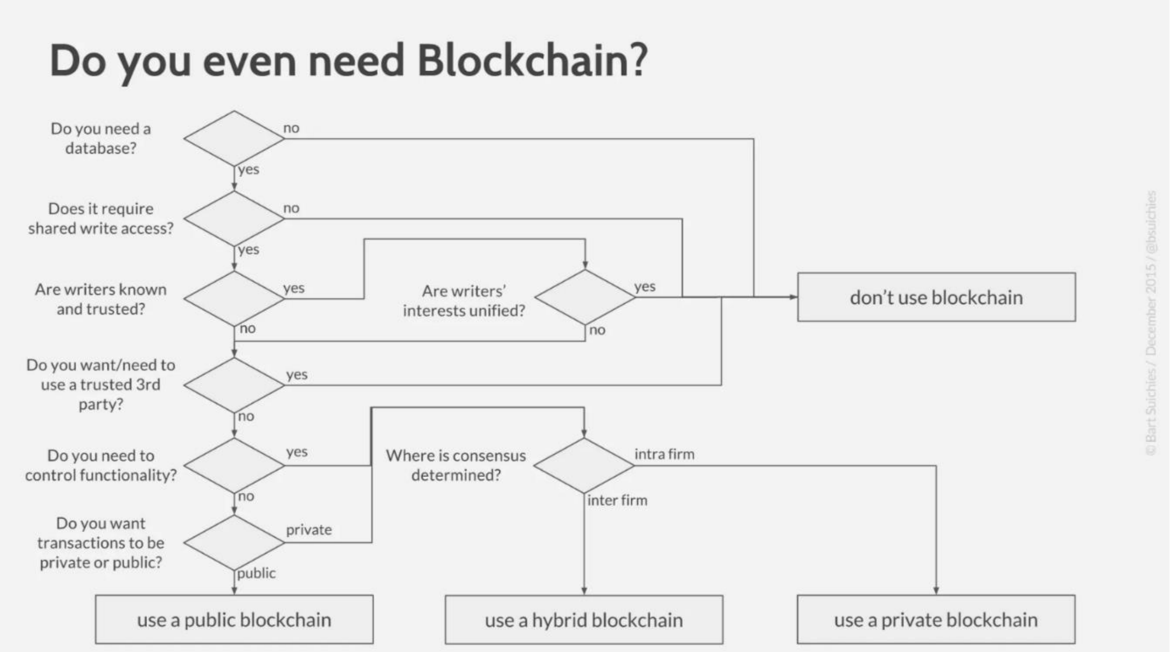

Figure 9. A decision model for blockchain use cases (Suichies 2015).

2.3.9 Blockchain technology adoption barriers

Despite its tremendous potential, several key barriers hinder the adoption of blockchain technology. These include high energy consumption, scalability issues, lack of regulations and standards, as well as significant investment costs. In this section, I will delve deeper into these barriers.

The high energy consumption of numerous blockchain applications presents a significant barrier. For instance, in 2018, the emission associated with Bitcoin (BTC), which is a proof-of-work blockchain, were argued to be on par with countries such as Sri Lanka or Jordan. Therefore, a barrier to the mainstream adoption of proof-of-work blockchains is the negative environmental impact it could have (Böhmecke-Schwafert, Wehinger, and Teigland 2022). However, this depends on the blockchain platform being used. For example, Bitcoin SV (BSV), which also is a proof of work blockchain, requires significantly less energy per transaction due to its larger block sizes and less congested network. According to Southurst (2022), proof of work becomes more efficient and sustainable as the total transaction number increases, and if the entire world used the BSV blockchain to process data, it would reduce the energy consumption of other existing systems.

IoT devices record vast amounts of data in real-time. Thus, scalability becomes a bottleneck for blockchain implementation when dealing with exponential amounts of data. An example of the substantial amount of data collected by IoT devices is the engine of an Airbus A380 aircraft. Each engine generates 10TB of data during a flight every 30 minutes. These vast amounts of data from the IoT devices are added to the blockchain and cause latency and storage problems (Zhang et al. 2020). D. Khan, Low Tang, and Manzoor Ahmed (2021) argue that most factors concerning the scalability problem are linked to the consensus mechanism. The currently available consensus mechanisms are not efficient enough to address the problem blockchain technology faces with scalability (D. Khan, Low Tang, and Manzoor Ahmed 2021). However, some may disagree with this claim. For example, the BSV blockchain has no default hard cap for block sizes creating unlimited potential for scaling. In comparison, Bitcoin (BTC) has a maximum block size of 2 MB, which is the source of its scalability problem. The BSV blockchain can process over 50,000 transactions per second, whereas BTC can handle only seven transactions per second (Bybit 2022).

The lack of regulations and standards for the use of blockchain is an important barrier to its adoption. Without standards, it becomes difficult to implement blockchain technology in organizations and across supply chains. Widespread global adoption requires standardization (Farooque et al. 2020). As Taiichi Ohno, the father of the Toyota Production System, said, "without standards, there can be no improvement". The lack of regulations and standards creates uncertainty for companies looking to use blockchain technology. However, there is constant work on developing standards for the use of blockchain. For example, the Informatic and Digitalization Research Group at Molde University College actively participates in committees developing blockchain standards for ISO and ETSI.

According to S. Khan et al. (2022), one of the primary barriers to blockchain-based supply chains is the lack of access to technology. Supply chain partners have a diverse range of resources and digital competence. Upstream partners such as farmers often do not have sufficient access to technology, making the implementation of blockchain more challenging (S. Khan et al. 2022).

High investment costs are a significant barrier to implementing blockchain technology. A well-developed IT infrastructure is necessary, including both hardware and software, which typically involves high investments. In developing countries, IT investments are often low, making the integration of blockchain in supply chains more challenging (S. Khan et al. 2022).

In addition, the oracle problem is a technical challenge recognized in the literature. Oracles are the means of communication between blockchain and the physical world. These are third parties, and unlike blockchain nodes, they are centralized and must be trusted (Böhmecke-Schwafert, Wehinger, and Teigland 2022).

3.0 Case description

This chapter provides information about the global textile industry, the EU strategy for sustainable and circular textiles, and the case companies participating in this research.

3.1 The textile industry

The textile industry is one of the most significant industries in the global economy, with an estimated revenue of 1.53 trillion U.S. dollars in 2022 (Smith 2023). However, despite its economic importance, it is the second largest polluter in the world. Its carbon emissions exceed those of all maritime transportation and international flights combined, resulting in significant social and environmental impacts throughout its supply chain (de Aguiar Hugo, de Nadae, and da Silva Lima 2021).

The textile industry's focus on fast fashion and constant trend changes encourages people to dispose of clothing that is no longer in fashion. Fast fashion is low-cost clothing that mimics luxury fashion trends, produced using a just-in-time manufacturing philosophy and quick response strategies. This allows fast fashion to take only weeks to get from the product design stage to the market. Fast fashion offers consumers a constantly changing selection of clothing, promoting impulse shopping, emotional purchasing, and a throwaway culture (Wang et al. 2020). This trend is illustrated in Figure 10, which depicts how global textile production has doubled between 2000 and 2015 while the average utilization of each garment has decreased over the past few decades (Gueye 2021). European Commission (2022) estimates that one truckload of textiles goes to landfill or incineration every second, and less than 1% of the material used in the production is recycled into new clothing. Furthermore, up to 35% of all the microplastics released into the environment can be traced back to textile products, with an estimated 500 thousand tons of microplastic fibers dumped in the oceans annually (de Aguiar Hugo, de Nadae, and da Silva Lima 2021; European Commission 2022).

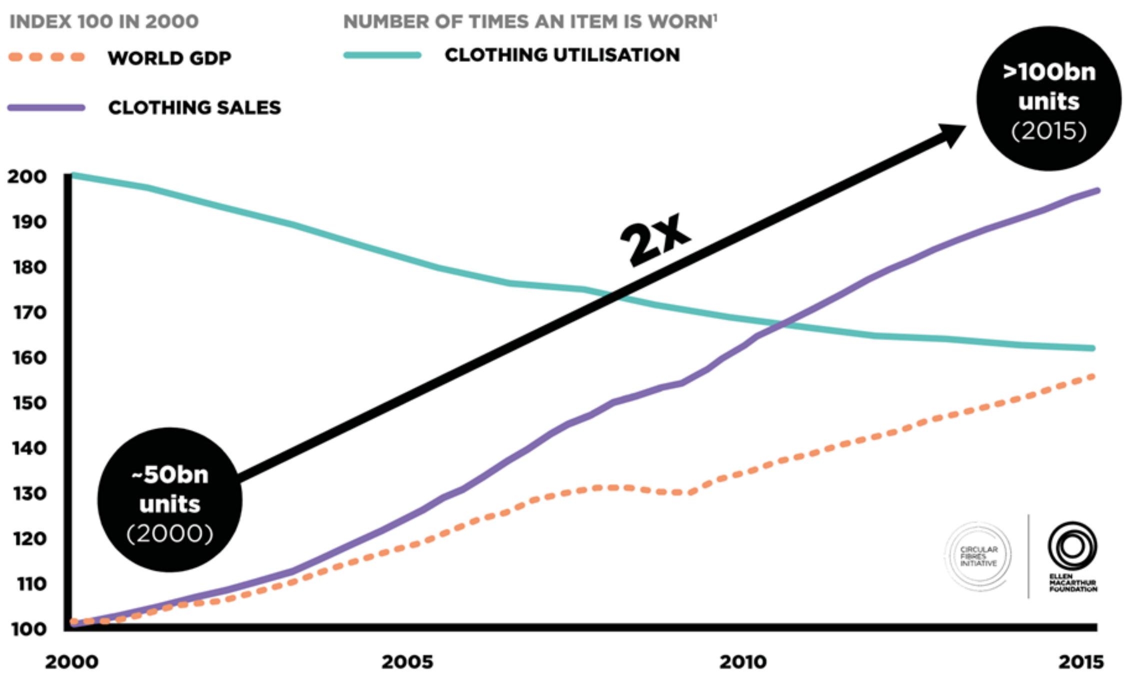

Figure 10. Sales and utilization trends of clothing 2000-2015 (Gueye 2021).

Despite its negative impact, the textile industry continues to operate using a linear model of extracting, producing, and disposing of resources, mainly driven by fast fashion. As a result, the textile industry is responsible for some of the most significant environmental impacts on our planet. This includes using more than 98 million tons of non-renewable resources every year, including oil for synthetic fibers, fertilizers for cotton plantations, and chemicals for dyeing fibers and fabrics. The textile industry also uses 93 billion cubic meters of water, resulting in severe water scarcity in many regions around the world. Furthermore, the production releases chemicals into waterways leading to water pollution and harm to aquatic life. In addition, the textile industry emits an estimated 1.2 billion tons of CO2 every year (de Aguiar Hugo, de Nadae, and da Silva Lima 2021).

The supply chains in the textile industry are among the longest and most complex of any industry, primarily because most manufacturers outsource production to countries with lower labor costs. Companies in the textile industry often lack complete visibility into the sources of the raw materials used in their production, making it difficult to get a complete understanding of their environmental and social impact. As a result, companies may unknowingly use materials produced with unethical practices such as forced labor. The lack of visibility has resulted in a widespread problem with worker exploitation, with the industry facing significant challenges regarding low wages, poor working conditions, and limited workers' rights (Bush and Chui 2022).

3.1.1 EU strategy for sustainable and circular textiles

In March 2020, the European Commission adopted the circular economy action plan as one of the main building blocks of the European Green Deal. The European Green Deal is the EUs roadmap to becoming the first climate-neutral continent through transforming the EU into a modern, resource-efficient, and competitive economy (European Commission 2022). In March 2022, the European Commission presented a proposal as part of the circular economy action plan to make sustainable products the norm in the EU. The commission proposed new rules to make almost all physical goods on the EU market more sustainable, circular, and energy efficient throughout their whole lifecycle. Included in this package was the EU strategy for sustainable and circular textiles. This strategy outlines the European Commission's plan to make all textile products more durable, repairable, reusable, and recyclable, and to a great extent, made of recyclable fibers and free of hazardous chemicals by 2030. The strategy also includes tackling fast fashion to create long-lasting, high-quality textiles, make profitable re-use and repair services widely available, and ensure good working conditions and fair wages for production workers (European Commission 2022).

The European Commission outlines several key actions in the textile strategy, including setting design requirements for textiles, tackling overproduction and overconsumption, and incentivizing circular business models. However, one of the key actions outlined in the textile strategy is very relevant to the objectives of my research, namely the introduction of digital product passports in the EU market (European Commission 2022).

3.1.1.1 Digital product passport (DPP)

A DPP collects and stores product-related data throughout a product's life cycle and share it across the entire supply chain. The European Commission wants to use DPPs as a tool to enhance transparency on products sold in the EU market to promote the shift towards a CE. DPPs have the potential to make the environmental and social impact of products visible, traceable, and easily accessible, enabling companies to create more circular products and reduce waste and resource consumption. By linking performance requirements to the DPP data, the European Commission aims to incentivize circularity. DPP regulations are currently being drafted, and the European Commission plans to make DPP mandatory on all textile products sold in the EU market by 2030 (WBCSD 2023).

One of the key questions when it comes to the implementation of DPPs is concerning data storage. First, it needs to be decided whether data storage should be EU- or company-managed. After this, the question is whether to store data centralized or decentralized. Centralized storage options, such as cloud storage, offer significant benefits due to wide use, ease of implementation, and low cost. Decentralized options such as the blockchain have a high cost and novelty but allow for higher data security, transparency, and traceability (WBCSD 2023).

3.2 Case companies

3.2.1 H&M Group

H&M Group was founded in Sweden in 1947 by Erling Persson. H&M Group initially focused on selling women's clothing, but after a decade the company expanded into Norway and began offering men's clothing as well. Today, H&M Group has grown to become the world's second-largest fashion company. The group comprises several brands, including H&M, Afound, ARKET, COS, H&M Home, Monki, & Other Stories, Weekday, and the latest addition, H&M Move. As of 2021, H&M Group has over 4,800 stores in 77 markets worldwide. H&M Group focuses on omnichannel sales and online shopping is available in 57 countries. H&M Group directly employs more than 100,000 people (Ellen MacArthur Foundation 2021).

3.2.2 Skogstad Sport AS

Skogstad is one of Norway's leading brands of outdoor and sportswear. Since its inception in 1937 by Halstein Skogstad, the company has been committed to producing high-quality and functional clothing for the whole family. Skogstad is located in Innvik, Norway, and has established distribution in several countries. Skogstad directly employs 101 people and had a revenue of 174 million NOK in 2021 and is thus considered a medium-sized enterprise. The brand's core values are centered on environment sustainability, ethical business practices, and product design, quality, and functionality. Their vision is to create outdoor joy with quality products at a reasonable price (Skogstad n.d.).

4.0 Methodology

This chapter outlines the methodology used in this research to answer the research questions. In their book, Saunders, Lewis, and Thornhill (2019) present the "research onion" as a useful metaphor for understanding the various layers of issues involved in the selection of data collection techniques, see Figure 11. The core of the onion represents the central aspect of data collection, while the outer layers represent important considerations that must be taken into account and explained in order for the research to be taken seriously. Following the layers of the research onion step-by-step provides an approach to developing a research design (Saunders, Lewis, and Thornhill 2019). In the following sections, I will use the various layers of the research onion to outline the research design for this research.

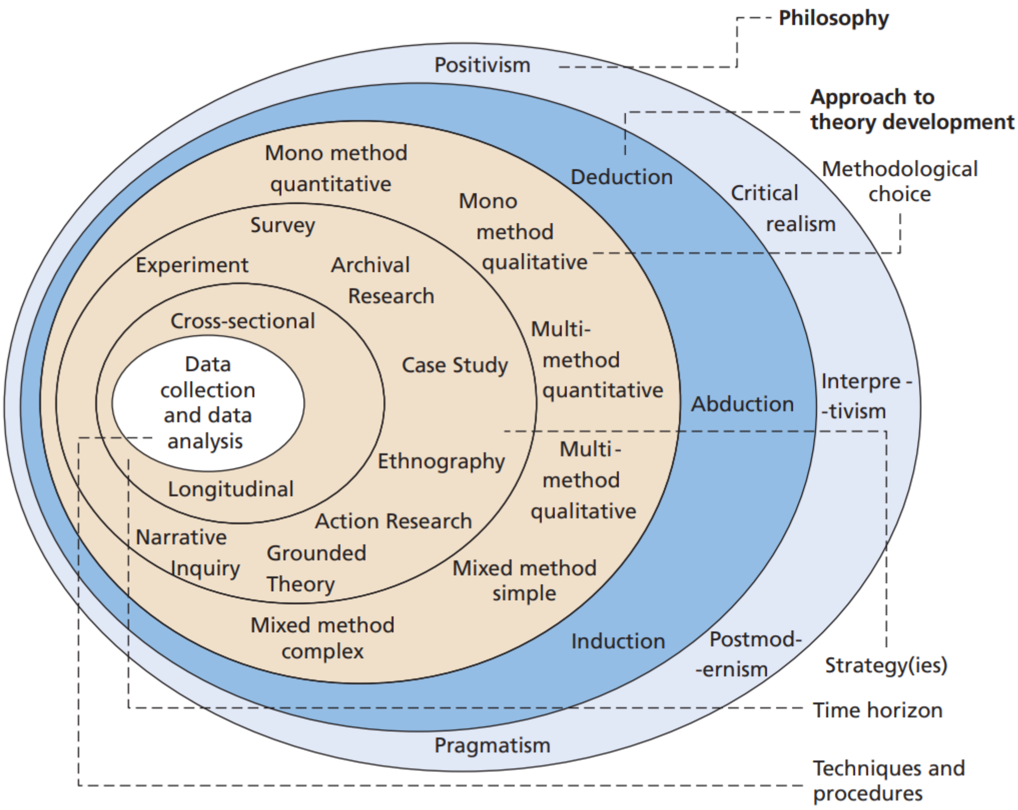

Figure 11. The research onion (Saunders, Lewis, and Thornhill 2019).

4.1 Research philosophy

The first layer of the research onion is the research philosophy. Research philosophy is the overarching term that relates to the development of knowledge and the nature of that knowledge. As researchers, we make assumptions about human knowledge and the realities encountered in research. This shapes the research questions, methods, and interpretation of our findings (Saunders, Lewis, and Thornhill 2016). According to Saunders, Lewis, and Thornhill (2016), understanding the assumptions we make about how the world works is beneficial in practice. By understanding these assumptions, we can evaluate their appropriateness and make necessary changes. There are three ways of thinking about research philosophy: ontology, which is concerned with the nature of reality, epistemology, which is concerned with what constitutes acceptable knowledge in a field of study, and axiology, which deals with the understanding of the value in the research (Saunders, Lewis, and Thornhill 2016).

Saunders, Lewis, and Thornhill (2016) presented five research philosophies in business and management research: positivism, interpretivism, critical realism, postmodernism, and pragmatism. Positivism is a philosophical position that emphasizes collecting data about observable reality and searching for regularities and causal relationships to create law-like generalizations. It is a value-free approach, where the researcher is external to the data collection process and focuses on facts rather than impressions. Interpretivism is critical of positivism and holds that the social world of business and management is too complex to be reduced to law-like generalizations. The reality being researched can only be understood through social constructions making knowledge relative and subjective (Melnikovas 2018). Critical realism is a philosophical approach that aims to explain the underlying structures of reality that shape the events we observe. It assumes that reality is external and independent but not fully accessible through our perception and understanding. Critical realism emphasizes the importance of recognizing that our senses can deceive us and encourages researchers to consider the broader context of what they observe (Saunders, Lewis, and Thornhill 2016). Postmodernism emphasizes the role of language and power relations in shaping our understanding of the world. Postmodernist researchers aim to challenge established ways of thinking, exposing power relations and giving voice to marginalized perspectives. They recognize that the power dynamics between researcher and research subjects play a role in shaping the knowledge created, and make a conscious effort to be reflective about their thoughts and writing (Saunders, Lewis, and Thornhill 2016).

The final research philosophy is pragmatism. Pragmatism assumes that within the research, it is possible to adapt both positivist and interpretivist positions, depending on the research questions (Melnikovas 2018). It acknowledges that multiple perspectives and methods can be used to interpret the world and conduct research and prioritizes the collection of credible, reliable, and relevant data to advance the research (Saunders, Lewis, and Thornhill 2016). This research employs a pragmatic research philosophy. This research acknowledges that there are numerous ways to interpret the world and conduct research. Either or both observable phenomena and subjective perceptions gathered from the case companies can provide acceptable knowledge to answer the research questions. There is no single perspective that can provide a comprehensive understanding of a given phenomenon, and there may be multiple interpretations of reality (Saunders, Lewis, and Thornhill 2016).

4.2 Approach to theory development

The second layer of the research onion is the approach to theory development. Saunders, Lewis, and Thornhill (2016) distinguish between three main approaches to theory development: deductive, inductive, and abductive. Deductive research is a scientific approach that begins with a theory and uses hypothesis testing and data collection to confirm or disprove it. It seeks to establish causal relationships, operationalize concepts, and generalize findings. This approach is often used in natural sciences to explain laws and predict phenomena (Saunders, Lewis, and Thornhill 2016). Inductive research starts by collecting data through interviews or observation and then developing a theory based on the analysis of the collected data. This approach is commonly used in the social sciences (Saunders, Lewis, and Thornhill 2016). Abductive research combines elements of both deductive and inductive approaches. The research starts by observing an empirical phenomenon, then developing a plausible theory, and then testing and revising the theory using both existing and new data. The abductive approach is more like how business and management researchers conduct their research (Saunders, Lewis, and Thornhill 2016). The selection of an approach to theory development is important as it allows for more informed decisions to be made regarding research design, strategies, and methods. Additionally, understanding different research traditions enables researchers to adjust their design to accommodate any limitations, such as limited data availability or a lack of prior knowledge (Saunders, Lewis, and Thornhill 2019).

This research has an inductive approach to theory development. The research moves from specific data collected from the case companies and then develops a broader generalization and theory based on the analysis of the collected data. Although an abductive approach is more commonly used in business and management research, the research utilizes an inductive approach because it starts by collecting data from a few case companies and then tries to generalize the findings in the whole textile industry (Saunders, Lewis, and Thornhill 2016).

4.3 Research design

The research design outlines the strategy for addressing the research questions. It encompasses well-defined objectives, data sources, approaches for collecting and analyzing data, ethical considerations, and limitations. The research design can be either quantitative, qualitative, or a combination of both and is designed to fulfill either an exploratory, descriptive, explanatory, or evaluative purpose or some combination of these (Saunders, Lewis, and Thornhill 2016). Within business and management research, the use of multiple methods has been advocated to overcome limitations associated with using only a single method and with enhancing data collection, analysis, and interpretation (Saunders, Lewis, and Thornhill 2016).

Quantitative research design is associated with positivism and a deductive approach to theory. However, quantitative research design can also be used within realist and pragmatist philosophies and incorporate an inductive approach. Quantitative research examines relationships between numerical variables and is primarily associated with experimental and survey research strategies (Saunders, Lewis, and Thornhill 2016).

This research employs a qualitative research design. Qualitative research is associated with an interpretive philosophy due to its naturalistic nature, but it is also used in realist and pragmatist philosophies. Qualitative research aims to make sense of the subjective and socially constructed meanings expressed about the phenomenon studied and their relationships (Saunders, Lewis, and Thornhill 2016). Researchers typically use multiple data forms collected by examining documents, observing behavior, or interviewing participants. The inductive approach is generally used by qualitative researchers, building patterns, categories, and themes from the ground up by organizing data into increasingly more abstract information units. This inductive process involves a constant interplay between the emerging themes and the database until the researchers establish a comprehensive set of themes (Creswell and Creswell 2018). The most common research strategies in qualitative research are narrative research, ethnography, case study, and grounded theory (Creswell and Creswell 2018).

Research can have an exploratory, descriptive, explanatory, or evaluative purpose or some combination of these. How you formulate your research question will determine the purpose of the research (Saunders, Lewis, and Thornhill 2016). This research aims to explore the potential of blockchain-based circular supply chains in the textile industry, therefore it is exploratory. Exploratory research is a useful tool to gain deeper insights into a topic of interest. By asking open-ended questions, this type of research can clarify your understanding of a problem and help determine if it's worth pursuing further (Saunders, Lewis, and Thornhill 2016). Regarding this research, it may not be the optimal solution for the textile industry to employ blockchain technology to transition to a CE. Nonetheless, it's worth investigating to determine its feasibility and potential. Exploratory research can be done through literature review or interviews such as expert interviews and semi-structured. It is a flexible and adaptable approach to change, allowing for new data and insights to guide the research process (Saunders, Lewis, and Thornhill 2016).

4.4 Research strategy

The fourth layer of the research onion concerns the choice of research strategy. According to Saunders, Lewis, and Thornhill (2016), the research strategy is the plan of how the researcher will go about answering their research questions. It is the methodological link between your research philosophy and subsequent choice of methods to collect and analyze data. The research strategy can be determined by aligning the research questions and objectives with the overall philosophy, approach, and purpose of the study while also considering practical considerations such as the existing knowledge in the field, available resources, and access to participants and data (Saunders, Lewis, and Thornhill 2016). Different research strategies include experiments, surveys, and ethnography. However, this section will focus on the relevant strategy for this research, namely case study research.

A case study is a research strategy that examines a specific topic or phenomenon within its real-world context. It aims to gain a deeper understanding of the topic by studying it within its natural setting and is commonly used in exploratory research. Both quantitative and qualitative methods may be used, and multiple sources of data may be gathered for triangulation to ensure accuracy. Unlike experimental research, where variables are tightly controlled, or survey research, where the context is limited, case studies are often used when boundaries between the phenomenon being studied and the context within which it is being studied are not apparent. However, conducting a case study can be challenging because of its intensive and in-depth nature, as it requires the ability to identify, define and gain access to the case study setting (Saunders, Lewis, and Thornhill 2016).

According to Saunders, Lewis, and Thornhill (2016), there are four case study strategies based on two dimensions: the number of cases being studied (single case versus multiple cases) and the level of analysis (holistic case versus embedded case). Single case studies are commonly used to provide an in-depth understanding of a critical or unique case, while multiple case studies are used to replicate findings across multiple cases, for example, several companies in an industry. The choice between a single or multiple case study depends on the nature of the research question and objectives. Whether a case study is holistic or embedded depends on the depth of your research. In a holistic approach, the entire case company as a whole is the focus, while an embedded approach involves more than one unit of analysis and examines just some aspects of each case (Saunders, Lewis, and Thornhill 2016).

This research uses embedded multiple case studies to answer both research questions. Two case companies are studied to replicate the findings and generalize them across the textile industry. The case study is embedded because it encompasses two companies and focuses on their respective SCM practices in the context of CE. This research is a multiple case study because the nature of the research questions is to explore the potential of blockchain-based circular supply chains in the textile industry as a whole. Thus, the aim is to replicate the findings across a whole industry and not just one unique case (Saunders, Lewis, and Thornhill 2016).

4.5 Data collection and data analysis

The data collection and analysis are at the center of the research onion. The following sections present the primary and secondary data used in this research and how it was collected and analyzed. Further, I examine the validity and reliability of the data used.

4.5.1 Primary data

In this research, the main strategy for collecting data was through interviews. Interviews range from highly formalized and structured with predefined questions for each participant to informal and unstructured conversations. The approach in this research was semi-structured interviews. Semi-structured interviews are non-standardized qualitative research interviews with no predetermined and standard set of questions. The researcher uses a list of themes and some key questions to be covered that may vary from interview to interview. The order of the questions may be varied depending on the flow of the conversation, and additional questions may come up in the conversation to explore different points further (Saunders, Lewis, and Thornhill 2016). The aim is to create a discussion around the research topic therefore data should be captured by audio-recording to not lose the flow of the conversation. Semi-structured interviews may lead the discussion into areas that you had not previously considered but which are significant for your understanding. The result is a rich and detailed set of data. However, it is important to be aware that the way you interact with your interviewees and pose questions will impact the data that is collected (Saunders, Lewis, and Thornhill 2016).

I conducted one semi-structured interview with Skogstad Sport AS. H&M group did not have time for an interview. However, their sustainability department kindly responded to my inquiries via email and granted me access to relevant company records and reports. For Skogstad, an interview guide was provided before the interview to allow them to prepare their responses and seek input from others within their organization if necessary. The interview guide can be found in Appendix A. The interview focused on the case company’s current SCM, its measures concerning sustainability and CE, and its views on the potential of technology to enhance sustainability. The interview took place in February over Teams and lasted around one hour. The interview was recorded with the permission of the respondents and in compliance with privacy regulations. The interviews were transcribed and sent to the case company giving them a chance to clear up any misunderstandings and provide additional information. After the interview was transcribed, I sent some follow-up questions by mail to both H&M Group and Skogstad throughout the writing process. A good dialog was kept with both case companies throughout the semester.

I also conducted an expert interview with a blockchain expert. This interview was held in March after all relevant data were collected from the case companies. The interview was conducted over Teams and lasted a little over one hour. An interview guide was also provided to the blockchain expert before the interview to allow him to prepare. The interview guide can be found in Appendix B. The interview focused on blockchain applications in SCM, in the CE, and specifically in the context of the case companies and the textile industry. The interview was recorded with the permission of the respondent and in compliance with privacy regulations.

4.5.2 Secondary data

Secondary data are data that was initially collected for some other purpose. With further analysis, these data can provide additional or different knowledge, interpretations, or conclusions. Within business and management research, secondary data are often used as part of a case study or survey research strategy. As students, we often believe we need to collect new data for our research, but we often lack the resources to do so. Fortunately, the availability and accessibility of secondary data sources have increased with the growth of the internet, making it easier to find useful data to answer our research questions (Saunders, Lewis, and Thornhill 2016).

Saunders, Lewis, and Thornhill (2016) refer to the secondary data used in this research as document secondary data. These data are increasingly available online and include both text and non-text materials. Such materials can be gathered from various sources like organizations' websites, administrative records, reports to shareholders, etc. Secondary data can be used in combination with primary data collected through interviews or questionnaires (Saunders, Lewis, and Thornhill 2016). I have used secondary data publicly available on the case companies' websites and private records I have been granted access. All case companies have an extensive sustainability page on their website, which I have used as a complementary source to the primary data obtained through the interviews. For the H&M Group case, I have relied primarily on records and reports that I have been given access to as well as a comprehensive case study conducted by the Ellen MacArthur Foundation, available on their website.

4.5.3 Data analysis

To analyze the collected data, this research uses the model for data analysis in qualitative research presented by Creswell and Creswell (2018), see Figure 12. The model outlines a sequential analysis process from the specific to the general and involves multiple levels of analysis (Creswell and Creswell 2018).

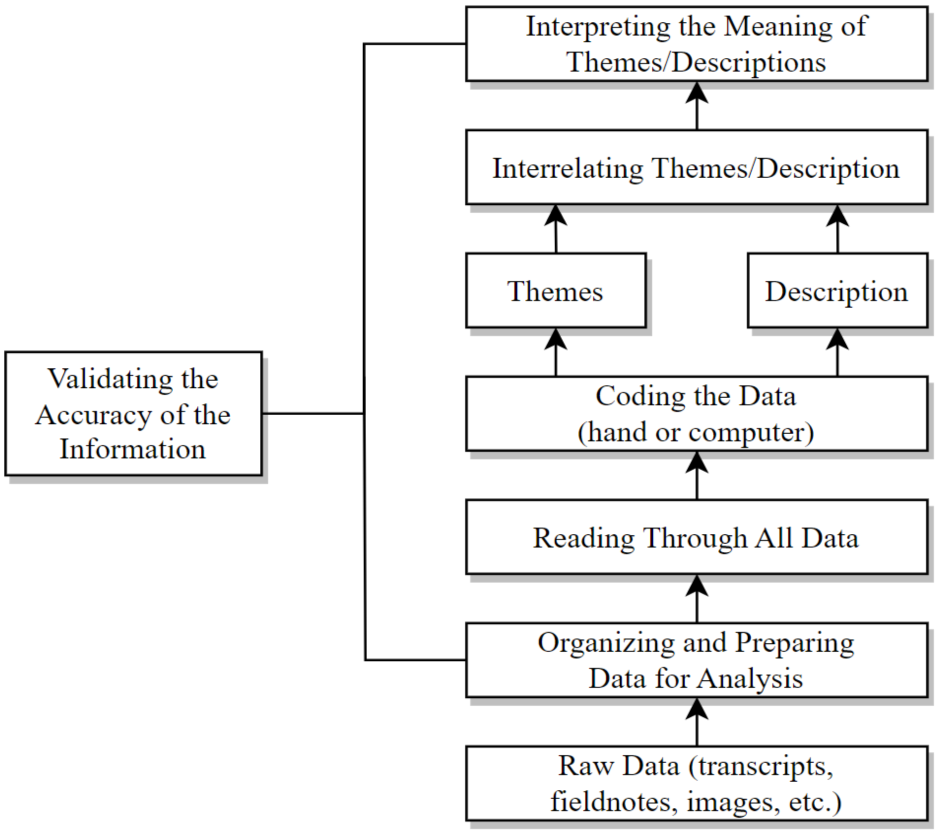

Figure 12. Data analysis in qualitative research (Creswell and Creswell 2018).

First, I organized and prepared the data collected from the semi-structured interviews and the relevant secondary data. The semi-structured interviews were transcribed and translated from Norwegian to English, and the secondary data was sorted into different types of data. After this, I read through all the data and made notes to get a general sense of the information. Following the model, the next step was coding the data. Coding the data involves segmenting the data into categories and labeling these categories (Creswell and Creswell 2018). I generated themes related to the two case companies and the blockchain expert from the coding process. These themes represent the major findings and are used as headings in the findings chapter of this thesis. Interpreting the meaning of the themes is done in the discussion chapter by comparing the findings with relevant literature.

The final step in the analysis process is validating the accuracy of the information. Validity is the extent to which data collection methods accurately measure what they were intended to measure (Saunders, Lewis, and Thornhill 2016). Reliability refers to the extent to which data collection methods give consistent findings across different researchers and projects (Creswell and Creswell 2018). To ensure validity, this research employs some of the validity strategies presented by Creswell and Creswell (2018). First, this research triangulates multiple data sources, including semi-structured interviews, inquiries by mail, and secondary data sources. In the discussion, contradictory evidence is presented to add to the validity of the findings. Finally, my supervisor continuously reviewed drafts of the thesis throughout the writing process. This makes sure that the research resonates with people other than me. The reliability when using semi-structured interviews depends on several factors, such as the analysis process and the potential for bias. The interview guide provides some structure for the interviews and ensures that the same topics are covered.

4.6 Chapter summary

This section provides a summary of the methodology employed by this research. This research uses the "Research onion" framework presented by Saunders, Lewis, and Thornhill (2016) to develop a research design. A pragmatic research philosophy is employed, and the research acknowledges that there are numerous ways to interpret the world and conduct research. The approach to theory development is inductive. The research moves from collecting data from the case companies, H&M Group and Skogstad, to generalizing the findings in the textile industry. This research employs a qualitative research design with an explorative purpose. An embedded multiple case study is used to answer both RQ1 and RQ2. The case study is embedded because it encompasses two companies and focuses on their respective SCM practices in the context of CE. It is a multiple case study because the nature of the research questions is to explore the potential of blockchain-based circular supply chains in the textile industry. Thus, the aim is to replicate the findings across a whole industry and not just one unique case. This research's primary data collection strategy is semi-structured interviews with the case companies for RQ1 and RQ2 and the blockchain expert for RQ2. This research also uses secondary data publicly available on the case companies' websites and private records granted access to by the case companies.

5.0 Findings

The following chapter presents the findings from the semi-structured interviews with the case companies, secondary data sources, and the findings from the interview with the blockchain expert. In addition, it provides an analysis of whether blockchain should be used in the textile industry's efforts to move toward circular supply chains.

5.1 H&M Group

5.1.1 H&M Group's supply chain management

H&M Group's supply chain consists of up to 6 tiers of suppliers, from raw materials to finished garments. The number of tiers in their supply chains varies depending on the product type and materials used, ranging from a few tiers for certain products to several tiers for others, see Figure 13. Noticeably, H&M Group does not own any factories themselves. The first tier in H&M Group's supply chain comprises suppliers who are responsible for manufacturing and processing the products. Their tasks include garment washing, dying, cutting, sewing, and finishing the products. The second to fourth tiers consist of companies that specialize in component production and processing. These companies are responsible for yarn spinning, knitting, and producing trims such as buttons, zippers, Velcro, and labels. The fourth to sixth tiers in H&M Group's supply chain involve raw material production. This includes everything from farmers cultivating and extracting raw materials to cotton grinning and fiber production (H&M Group 2023).

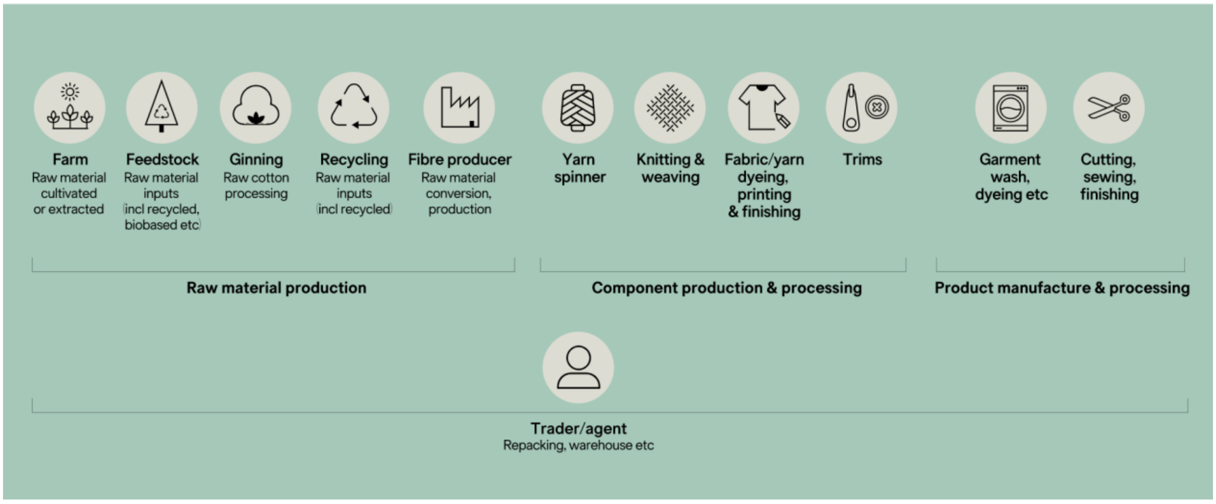

Figure 13. H&M Group's upstream supply chain (H&M Group 2023).

H&M Group does business with more than 602 commercial product suppliers who manufacture products for the H&M Group brand across 1519 tier-one factories situated in Europe, Asia, and Africa. China and Bangladesh are the primary production markets for H&M Group's clothing. On average, H&M Group maintains supplier relationships for eight years. However, some suppliers have been doing business with H&M Group for more than 25 years. H&M Group aims to establish long-term relationships with its suppliers that are built on mutual trust and transparency. Currently, H&M Group's suppliers employ approximately 1.5 million people (H&M Group 2023).

5.1.1.1 H&M Group's purchasing practices

H&M Group, like most fashion brands, do not make fashion, they buy fashion. H&M Group designs its products in-house and outsources the production. H&M Group are aware that their buying behavior and standards can impact suppliers' practices and working conditions. Therefore, they are committed to developing responsible purchasing practices. H&M Group is a founding member of ACT, along with 18 other brands. ACT was established in 2014 to promote responsible purchasing practices and outlines five commitments: 1) including wages as itemized costs in purchasing prices, 2) offering fair payment terms, 3) improving planning and forecasting, 4) providing training on responsible sourcing and buying, and 5) implementing responsible exit strategies (H&M Group 2023).

H&M Group emphasizes developing close partnerships with their suppliers. They have established 16 production offices across Europe, Asia, and Ethiopia to work closely with over 600 suppliers. These production offices facilitate partnerships built on mutual trust, which is essential for sustainable and responsible purchasing practices. H&M Group's purchasing practices are governed by digital systems ensuring adherence to payment terms and minimizing the risk of human error. Payment terms have a big impact on suppliers' financial resilience and ability to invest. Thus, H&M Group has implemented a 60-day payment schedule in line with industry practice. However, H&M Group's suppliers receive payments on average 15 days after the goods are delivered and the invoice is sent (H&M Group 2023).

H&M Group uses a supplier relationship management system to evaluate and develop their suppliers across several business and sustainability parameters. High-performing suppliers are rewarded by receiving advanced production plans to prepare for fluctuations in demand. H&M Group plan their order with their best-performing suppliers as long as three to five years ahead, giving their suppliers stability to invest in their facility and workforce (H&M Group 2023).

5.1.2 H&M Group and circular economy

"*With our size comes responsibility. The way fashion is consumed and produced today is not sustainable. We have to transform the industry we are in. Our ambition is to transform from a linear model to become circular*" – Head of Sustainability at H&M.

H&M Group, as a major player in the fashion industry, wants to be a leader in the transition towards CE. H&M Group joined the Ellen MacArthur Foundation as a strategic partner in 2015. In 2016, H&M group announced its ambition to become a circular business to tackle fast fashion, textile waste, the disposal of unsold textiles, and unethical labor. H&M Group aims to design all products for circularity by 2025 and become climate positive by 2040 (Ellen MacArthur Foundation 2021).

H&M Group has developed a strategy for its shift towards CE that comprises three pillars: circular products, circular supply chains, and circular customer journeys. Under the pillar of circular products, H&M Group aims to create durable products from sustainable and recycled materials that can be recirculated several times. With circular supply chains, H&M Group emphasizes establishing supply chains that recirculate products and support circular production processes and material flows. As for circular customer journeys, H&M Group focuses on providing accessible ways for customers to engage in circular fashion, including repairing, reusing, and recycling products (Ellen MacArthur Foundation 2021).

In the past, H&M Group has had a silo mentality by focusing on becoming circular in each stage of their supply chain separately. However, they eventually recognized that to reach their circular ambitions, they needed to redesign every stage of their products' life cycle and take a more holistic approach (H&M Group 2021).

H&M Group views design as their first opportunity to enable more circular products, and as mentioned earlier, they aim to design all their products for circularity by 2025. H&M Group has aligned its circular product development tool, Circulator, with the Ellen MacArthur Foundation's CE vision. H&M Group's Circulator tool supports product teams to design products with more sustainable sourced materials and products that are more durable and/or recyclable, enabling them to remain in circulation longer (H&M Group 2021).

To reduce their environmental impact, H&M Group aims for 100% recycled or more sustainable sourced materials by 2030 and 30% recycled materials by 2025. In 2021 H&M Group achieved 17.9% recycled material and 80% more sustainable sourced materials. This was a tripling of recycled materials from the previous year and was largely due to increased volumes of recycled cotton and polyester. H&M Group base its material selection on third-party lifecycle assessment data and benchmarks (H&M Group 2021). H&M Group has the world's largest garment collecting program and has been operating this initiative since 2013. Their stores have recycling boxes where customers can bring unwanted textiles or clothes from any brand in any condition. In 2020, the garment collection program collected 18,800 tons of unwanted textiles and clothes (H&M Group 2021).

H&M Group is an advocate of increased traceability and views it as a vital component of their supply chains and an enabler of the CE. H&M Group welcomes the EU's initiatives for implementing digital product passports (DPPs) and is currently working towards integrating DPPs in their supply chains. H&M Group aim to have all product-related data digitally available for their customers. In their efforts to implement DPPs, they recognize the current challenges connected to the DPPs and are foreseeing a transition period to allow the EU, as well as the textile industry, to set up the needed infrastructure (H&M Group Sustainability Department 2023).

H&M Group is not only aiming to transform its supply chain to become circular but also wants to help the fashion industry to shift towards circular supply chains. H&M Group has introduced Treadler, a B2B supply chain service that offers access to parts of their circular supply chain to other companies. By allowing others to access their circular supply chain, they enable other brands to overcome initial barriers and accelerate their transition to CE (Ellen MacArthur Foundation 2021).

5.1.3 H&M Group's blockchain-based circular supply chain

5.1.3.1 Blockchain-based clothes rental service

In 2021 H&M Group launched a one-year pilot project in one of their stores in Berlin, Germany, which used Blockchain technology and IoT tags to power a clothes rental service. Customers could then rent garments by scanning IoT-connected stickers in the garments with their smart phones. This was a collaboration with Lablaco and was facilitated on their SPIN platform. Lablaco is the world's leading circular fashion ecosystem powered by blockchain. To access the service, customers had to sign up for SPIN and then pay daily hire fees (Lablaco 2021).

The goal of the pilot project was for H&M Group to test new circular business models to be able to reduce their materials consumption. Blockchain was used in combination with IoT networks to securely track rental information on each garment. The SPIN platform allowed H&M Group to easily tokenize their products on a blockchain. Customers could then scan the tag of rented clothes and see the whole journey of the items as well as the entire rental history. This offered total transparency about the clothes in the collection by tracing the item's journeys on the blockchain. Customers could also add information to the blockchain themselves by uploading photos of the garment along with style suggestions for each item (Lablaco 2021; H&M Group 2021).

H&M Group's sustainability department stated that this pilot project was more about H&M being able to offer a rental service than testing whether blockchain is a good technical solution. However, the pilot project was a success in that blockchain was able to deliver a technical solution for the rental service, and the overall customer feedback was positive. The pilot project revealed that customers were interested in renting clothes from H&M, and the engagement rate was encouraging. Focus groups indicated that customers found the feature of viewing outfit pictures uploaded on the blockchain by previous renters inspiring. However, customers did not like to upload their own pictures. Minor bugs were reported during the use of the rental service, but this is considered normal for a pilot project. H&M Group was pleased with its collaboration with Lablaco, and they are continuing their collaboration to explore new opportunities to create new solutions on the blockchain (H&M Group Sustainability Department 2023).

5.1.3.2 Blockchain-based supply chain traceability

H&M Group places a strong emphasis on supply chain transparency and traceability and views this as an important step towards its circularity goals. H&M Group aims to increase supply chain traceability and transparency to create greater accountability for where materials and products originate and to drive positive change in the fashion industry. Achieving transparency and traceability in companies as large as H&M Group can be significantly more difficult than in SMEs. However, H&M group aims to leverage its size to drive industry-wide transformation by exploring ways to make traceability solutions practical and scalable on a commercial level (H&M Group 2022).

H&M Group has partnered with TextileGenesis, which provides textile traceability technology. TextileGenesis' traceability platform uses blockchain technology to provide a highly valuable solution to enable improved supply chain traceability and transparency. According to TextileGenesis, up to 30% of all sustainable fibers could be fake. That is why blockchain is necessary to create a digital chain of custody for sustainable fibers in the finished product (Gautam 2020). Blockchain enables the traceability platform to track and document each step of a garment's creation, from fiber to finished product, using a digital token called Fibercoin to track the materials. The blockchain records a garment's journey through the supply chain, TextileGenisis' platform shares the data recorded, and H&M Group is exploring how to scale it (H&M Group 2022).

In 2022, H&M Group implemented this technology on all man-made cellulosic and recycled polyester following several pilot projects in 2021. By the end of 2022, H&M Group aimed to trace over 200 million pieces using blockchain technology. H&M Group acknowledges that there are several traceability solutions currently available, but it is uncertain how many can be scaled to fit the size of a company such as H&M Group. H&M Group's pilot projects with TextileGenisis will bring a better understanding of the capabilities of blockchain technology. Despite the potential disruptions to established practices within the fashion industry, H&M Group believes that integrating blockchain technology can drive the industry towards a future where traceability is easily accessible and highly regarded. H&M Group aims to collaborate with partners across the supply chain and industry to develop shared tools. By working together, the industry can achieve a greater positive impact and reduce duplication of efforts. H&M Group believes that combining technologies and shared-industry databases can enhance supply chain traceability (H&M Group 2022).

H&M group acknowledges that this is a vast project and will take both time and industry cooperation to implement completely. To successfully implement the blockchain solution, all upstream suppliers in the supply chain must adopt and use the data platform provided by TextileGenesis. In addition, reliable systems must be established to verify the accuracy of data entered by the suppliers on the blockchain (H&M Group 2022).

5.2 Skogstad Sport AS

5.2.1 Skogstad’s supply chain management

Skogstad operates an office in China, which was established by the current CEO, who lived there for more than a decade. This office comprises nine employees who work closely with all their first-tier suppliers, as Skogstad has built their supplier base around that office. As a result, the company has a significant advantage in terms of insights and follow-up with their suppliers in China. All of Skogstad’s production takes place in China, and they have established long-term relationships with 17 first-tier suppliers as of 2022. Representants from Skogstad travel to China tree to four times a year to review the suppliers and maintain a strong relationship. Through these visits, they gain valuable insights into the manufacturing of their products and can identify opportunities for improvement. Skogstad strives for long-term relationships with all their suppliers, some of whom have been with the company for over a decade, with an average of more than three years. Furthermore, Skogstad invests in their suppliers, having, for example, assisted in the development of a factory to meet the Nordic Swan Ecolabel standards (Skogstad 2023b).

To ensure the smooth operation of its supply chain, Skogstad’s China office closely monitor their suppliers and ensure that the containers are loaded and transported from the ports in China. Skogstad primarily ships their products by sea to reduce emissions but may occasionally use air transportation when time is of the essence. Skogstad places a strong emphasis on cross-docking, which their China office implements to consolidate shipments from multiple suppliers into one container to avoid shipping partially filled containers (Skogstad 2023b).

To differentiate and prioritize shipments, Skogstad utilizes white and brown cardboard boxes for packaging their products. White boxes are used for customer pre-orders that are shipped directly to the customers, while brown boxes are used for products shipped to their warehouse in Innvik, Norway. This visual distinction makes it easy to identify white boxes for sorting to the customer and brown boxes for direct delivery to their warehouse (Skogstad 2023b).

“*Sorting the white and brown cardboard boxes serves a purpose in our cross-docking operations. For instance, if our supplier has a shortage of 1000 zippers and can only deliver 4000 fleeces out of an order of 5000, we prioritize shipping the white boxes. This* *ensures that customers receive their pre-ordered items on time, while the delayed items are sent to our supplementary warehouse*" – Logistic Manager at Skogstad (Skogstad 2023b).

5.2.2 Skogstad's traceability and transparency

Skogstad has good control over their shipments as their suppliers in China use the same web-based packaging system as Skogstad uses in Norway. By scanning every product, Skogstad can easily track their location and content throughout the supply chain. This ensures a high level of traceability and transparency in their transportation process. Skogstad is in the process of implementing a new system in their warehouse that will strengthen its control over its product traceability. Their current system provides full control over their products from their suppliers in China to the ports in Ålesund or Oslo. The new system will enhance this capability by scanning every box upon its arrival at their warehouse in Innvik. This will enable them to track the precise location of each box in their inventory (Skogstad 2023b).

Skogstad has control over their first and second-tier suppliers, and they are now focused on increasing traceability back to suppliers that provide them with raw materials. Skogstad has already achieved traceability back to their raw material suppliers of wool. Skogstad has access to documentation that provides information about the farm and cultivation methods of wool. Their suppliers are required to disclose information about their subcontractors, which allows them to obtain this data. Skogstad's China office plays a vital role in this process. Skogstad's first-tier suppliers are required to enforce the same set of requirements on their own suppliers as those imposed by Skogstad. To promote transparency and traceability across the entire supply chain, Skogstad employs two management documents: a policy for sustainable business practices that outline minimum requirements for their suppliers and a guideline document for suppliers that outlines the requirements Skogstad can impose and what the suppliers can impose on Skogstad (Skogstad 2023b).

Regarding the EU digital product passport (DPP), this is not something Skogstad has looked into yet. However, they are aware that the EU is planning to make DPP mandatory on all textile products sold in the EU by 2030. Skogstad is focused on ensuring transparency and traceability in their supply chains and is positive to any development in this area (Skogstad 2023a).

5.2.3 Sustainability in Skogstad

Skogstad places great emphasis on sustainability and has taken significant steps in this area, such as implementing a ban on chemicals and using recycled materials. They aspire to contribute to a more sustainable industry and have strengthened their efforts by hiring a dedicated Sustainability Manager. The management acknowledges that sustainability is crucial to stay competitive in the textile industry (Skogstad 2023b).

Skogstad aims to source 100% sustainable materials or certified materials by 2030. However, unlike H&M Group, Skogstad faces another challenge as they operate in the sports industry. A lot of their clothing is technical and made from synthetic materials. Altering the composition of these materials with sustainable alternatives may affect the quality of their products. Nevertheless, Skogstad remains dedicated to testing new materials to find materials that maintain its product quality while meeting its sustainability goal. Skogstad does not only focus on the environmental aspect of sustainability but also the social aspect of sustainability. With more than 2000 workers employed just by their first-tier suppliers, Skogstad recognizes its responsibility to ensure that their suppliers follow ethical labor practices and respect human rights throughout the supply chain (Skogstad 2023b).

Skogstad offers a range of products, predominantly geared towards sports and outdoor activities, largely made from synthetic fibers, although some of their product lines incorporate organic fibers. As a result, their manufacturing processes involve the use of various chemicals. However, the company is committed to maintaining a zero-tolerance policy towards hazardous chemicals and adheres to the EU's strict regulations regarding chemical usage. Additionally, Skogstad consults with research communities to ensure their practices align with the latest research. In some cases, Skogstad exceeds EU regulations, such as their decision to discontinue the use of the chemical PFAS in 2014, well ahead of the recent proposal for a ban by the Norwegian government and several other EU countries in February 2023. Skogstad's team includes highly skilled personnel with expertise in chemicals who closely monitor developments in this field. When it comes to waste materials from production, these are collected by their suppliers and sold to recycling companies in China. Skogstad has noted that China is much better than Norway when it comes to sustainability and recycling and has a lot better facilities and methods of handling waste (Skogstad 2023b).

5.2.4 Skogstad and circular economy

Skogstad wants to contribute to the shift towards circularity by promoting circular business practices. They launched a workgroup for circularity in January 2023, where their goal is to work with circularity through workshops. In these workshops, they are especially focusing on UN sustainability goals 12 and 13, namely responsible consumption and production and climate action. The objective is to extend product life and give damaged and worn products a new life. They are currently providing a clothing repair service in Innvik, and their goal is to sell these mended secondhand garments in their stores. Additionally, Skogstad is training their store employees to perform simple repairs on-site to further promote their circularity efforts (Skogstad 2023b).

Skogstad sees a lot of potential in the sharing economy, including opportunities for renting out clothes, reusing items, and collecting used clothes in-store. Skogstad experiences that there are currently too many laws and regulations that make the process of initiating such circular business models difficult for businesses. For example, if Skogstad wants to sell secondhand clothes, they must have a receipt showing that the product was sold by them. This makes the process very resource intensive. Skogstad believes that simplifying the regulations could encourage more companies to adopt such circular business models, particularly collecting clothes for recycling. Although companies like Skogstad can collect and handle used clothing more responsibly than consumers, profitability is a crucial consideration. Businesses will not undertake such initiatives solely for altruistic reasons, and there must be some form of profitability involved. The same applies to using more recycled and sustainable materials. Today, companies must take the additional cost themselves, but not all companies may have the capacity to do so. Thus, there is a need for government incentives that could accelerate the transition to CE (Skogstad 2023b).

Skogstad recognizes the importance of stakeholder input when implementing new sustainable or circular solutions. Simply switching to more sustainable materials without considering their impact on product quality or security during transportation would not be beneficial. Thus, Skogstad makes it a priority to carefully consider the pros and cons of any new solutions before implementing them. For example, Skogstad has chosen not to switch to biodegradable packaging and continues to use recycled plastic packaging. They analyzed to see if it would be beneficial for them to switch but found some key challenges. Firstly, waste facilities in Norway do not possess the necessary capability or capacity to process biodegradable packaging. Secondly, they are concerned that switching to biodegradable packaging may compromise the security of the product during transportation (Skogstad 2023b).

"*Just the other day we had a container in Oslo with water damage, and if it weren't for the plastic packaging, the products would have been damaged. If we are to introduce more sustainable packaging, it must not compromise the product's integrity or safety during transportation*" – Logistic Manager at Skogstad (Skogstad 2023b).

Skogstad has decided to simplify their collections by reducing the volume and prioritizing basic and key products. To enhance customer satisfaction and encourage consumers to use the products longer, they are ensuring that the colors from different seasons can be easily combined with previous collections. Skogstad acknowledges that it is ultimately the consumer's responsibility to maintain the quality of the product, so their marketing department is actively engaged in educating customers on how to take better care of their products (Skogstad 2023b).

Skogstad has faced challenges in designing products that can be disassembled and separated into different materials at the end of their lifecycle, given the nature of their products. For instance, their rain jackets have tape that is difficult to separate from the zipper and the synthetic material, which is necessary for maintaining the required technical properties that customers demand, such as waterproofing at the seam along the zipper (Skogstad 2023b).

Skogstad offers certain products with zippers or inserts in the pants so that they can be easily folded down. This feature is particularly useful for their children's clothing, as kids tend to outgrow their clothes quickly. By simply folding down or extending the pants, consumers can prolong the life of their Skogstad products, eliminating the need to purchase, e.g., a new snowsuit every winter (Skogstad 2023b).

5.3 Technical solution for circular supply chains in the textile industry

5.3.1 Decision model for blockchain uses cases

In this section, I will use the decision model proposed by Suichies (2015) based on an article by Greenspan (2015), see Figure 14, to suggest weather blockchain can be used in the textile industry or if some type of centralized database is a better solution. This is important to do before jumping aboard the blockchain wagon because to use blockchain we need to understand if blockchain genuinely can add value to the textile industry's shift from a linear economy to CE. In many cases, a centralized database or other types of decentralized databases will work perfectly well (Greenspan 2015). Greenspan (2015) suggests several conditions that need to be fulfilled for a case to be a real blockchain use case, and are these conditions Suichies (2015) based his proposed decision model on. If not every single condition is fulfilled, the textile industry can save a lot of time and money because they don't need blockchain technology at all (Greenspan 2015).

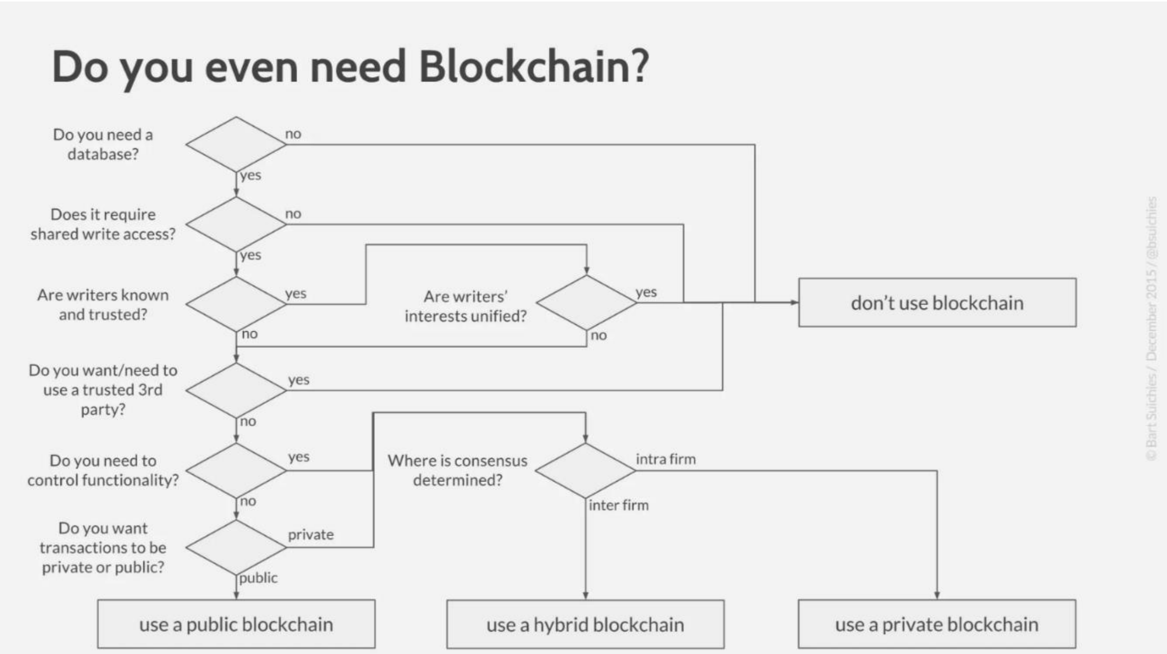

Figure 14. A decision model for blockchain use cases (Suichies 2015).

Do you need a database?

Databases are essential for the operation of any organization. They serve as an organized collection of structured data that is stored within a computer system. Organizations use databases to store, access, modify, and retrieve data (Oracle). Since a database will be beneficial in most cases, the question then shifts from whether you need a database to why you are using a database. In the case of the textile industry transitioning to circular supply chains, a database will be used to store product data across the entire supply chain. Since it will involve collaboration with every actor in the supply chain as well as partners outside the textile industry, this will require some form of shared database that every stakeholder can access.

Does it require shared write access?

Writing access means that a person or organization can record and store new data in the shared database. Blockchains are shared databases that allow for multiple writers. This means that to justify using blockchain there needs to be more than one entity that needs writing access in the shared database (Greenspan 2015). In the case of transitioning to circular supply chains in the textile industry will require closing the data gaps across their entire supply chains. Therefore, every stakeholder in the circular supply chain needs access to record new data in the shared database to enable transparency in all stages of the supply chain.

Are writers known and trusted?

If all writers are known and trusted, you don't need blockchain. Blockchain is a technology for shared databases with multiple writers that are unknown and untrustworthy (Greenspan 2015). The textile industry's complex supply chains consist of multiple tiers of suppliers, not all of which are known. This creates a lack of trust between the different actors involved in the supply chains. Each stakeholder in the supply chain is hesitant to trust others to record reliable data in the shared database, as they fear that other parties will prioritize their self-interest over the common good. Therefore, in the case of the textile industry, the writers are not known or trusted.

Do you want/need to use a trusted 3rd party?

Based on the decision model so far, we need a shared database with multiple writers who do not trust each other. And there is already an established solution to this problem in the form of a trusted intermediary, such as a bank. The bank controls the database and validates all transactions between parties. However, blockchain technology eliminates the need for a trusted third party (Greenspan 2015). The question for the textile industry then becomes whether they want or need a trusted intermediary. According to Greenspan (2015), some good reasons to prefer a blockchain over a trusted third party are lower costs, faster transactions, automatic reconciliation, or the inability to find a suitable intermediary. In the case of the textile industry, an intermediary means additional transaction costs and overhead costs that could be saved. Therefore, this research suggests that the textile industry doesn't need to use a trusted third party and that a blockchain should be used.

Do you need to control functionality?

In a centralized database, the organization that owns and operates the system has complete control over its functionality, including who can access it, who can modify it, and what data is stored. In a blockchain network, which is a decentralized database, control is distributed among the nodes in the network, and changes to the system must be approved by a consensus mechanism. Therefore, when considering using blockchain, it is important to determine whether you need to control the functionalities of the system or if its ok that this control is distributed to every node in the network (Greenspan 2015). Organizations that have full control over the functionality of the system can manipulate and delete recorded data to best serve their self-interest. However, in circular supply chains, ensuring a high degree of transparency, traceability, and security is important (Batista et al. 2019). Therefore, not having control over the functionality of the system will make the data recorded on the blockchain immutable, preventing actors in the supply chain from being able to manipulate the data. This will create greater transparency in the textile industry's supply chains which could help facilitate the shift toward a CE. Therefore, for the discussed use case in the textile industry, the benefits of decentralization would outweigh the need for control, and it would be better if the functionality of the system is not controlled by a single or a few entities.

Do you want transactions to be private or public?

To successfully establish circular supply chains in the textile industry and maximize resource recovery through circular flows of products, materials, and energy, collaboration and information sharing with all stakeholders in the supply chain are important. But just how transparent should data sharing be in the case of the textile industry? Many companies may be hesitant to share sensitive data and want to maintain their competitive advantage. A good argument for keeping transactions private is that permissioned blockchains with known nodes offer a balance of transparency and privacy (Yang et al. 2020). However, if transactions are public, product data is easily accessible for all stakeholders and will increase transparency and promote collaboration with partners within and outside the industry to optimize the use of goods and materials, which is key in circular supply chains (Batista et al. 2019).

Additionally, the textile industry is one of the prioritized industries for the EU digital product passport (DPP). The EU DPP is planned to become mandatory on all textile products sold in the EU market by 2030. The EU DPPs are supposed to enhance transparency on products sold in the EU market to promote the shift towards a CE. The aim is to make it easier for customers to make informed decisions by making the environmental and social impact of products visible, traceable, and easily accessible. Therefore, under the DPP regulations, all product-related data throughout a product's life cycle need to be publicly available across the entire supply chain. The European Commission urges all companies to take action as soon as possible to prepare for the DPP implementation to ensure their organization is equipped for future reporting and the shift towards a CE (WBCSD 2023). Based on these arguments, this research suggests that transactions should be public when it comes to the case of the textile industry shifting towards circular supply chains.

Based on the decision model, the available evidence suggests that in the case of the textile industry shifting towards circular supply chains, a public blockchain is required as a technical solution. This means that currently, no other technical solution can match blockchain technology to solve the problem at hand. However, this does not mean that there can be a better solution in the future.

5.3.2 Blockchain as a technical solution in supply chains

In the interview with the blockchain expert, Varma (2023) argued that traditional supply chains have already transformed due to digitalization and that they are changing once more with the adoption of blockchain technology. Supply chains face several challenges, such as high costs, errors, fraud, and administration. The integration of blockchain and IoT has the potential to disrupt supply chains across the globe by reducing these challenges and increasing transparency (Hughes et al. 2019). Varma (2023) highlights several key supply chain applications that are well-suited for blockchain technology, including procurement, traceability, and fair trade. However, he believes that traceability is the biggest problem blockchain technology can solve for supply chains. Varma (2023) argues that blockchain technology can help solve the problem of preserving data integrity across various parties within supply chains.

Tracing material flows is one of the promising applications of blockchain in SCM. Blockchain provides a secure and trustworthy way of exchanging data, enabling end-to-end transparency throughout the supply chain (Kopyto et al. 2020). In the study by Kopyto et al. (2020), they found that the immutability of blockchain data is one of the main factors making the technology suitable for tracing material flows. However, experts are unsure if blockchain will become the dominant standard in the future. The main challenge in tracing is not just storing the data but physically tracking the item. Thus, blockchain will not be the sole solution to this challenge and will need to be combined with other technologies like the Internet of Things (IoT) to trace products along the supply chain (Kopyto et al. 2020). Varma (2023) argues that IoT technology will be an important part of enabling the use of blockchain technology in SCM and will provide automation to data collection.

According to Varma (2023), in the expert interview, he believes that smart contracts will be very beneficial for SCM. This is supported by the study done by Kopyto et al. (2020). They predict that smart contracts will drive the greatest efficiency improvements in SCM due to their ability to automate processes, enforce contracts, connect unknown and untrusted parties, and provide cost savings. The result of the study predicts that operational tasks within SCM will largely be replaced by smart contracts by 2035 (Kopyto et al. 2020). Varma (2023) believes that IoT technology will provide automation of smart contracts through IoT devices being able to validate conditions codified in the smart contracts. However, barriers to implementation are also expected, including the complexity of translating non-standard supply chain processes into algorithms and slower implementation in developing countries limiting the short term widespread realization of global supply chain automation (Kopyto et al. 2020).

According to Varma (2023), the most significant challenges of implementing blockchain technology in SCM are change management and redefinition of the supply chain flows in a decentralized environment. He believes most current implementations fail because organizations resist change and the need for a mindset shift toward decentralization. Some key challenges include the cost of implementation, the need for interoperability between different blockchains, and ensuring that all supply chain actors are willing to participate in the blockchain network (Varma 2023). Varma (2023) also notes that many organizations fear that by being transparent, competitors may replicate their processes.

5.3.3 Blockchain as a technical solution for circular supply chains

In the interview with the blockchain expert, Varma (2023) argues that blockchain technology features such as immutability, transparency, and traceability make it suitable for promoting sustainability in supply chains. By implementing blockchain technology, organizations can effectively track their supply chains, monitor their environmental impact, and verify the sustainability of their products. This can lead to increased accountability, reduced waste and emissions, and the promotion of sustainable practices (Varma 2023). Improved transparency through blockchain technology in SCM is also expected to increase organizations' motivation to produce high-quality and sustainably made products. However, while blockchain can prevent data manipulation, it cannot guarantee the authenticity of data inputs. Physical evidence of sustainable practices, such as working conditions and the use of non-toxic materials, must be converted to digital information, which is currently a bottleneck (Kopyto et al. 2020). Kopyto et al. (2020) argue that complete and globally acceptable blockchain solutions are not expected until 2035, so sustainability standards will likely be monitored and reported through traditional means and selective blockchain support.

According to Varma (2023), the potential of blockchain technology in the CE is immense and can support the shift from a linear economy to a CE. Hughes et al. (2019) also support this claim, arguing that blockchain technology can drive the CE by providing information on recycled components. Technology innovation is an important driver in facilitating the recovery and reuse of materials. By providing a secure and transparent platform for tracking and tracing products and materials across the supply chain, blockchain can help ensure that materials are reused, remanufactured, recycled, or disposed of sustainably. This can have a significant impact on the environment, as it reduces the amount of waste that is generated and promotes efficient use of resources (Varma 2023). By tracking and tracing products and materials across the supply chain, blockchain can enable the verification of sustainable practices and facilitate the exchange of information and data between different actors in the supply chain (Varma 2023).

Varma (2023) argues that blockchain technology can facilitate circular supply chains by identifying opportunities for value recovery in all stages of the supply chain and secondary supply chains. Blockchain can enable the exchange of information between different stakeholders in secondary supply chains, enabling collaboration with partners inside and outside the industry resulting in more efficient and effective value recovery. The same is true for reverse logistics, where the exchange of information between actors in the supply chain and increased transparency enables more efficient and effective reverse logistics (Varma 2023). Reverse logistics is required to facilitate circular flows for the repair, remanufacturing, and recycling of products and materials and can benefit from blockchain reaching beyond the point of consumption (Böhmecke-Schwafert, Wehinger, and Teigland 2022).

5.3.4 Blockchain as a technical solution in the textile industry

In the interview with the blockchain expert, Varma (2023) argues that the potential benefits of using blockchain in the textile industry include increased transparency, traceability, and sustainability. Blockchain can enable secure and transparent tracking of materials and products, which can help ensure the ethical sourcing of raw materials and improve the sustainability of the textile industry. Successful implementation of blockchain technology in the textile industry would require the participation of all stakeholders in the supply chain, including suppliers, manufacturers, distributors, and retailers (Varma 2023). Despite the potential benefits, there are some key limitations, such as the high cost of implementation and the need for all stakeholders to participate in the blockchain network. The implementation of blockchain by only one company would have limited effectiveness in promoting sustainability and circularity in the industry. Thus, the entire industry must adopt blockchain technology to maximize its benefits (Varma 2023).

According to Varma (2023), the adoption of blockchain technology can support the textile industry's transition to circular supply chains. By utilizing blockchain, a garment's path throughout its life cycle can be securely tracked and traced. This can help preserve the value of the garments and identify opportunities for value recovery when the garment reaches the end of its useful life. Additionally, blockchain can facilitate collaboration across supply chains and industries, enabling more efficient and effective value recovery. An example of this is the use of recycled polyester and nylon to make clothes from waste materials like plastic bottles from secondary supply chains. This helps to reduce the need for extracting more oil (Varma 2023).

Varma (2023) also mentioned the great potential of blockchain technology in the context of the European Commission's proposal for Digital Product Passports (DPP). The European Commission's strategy is to make DPP mandatory on all textiles sold in the EU by 2030. Varma (2023) believes that blockchain technology can provide a technical solution to DPP data storage by enabling secure and transparent tracking and tracing of the products and materials throughout their life cycle. However, ensuring interoperability between different blockchain networks and ensuring that all stakeholders in the supply chain are willing to participate in the blockchain network may be a challenge (Varma 2023).

Based on the decision model proposed by Suichies (2015), this research suggests that the best option for a technical solution for textile organizations looking to switch to circular supply chains would be a public blockchain. Varma (2023) support these findings, suggesting that a public blockchain with tokenization capabilities could be a suitable option for companies in the textile industry. A public blockchain can enable more trust, transparency, and inclusivity in the network while still maintaining privacy through tokenization (Varma 2023). Varma (2023) emphasizes that implementing tokenization on a public blockchain may require additional resources and expertise, which could impact the cost and complexity of the implementation process. Additionally, the company must ensure that the tokenization process does not compromise the accuracy and reliability of the data represented by the tokens. The choice of which type of blockchain to use in the textile industry will depend on the specific needs, goals, and resources of each company, as well as the level of decentralization, transparency, and privacy they require in their supply chain operations (Varma 2023).

5.4 Summary of findings

A summary of key findings is presented in the table below.

#	Findings	Supported by
1	**Supply chain management:** • H&M Group and Skogstad design their products in-house and outsource the production. • Long and complex supply chains with up to 6-tiers of suppliers from raw materials to finished garments. • Focus on developing long-term partnerships with first-tier suppliers. • Focus on sustainable and responsible purchasing practices.	Interview with Skogstad (2023b) and secondary data from H&M Group (2023).
2	**CE in the textile industry:** • CE is already a major focus in the textile industry. • Siloed approach to CE. • H&M Group and Skogstad aim for 100% sustainable materials by 2030. • Sustainable materials for technical clothing represent a challenge in terms of product quality and recycling. • H&M Group and Skogstad aim to extend product life. • The sharing economy holds vast potential, including renting out clothing and collecting used garments. • Less than 1% of materials are recycled into new clothes. • Recognizes the responsibility to ensure that suppliers follow ethical labor practices and respect human rights. • Current regulations restrict circular business models. • Need government incentives to accelerate the transition to CE.	Interview with Skogstad (2023b) and secondary data from H&M Group (2021) and European Commission (2022).

3	**Supply chain transparency and traceability:** • H&M Group and Skogstad are positive to development in supply chain transparency and traceability. • Currently using centralized systems to track products and rely on physical visits to control suppliers. • H&M Group have started to use blockchain to trace some of their resource flows across their supply chain.	Email inquiry with H&M Group Sustainability Department (2023) and Skogstad (2023a) and secondary data from H&M Group (2022).
4	**Technical solution for circular supply chains in the textile industry:** • Evidence suggests that a public blockchain is needed for the textile industry to move toward circular supply chains.	The decision model by Suichies (2015) based on the article by Greenspan (2015),
5	**Blockchain in SCM:** • Increase supply chain traceability and transparency. • Remove the need for trust and facilitate collaboration. • Immutable data makes the technology suitable for tracing material flows, but it cannot guarantee the authenticity of data inputs. • IoT is an essential part of enabling blockchain in SCM. • Implementation fails due to inadequate change management and a lack of a decentralized mindset.	Interview with blockchain expert Varma (2023) and the study done by Kopyto et al. (2020).
6	**Blockchain-based circular supply chains:** • Blockchain enables a circular supply chain by facilitating transparency, traceability, and collaboration. • Transparency and traceability help identify opportunities for value recovery in all stages of the supply chain and secondary supply chains. • Improved transparency increases accountability and motivates companies to produce high-quality, sustainable products. • Tracing products helps keep them at their highest value as long as possible and identifies opportunities for value recovery at the end of their useful life. • Facilitates reverse logistics and collaboration with cross-sector partners.	Interview with blockchain expert Varma (2023).
7	**Blockchain in the textile industry:** • Increased transparency and traceability in the textile industry, ensuring sustainable and ethical sourcing of clothes. • Successful implementation requires the participation of all stakeholders. • A public blockchain with tokenization capabilities could be suitable for the textile industry's move toward more circular supply chains. • Provides a technical solution to DPP data storage.	Interview with blockchain expert Varma (2023).

6.0 Discussion

6.1 Circular economy discussion

The textile industry is one of the largest global polluters. Fast fashion and constant trend changes encourage customers to dispose of clothing, leading to a culture of waste. Additionally, the supply chains in the textile industry are long and complex, with most manufacturers outsourcing production to countries with lower labor costs, resulting in challenges such as worker exploitation. The textile industry is undergoing a significant global shift towards embracing CE, which is being reinforced by regulatory measures introduced by the EU and the Norwegian government to promote circularity (European Commission 2022). To discuss the potential of CE in the textile industry, I will use the five underlying circular business models proposed by Accentura (2014) as a framework, along with relevant literature and the findings from the two case companies.

6.1.1 Circular supplies

Based on the two case companies, the circular supply business model appears to be a big focus in the textile industry. Both H&M Group and Skogstad are phasing out the use of virgin resources and focusing on increasing the share of fully renewable, recyclable, and biodegradable resources in their production. H&M Group aims for 100% more sustainable sourced materials by 2030 and 30% recycled materials by 2025 (H&M Group 2021). Skogstad aims to source 100% sustainable materials or certified materials by 2030. However, a lot of Skogstad's products are made from synthetic materials, and altering the composition of these materials with sustainable alternatives may affect product quality. Nevertheless, Skogstad remains open to innovations and to testing new materials to find materials that maintain its product quality while meeting its sustainability goal. Skogstad is also committed to maintaining a zero-tolerance policy towards hazardous chemicals and adheres to the EU's strict regulations regarding chemical usage (Skogstad 2023b).

In the interview with Skogstad, they argued that just switching to sustainable materials without evaluating their impact on product quality or transportation security is not a good approach. In certain situations, opting for less sustainable materials can be more sustainable overall, as exemplified by Skogstad's decision not to use biodegradable packaging. By maintaining the use of plastic packaging, their products are protected against water damage during transportation (Skogstad 2023b). After all, it is not sustainable if the biodegradable packaging ends up causing damage to an entire shipment of products that would have otherwise been fine with plastic packaging.

6.1.2 Resource recovery

When it comes to the resource recovery business model, it seems from the two case companies that the textile industry has a lot of potential for improvement. Less than 1% of the material used in the textile industry's production is recycled into new clothes (European Commission 2022). Resource recovery can improve the resilience and robustness of companies and supply chains. Using recycled materials reduces the dependency on global commodity markets, decreasing the risk of raw material price fluctuations, resource scarcity, and supply shortages caused by geopolitical and natural events (Hofmann 2019).

H&M Group's extensive garment collection program collected 18,800 tons of unwanted textiles and clothes in 2020 in their in-store recycling boxes (H&M Group 2021). On the other hand, Skogstad believes that too many regulations make it difficult to collect clothes from customers for recycling. They argue that simplifying these regulations could incentivize more textile companies to start collecting used clothes. Textile companies can collect and handle used clothing more responsibly than consumers. Yet, the ultimate responsibility for what happens to the products at their end of life lies with the customers (Skogstad 2023b). Nevertheless, it can be argued that implementing better and easier systems for collecting clothes could encourage customers to recycle their clothes. However, offering services like this is costly for textile companies, and there needs to be a profitability perspective because companies will not undertake such initiatives solely for altruistic reasons. Today, companies must take the additional cost themselves, but not all companies may have the capacity to do so. Thus, there is a need for government incentives to facilitate clothes collection for recycling (Skogstad 2023b).

Recycling byproducts from production and using waste as a resource is also important in the resource recovery model (Accentura 2014). Skogstad's suppliers sell the byproducts from their production to recycling companies in China. However, Skogstad is unsure what happens to it after it reaches the recycling companies (Skogstad 2023b). Using waste as a resource is an important way to recover resources, whether from companies' production or secondary supply chains. Both H&M Group and Skogstad use recycled polyester which is made from plastic waste from secondary supply chains. Additionally, Skogstad uses recycled plastic in their packaging (H&M Group 2021; Skogstad 2023b). However, it is important to remember that recycling is a very energy-intensive process and that the greatest environmental benefits come from extending the life of the products.

6.1.3 Product life extension

The production life extension business model aims to keep products at the highest value as long as possible by reselling, repairing, or remanufacturing (Accentura 2014). This circular business model has a lot of potential to tackle fast fashion in the textile industry. Currently, slow fashion cannot compete with large-scale fast fashion companies, which benefit from economies of scale (de Aguiar Hugo, de Nadae, and da Silva Lima 2021). Fortunately, product life extension appears to already be a significant priority in the textile industry, based on the two case companies and Skogstad in particular. However, H&M Group, as a fast fashion brand, seems to be lagging behind in embracing this particular circular business model. Nevertheless, H&M Group aims to design all products for circularity by 2025 and their Circulator tool helps their product teams design more durable products enabling them to remain in circulation longer. H&M Group also focuses on providing accessible ways for customers to engage in circular fashion, including repairing and reusing products (H&M Group 2021).

Skogstad focuses on encouraging consumers to use their product longer. They acknowledge that it is ultimately the consumer's responsibility to maintain the quality of the product, so their marketing department is actively engaged in educating customers on how to take better care of their products. Skogstad also focuses on designing their product to last longer. For example, they offer children's clothing with zippers or inserts that can be easily folded down to extend the lifespan of the product, given that kids tend to outgrow their clothes quickly (Skogstad 2023b). Additionally, Skogstad provides a small-scale clothing repair service in Innvik, and their store employees are trained to perform simple repairs on-site. Their goal is to sell these repaired clothes in their stores. However, reselling clothes is currently highly regulated, making the process of initiating such initiatives difficult (Skogstad 2023b).

6.1.4 Sharing platform

The sharing platform business model creates a platform for product users to collaborate and share resources such as excess capacity or underutilized assets. This business model can benefit organizations with low utilization or ownership rates for their products and assets (Accentura 2014). One could make an argument that the assets owned by manufacturing suppliers in the textile industry, such as production machines that have excess capacity or are underutilized, could benefit from being shared. In addition, H&M Group offers access to parts of their circular supply chain to other companies to enable them to overcome initial barriers and accelerate their transition to a CE (H&M Group 2021).

6.1.5 Product as a service

One of the main goals of CE is to achieve dematerialization by decoupling economic growth from the utilization of natural resources. In order to reduce resource and energy consumption, companies should move away from tangible products and instead offer services and capabilities (Hofmann 2019). The product as a service business model focuses on just this, providing a rental or pay-per-use arrangement for products instead of selling them (Accentura 2014). Based on the case companies, this is something the textile industry wants to implement. For example, H&M Group launched a pilot project in 2021 for a rental service for their products using blockchain technology and IoT tags (Lablaco 2021). However, an interesting argument in this regard is whether customers want to rent clothes they use frequently or just clothes for special occasions, such as dresses and suits. According to Gueye (2021), while we buy more clothes than ever, we use each item less frequently. Therefore, there is a good argument for making renting non-basic clothes the norm, and the success of H&M Group's pilot project showed that customers are interested in renting clothes (H&M Group Sustainability Department 2023). Skogstad also sees a lot of potential in the sharing economy. However, as a SME, they don't have the resources to run pilot projects in the same capacity as H&M Group (Skogstad 2023b). The product as a service business model would also incentivize the textile industry to design product with higher quality to last longer due to the value-creating opportunities in rental services comes from the product's longevity and reusability (Chong-Wen 2020).

6.2 Circular supply chain discussion

From the circular economy discussion, it appears that there is a lot of untapped potential for resource recovery in the textile industry, with less than 1% of the material used in the textile industry's production being recycled into new clothes (European Commission 2022). While H&M Group collected 18,800 tons of unwanted textiles and clothes in 2020

(H&M Group 2021), this was only from one stage of their supply chain. Therefore, there are still vast opportunities for resource recovery along the rest of their supply chain. From the case companies, it seems that a lot of the efforts made to transition to a CE are limited to measures within the focal companies or between a few supply chain actors, leading to siloed approaches. However, to maximize resource recovery, there are a lot of possibilities for closer collaboration between all the actors across the entire supply chain and with cross-sector partners in secondary supply chains. Therefore, there is a lot of potential for circular supply chains in the textile industry.

The textile industry has some of the longest and most complex supply chains of any industry, exemplified by H&M Group's supply chain with up to six tiers of suppliers for raw materials to finished garments across Europe, Asia, and Africa (H&M Group 2023). Circular supply chains represent a holistic approach to CE for H&M Group and Skogstad and encompass both reverse and forward circular resource flows to maximize resource recovery (Batista et al. 2019). Increased resource recovery can improve the resilience and robustness of the textile industry by decoupling revenues from material input and enhancing resource efficiency. Since by using recycled materials, H&M Group and Skogstad reduce their dependency on global commodity markets, thereby reducing the risks associated with fluctuations in raw material prices, resource scarcity, and supply shortages resulting from geopolitical and natural events. In addition, reducing raw materials consumption upstream in the supply chain can significantly decrease emissions in the textile industry (Hofmann 2019).

Circular supply chains consist of a supply network of organizations collaborating to implement resource recovery flows. Therefore, collaboration between actors across the supply chain and cross-sector partners is required to implement the different circular resource flows in a circular supply chain (Batista et al. 2019). H&M Group and Skogstad focus on establishing long-term relationships with their first-tier suppliers, with H&M Group having an average supplier relationship of eight years and Skogstad averaging over three years (H&M Group 2023; Skogstad 2023b). However, this is only with their first-tier suppliers, and circular supply chains require collaboration across their entire supply chains and with partners outside the industry to maximize resource recovery and value creation. Focusing on cross-sector collaboration is important because recycled materials don't always add value within the same supply chain but can add value in secondary supply chains in other industries. Therefore, while the CE aims to close material and energy loops, circular supply chains also aim to create an open loop system with circular flows of resources with secondary supply chains (Farooque et al. 2019).

Digital technologies have become important in facilitating the adoption of CE principles in the supply chain (Kayikci et al. 2022), and according to de Jesus and Mendonça (2018), technology innovations are an important driver to enable circular supply chains. Currently, H&M Group and Skogstad's technical solutions are not capable of fully realizing the potential of circular supply chains. Therefore, a better technical solution is needed to enable the traceability, transparency, and collaboration required for maximizing resource recovery in the textile industry.

6.3 Technical solution for circular supply chain discussion

As discussed, a better technical solution is needed for the textile industry to transition to circular supply chains. According to de Jesus and Mendonça (2018), the availability of technical solutions is a significant barrier to facilitating circular supply chains. This means that technological innovations are an important driver when it comes to enabling circular supply chains in the textile industry. This is supported by Hofmann (2019), who argues that the adoption of new technologies such as blockchain, IoT, or big data is crucial.

This research uses the decision model proposed by Suichies (2015) based on an article by Greenspan (2015) to decide what technical solution would be best to facilitate circular supply chains in the textile industry. The decision model helps to understand if blockchain genuinely can add value to the textile industry or if a centralized database or other types of decentralized databases will be a better option (Greenspan 2015).

When using the decision model, this research establishes that the textile industry needs a form of shared database to facilitate collaboration between every actor in the supply chain and partners outside the textile industry. Batista et al. (2019) argue that circular supply chains are enabled by close supply chain collaboration with partners within and outside the industry. Furthermore, following the decision model, the research shows that every stakeholder in the circular supply chain needs access to record new data in the shared database. This is because to maximize resource recovery facilitating data collection across the entire supply chain is important to close data gaps and enable full transparency (Hofmann 2019). Additionally, the supply chains in the textile industry are long and complex, consisting of multiple tiers of suppliers, not all of which are known, creating a lack of trust (H&M Group 2023; Skogstad 2023b).

The fourth stage of the decision model is the first stage where centralized databases can be ruled out as valid options for the textile industry. This stage questions whether a trusted third party is needed (Suichies 2015). Blockchain technology replaces trust with cryptographic proof and eliminates the need for trusted third parties. This enables direct transactions between unknown and untrusted parties, resulting in reduced transaction costs and quicker transactions (Kopyto et al. 2020). Based on the decision model used in this research, the textile industry doesn't need a trusted third party, and a blockchain should be used. The reason behind this is that trusted third parties result in additional transaction costs and overhead costs that could otherwise be saved. This is supported by Varma (2023), who states that the adoption of blockchain technology can support the textile industry's transition to circular supply chains.

In the decision model, the fifth and sixth stages focus on determining what type of blockchain should be used. Regarding whether control of functionality is needed, the question is whether to use a public, private, or hybrid blockchain. Public blockchains are decentralized and use consensus mechanisms to reach consensus in the network, while private blockchains are permissioned and controlled by a single organization (Yang et al. 2020). Circular supply chains need full transparency and data security to maximize resource recovery (Hofmann 2019). Decentralization of control enhances data security and transparency in the network (Kopyto et al. 2020). Thus, this research suggests that the benefits of decentralization would outweigh the need for control, and it would be better if the functionality of the system was not controlled by the focal company. Furthermore, regarding the question of whether transactions should be public or private, the best option for enabling circular supply chains in the textile industry would be to keep them publicly available. Even though many companies may be hesitant to share sensitive data, making transactions public increases transparency and promotes collaboration with all stakeholders in the circular supply chain. In addition, with the EU DPP becoming mandatory, such data needs to be made publicly available anyways. Thus, the evidence suggests that a public blockchain is the best option to enable circular supply chains in the textile industry. This is supported by Varma (2023) who also suggest a public blockchain.

Despite the potential benefits as an enabler of circular supply chains, blockchain technology has high initial investment costs and market uncertainty. For SMEs, such as

Skogstad, the high investment costs are an even bigger barrier in the transition to circular supply chains (de Jesus and Mendonça 2018). Therefore, there needs to be incentives for the textile industry to invest in blockchain. The EU DPPs are a good incitive for investing in technology innovation as the EU plans to make DPP mandatory on all textile products sold in the EU market by 2030 to promote the shift towards CE (WBCSD 2023). Both H&M Group and Skogstad advocate for increased transparency in supply chains and are positive about the EU DPP initiative. Skogstad is aware of DPPs but has not discussed it internally yet. H&M Group, on the other hand, are already working on integrating DPPs in their supply chains (H&M Group Sustainability Department 2023). Although the EU is not incentivizing companies to invest directly in blockchain, blockchain can be a potential technical solution for DPP's data storage problem. H&M Group stated that they are waiting to see what the EU recommends regarding technical solutions for data storage (H&M Group Sustainability Department 2023).

6.4 Blockchain-based circular supply chains discussion

From the discussion on technical solutions for circular supply chains, a public blockchain is the best option to enable circular supply chains in the textile industry. Using a public blockchain as a global data layer enables supply chain actors to securely connect and open their data silos leading to global traceability and transparency (Varma 2023). As discussed earlier, H&M Group and Skogstad need to increase transparency, traceability, and collaboration to enable circular supply chains. The findings show that both H&M Group and Skogstad strongly emphasize transparency and traceability in their supply chain. Skogstad uses traditional centralized databases to track the location of their products. However, their current system limits their ability to trace the origin of material flows across their supply chain (Skogstad 2023b). H&M Group also primarily uses traditional centralized databases. However, they have started to use blockchain to trace some of their material flows using a digital token called Fibercoin. H&M Group advocates for the integration of blockchain technology and collaboration with industry partners to enhance supply chain traceability (H&M Group 2022).

Batista et al. (2019) argue that circular supply chains are enabled by close collaboration with all actors across the supply chain and cross-sector partners outside the industry. Close collaboration requires free communication and data sharing between supply chain partners. However, this is difficult to achieve in complex systems with a lack of trust, like the textile industry. Fortunately, blockchain enables decentralized, trust-free networks facilitating faster and more efficient data sharing without establishing trust between parties (Wang et al. 2020). Therefore, H&M Group and Skogstad need a public blockchain. According to Varma (2023), blockchain can enable collaboration through information sharing between stakeholders in the circular supply chain, including cross-sector partners in secondary supply chains. The use of a public blockchain makes real-time data continuously accessible to all relevant stakeholders in a circular supply chain, which increases trust and improves companies' collaboration capabilities (Kayikci et al. 2022). Successful blockchain-based circular supply chains require effective change management and all stakeholders to participate and use the same blockchain platform (Varma 2023). However, a lack of regulations and standards can make implementing blockchain this challenging (Farooque et al. 2020).

Blockchain enables collaboration by increasing traceability and transparency. Tracing resource flows is one of the most promising applications of blockchain in circular supply chains (Varma 2023). According to Kopyto et al. (2020), the immutability of data is the main factor making blockchain suitable for tracing resource flows. Blockchain provides a secure and trustworthy way of exchanging data, enabling end-to-end transparency throughout the supply chain (Kopyto et al. 2020). Furthermore, blockchain enables highly traceable products, facilitating more effective resource recovery and reducing textile waste and virgin materials in the circular supply chain (Kayikci et al. 2022). Tracking and tracing help keep clothes at their highest value as long as possible and identify opportunities for value recovery when the garment reaches the end of its useful life. The social aspect of sustainability is also important in the textile industry. Increased transparency and traceability make it easier for H&M Group and Skogstad to ensure that their suppliers follow ethical labor practices and respect human rights (Varma 2023).

Although reverse logistics is common in most supply chains today, incorporating blockchain technology can enhance efficiency in reverse resource flows. By enabling easier tracking of the movement of returned products and materials, blockchain can help companies manage their returns and disposal processes. Blockchain can also facilitate the flow of textile waste and secondary materials between two companies from separate supply chains (Kayikci et al. 2022). Waste and secondary materials in one supply chain can create value in others, such as plastic bottles can become input in textile production as recycled polyester and nylon.

Data stored on the blockchain is immutable. However, it does not guarantee the authenticity of data inputs (Kopyto et al. 2020). Physical evidence of sustainable practices, such as working conditions and sustainable materials, must be recorded on the blockchain. Thus, blockchain needs to be combined with IoT to trace materials along all the different loops to enable blockchain-based circular supply chains in the textile industry (Kopyto et al. 2020). IoT can help unlock the value of blockchain in circular supply chains and enable H&M Group and Skogstad to increase resource recovery and reduce emissions and textile waste. However, the lack of access to technology for upstream suppliers and the high investment cost of the IT infrastructure needed are one of the primary barriers to enabling blockchain-based supply chains in the textile industry (S. Khan et al. 2022). In addition, the scalability of blockchains becomes an adoption barrier with the vast amounts of real-time data recorded by IoT devices. D. Khan, Low Tang, and Manzoor Ahmed (2021) argue that the currently available consensus mechanisms are not efficient enough to address the problem blockchain faces with scalability. However, others may argue that scalability is not a problem and that, e.g., the BSV blockchain, with no default hard cap for block sizes, has unlimited potential for scaling (Bybit 2022).

Although blockchain can support the move toward more circular supply chains, it is important to consider blockchain technology's environmental impact. Energy consumption is a significant barrier to adoption, with some blockchain platforms having emissions on par with entire nations such as Sri Lanka and Jordan (Böhmecke-Schwafert, Wehinger, and Teigland 2022). However, this depends on the blockchain platform used. Some argue that, for example, the public blockchain BSV would reduce the world's total energy consumption compared to the current systems (Southurst 2022).

7.0 Conclusion

7.1 Research summary

The purpose of this research has been to explore the potential of blockchain-based circular supply chains in the textile industry to address issues such as fast fashion, textile waste, the disposal of unsold textiles, and unethical labor practices. The answers to the research questions are summarized below.

RQ1: How can the textile industry move towards more circular supply chains?

As one of the largest global polluters, the textile industry has great potential for circular supply chains, with significant opportunities for resource recovery and value creation throughout the supply chain. However, current CE efforts in the textile industry are often siloed and limited to measures within the focal companies or with a few supply chain partners. An open loop system with closer collaboration across the entire supply chain and with cross-sector partners in secondary supply chains is needed to move toward more circular supply chains in the textile industry. An open loop system will facilitate circular flows with secondary supply chains and reverse logistics to improve resource and value recovery. In addition, with circular supply chains, the textile industry can improve the resilience and robustness of their supply chains by decoupling revenues from material input and enhancing resource efficiency. First, however, the textile industry must improve supply chain transparency and traceability because availability and access to reliable information are crucial to facilitate collaboration and trust. Therefore, a better technical solution is needed to enable the transparency, traceability, and collaboration required to support the move toward more circular supply chains in the textile industry. Furthermore, it is important to consider that the primary goal of the textile industry is to maximize profit. Therefore, to encourage companies to move towards more circular supply chains, it is important for governing bodies to enact legislation that provides incentives, such as the EU strategy for sustainable and circular textiles.

RQ2: How can blockchain technology support circular supply chains in the textile industry?

The first research question determined that a better technical solution as an enabler for circular supply chains is needed. According to the decision model and insight from the expert interview, this research suggests that a public blockchain is the best technical solution to enable circular supply chains in the textile industry. Blockchain technology can support circular supply chains by enabling the missing transparency, traceability, and collaboration. A public blockchain can act as a secure global data layer in the textile industry, removing the need for trust and allowing supply chain partners to collaborate and share data. By eliminating the need for trust, textile companies can collaborate with unknown supply chain partners, including cross-sector partners, without needing trusted intermediaries. This facilitates the transparency and traceability needed to move toward more circular supply chains to maximize resource recovery and eliminate textile waste easier. The end-to-end supply chain transparency allows real-time data to be accessible to all relevant stakeholders. This creates highly traceable products, reducing textile waste by enabling circular flows of products and materials within the same supply chain and across secondary supply chains. In addition, facilitating better circular material flows reduces the need for virgin materials in the production, resulting in lower emissions upstream in the supply chains. It is important to remember that value creation is not limited to economic value. Reducing emissions and ensuring fair labor practices also create value in the textile industry.

Successful implementation of blockchain-based circular supply chains requires effective change management and all stakeholders to participate. However, a lack of regulations and standards and the high investment costs could make global adoption in the textile industry challenging. In addition, problems related to scalability and energy consumption are debated and depend on the blockchain platform used.

7.2 Limitations of the study

This research employs a qualitative research design. Therefore, it is subjective and interpretive by nature. Consequently, it is important to acknowledge that my personal biases and experiences may influence my interpretation of the data.

A limitation of this research is the small sample size. Getting in contact with companies that were interested in participating in the research proved challenging. While the embedded multiple case studies only focus on two case companies, it provides valuable insights into their specific operations and practices. The findings can inform further research and serve as a starting point for other studies into the textile industry.

Due to the small sample size and subjective nature of qualitative research, one should be careful when generalizing the findings of this research to the textile industry. However, this study provides a foundation for further exploring the potential of blockchain-based circular supply chains in the textile industry.

Although this research suggests that blockchain technology is currently the most suitable technical solution for facilitating circular supply chains in the textile industry, it is important to acknowledge that there may be superior solutions in the future. Therefore, the findings of this research should be interpreted in the context of the limitations of the current technology landscape.

7.3 Suggestions for further research

Some suggestions for further research could be to explore how blockchain technology can be integrated with other emerging technologies, such as the IoT, artificial intelligence, or big data analytics, to enhance circular supply chains in the textile industry. It would also be interesting to research further how DPPs can promote CE and enable circular supply chains in the textile industry. In addition, researching how blockchain technology can be applied to more specific aspects of SCM in the textile industry could be interesting for future research.

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9.0 Appendix

9.1 Appendix A: Interview guide for the case companies

Sustainability

1. What is your approach to sustainability?
2. How do you work to improve sustainability? Do you have any sustainability goals?
3. What is your approach to the circular economy?
4. Do you have any thoughts on circular fashion?
5. How do you work to extend the life of your products?

Supply Chain Management

1. In your view, what are the main elements of your supply chain?
2. Can you explain your supplier strategy? What is your relationship with your suppliers?
3. How do you follow up on sustainability requirements with your suppliers?
4. How do you handle reverse logistics?

Design

1. How do you approach product design? Internally or externally in your supply chain?
2. What do you focus on in the design process?

Production

1. What materials/components are used in the production of your products?
2. Do you use sustainable materials, and if so, how do you ensure this?
3. What happens to the materials that are wasted during production and the byproducts that are produced?

Traceability

1. How do you trace products through your supply chains? Can you easily access information about the origin of products and materials upstream in your supply chain?
2. How do you track and trace environmental and social impact through your supply chain?

Transparency

1. How do you experience transparency in your relationships with your suppliers and other actors in your supply chain?

2. How and to what extent do you share information with internal and external actors in your supply chain?

Technology

1. In your view, is there any new technology that can help your business become more sustainable?
2. Do you have any thoughts regarding the following technologies: Blockchain, the Internet of Things (IoT), and Big Data? If yes, do you have any experience with this type of technology?
3. Are you familiar with digital product passports?

Wrap-up questions

1. Is there anything else you would like to add related to the topic of this interview?
2. Can I contact you in case I have some follow-up questions later in the writing process?

9.2 Appendix B: Interview guide for the blockchain expert

Blockchain

1. Could you give a definition of blockchain technology?

Supply chain management

1. In your opinion, what specific supply chain management processes do you believe are best suited for blockchain technology, and why?
2. How can blockchain help to increase transparency and traceability in supply chain management, and what benefits does this offer for businesses and consumers?
3. How do smart contracts work in the context of supply chain management, and what benefits do they offer?
4. What role does IoT play in enabling the use of blockchain technology in supply chain management, and what challenges must be overcome to fully realize its potential?
5. Do you have any real-world examples of blockchain implementation in supply chain management, including any notable success stories and lessons learned.
6. What are some noticeable challenges and limitations of implementing blockchain in supply chain management?

7. How do you think blockchain will transform traditional SCM processes, and what benefits will this bring to businesses and consumers?

Circular economy

1. What specific features of blockchain technology make it suitable for promoting sustainability in supply chains?
2. What are some of the potential challenges and limitations in using blockchain for promoting sustainability in supply chains?
3. In your opinion, what aspect of circular economy can benefit from blockchain technology?
4. How can blockchain technology support the transition to circular economy?
5. What aspects of circular supply chains can benefit from blockchain technology? How can blockchain facilitate value recovery in a secondary supply chain/industry from recycled materials that don't add value within the same supply chain?
6. Reverse logistics is required for the repair, remanufacturing, and recycling of products, how can blockchain facilitate this?
7. How can blockchain facilitate secondhand product sales (amazon model?) or rental?
8. How do you view the potential of blockchain when it comes to the European Commission proposal of Digital Product Passports (DPP)? DPP mandatory on all textiles sold in the EU by 2030.

The textile industry

1. In your opinion, what are the potential benefits and limitations of using blockchain in the textile industry?
2. How can the textile industry successfully implement blockchain technology? Would its implementation be effective if only one textile company adopted it, or is it necessary for the entire industry to embrace it?
3. Do you know of any example of blockchain being used in the textile industry today?
4. How can blockchain technology help the textile industry transition to circular supply chains?
5. How can smart contracts help the textile industry become circular?
6. What type of blockchain is the best for a textile company wanting to implement it in its supply chain operations to transition to circular supply chains?

Wrap-up questions:

1. Is there anything I didn't ask you that I should have?
2. If you were in my shoes, what else would you consider?