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Executive Master in Customs and Supply Chain Compliance

Can utilization of distributed ledger technology help resolve the compliance challenges with supply chain traceability?

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Executive summary

Companies are investing in supply chain traceability capabilities to comply with regulatory requirements and reduce their risk of exposure to unethical labour practises by third-party suppliers. This thesis will focus on the textile, fashion, and apparel industries and their supply chain traceability challenges in the context of mitigating the risk of exposure to unethical labour practises by third-party suppliers. The argument of this study is applicable to larger fashion and apparel industry firms. The question asked in this thesis is, can distributed ledger technology help resolve the compliance challenges with supply chain traceability? But existing obstacles to supply chain traceability include a lack of transparency, inadequate record-keeping as a result of the manual nature of information collection and processing, the extensive documentation required to ascertain traceability, and data manipulation. According to the research presented in this thesis, distributed ledger technology (DLT) has the potential to play a significant role in resolving issues related to supply chain traceability. DLT can improve transparency and increase stakeholder trust and accountability by providing a secure and transparent method for monitoring and validating transactions and data across the entire supply chain.

The methodology relied on in this thesis is, literature review and desk research to identify compliance concerns resulting from recently enacted legislation on compelled labour. The literature review will aid comprehension of the challenges of supply chain traceability and the role blockchain technology can play in enhancing traceability. Through case studies, it will be possible to gain insight into the implementation of DLT-based supply chain traceability solutions. In addition, interviews will help to gain a better understanding of the industry's supply chain traceability challenges and the complications caused by the implementation of compelled labour regulations. Based on the literature review, desk research, case studies, and interviews, I will draw conclusions and determine whether DLT-based solutions can improve supply chain traceability to comply with forced labour regulations.

Based on my research, I can conclude that DLT combined with existing technologies and industry best practises has the greatest potential to improve supply chain traceability, thereby facilitating compliance with ethical labour practises and decreasing the risk of forced labour and other noncompliance issues. My research concludes that, for this to occur, it is necessary to establish uniform standards for supply chain data, for the data to be interoperable, and that legal recognition of documents and supply chain records that are being digitised is essential, as physical documents and certificates are currently expected to be presented alongside digital records. There is currently no incentive to digitise the supply chain because there is no regulation involving the public recognition of digital records and documents that have been designated legally valid based on agreed-upon common standards for interoperability of supply chain data. Additionally, standardisation is crucial for the interoperability and growth of blockchain technology. To further address concerns regarding confidentiality, it is suggested that a private blockchain be investigated as a potential solution, as it may help to foster trust while safeguarding sensitive data. To expedite the processing of larger data sets, consensus protocols with fewer steps must be developed. Additionally, the audit trace of records corresponding to tangible objects must be verifiable. A blockchain-based supply chain tracing

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system must also prioritise security in order to establish long-term confidence in the technology. My investigation has led me to the conclusion that for blockchain technology to be adopted, all the above are necessary.

Based on my research, I have also concluded that implementing DLT requires extensive coordination among supply chain stakeholders; as a result, businesses must determine if it aligns with their business objectives and regulatory requirements. DLT should be implemented alongside other best practises and tools for supply chain traceability, including risk assessments, audits, and supplier engagement programmes. Significant potential advantages in terms of improved compliance, transparency, and trust make it a promising alternative for the apparel and fashion industries seeking to improve their supply chain practises and comply with the risk of coerced labour. While blockchain technology can aid in enhancing transparency and traceability, it is not a panacea that works.

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Chapter 1 Introduction

Supply chain traceability is a critical component of modern supply chain. It enables companies to drive operational efficiency and comply with regulatory requirements. Companies may increase supply chain transparency and trust by utilising technology and putting in place traceability systems. This allows them to provide value to their stakeholders and consumers. Recently, Germany has adopted the Act on Corporate Due Diligence Obligations in Supply Chains (Lieferkettensorgfaltspflichtengesetz – "LkSG") on 1st January 2023. The LkSG lays down extensive obligations for companies regarding their own business area, and their direct and indirect suppliers (Thoms & Fischer, 2022). Also under the Uyghur Forced Labour Prevention Act (UFLPA), the Forced Labour Enforcement Task Force is directed to develop a strategy for enforcing the ban on the importation of goods into the United States that were manufactured wholly or partially with forced labour in the People's Republic of China, specifically in the Xinjiang Uyghur Autonomous Region (Carlson & Weaver, 2022). Therefore, supply chain traceability is becoming more important and urgent in the face of increasing volatility, complexity, and uncertainty in the business environment. For example, under the obligations of the UFLPA, "An apparel importer in America must provide all transactional, financial, and transportation documents, including packing lists, bills of lading, country-of-origin certifications, invoices, purchase orders, contracts, production records, inventory of inputs/outputs, proofs of payment, and transportation records for all stages of the garment manufacturing process, including the cotton, spinning, yarn, fabric materials, and finished garment. The supporting documents must demonstrate the countries of origin of the raw cotton, as well as where the purchase, manufacture, and transportation of the different inputs throughout the supply chain took place. Based on these documents, US Customs and Border protection agency (CBP) conducts an applicability review and determines whether the supply chain includes any inputs from the Xinjiang Uyghur Autonomous Region (XUAR) (Office of Trade, US Customs and Border Protection, 2022). Thus, the U.S. enacted UFLPA law creates a presumption of forced labour in the production of goods sourced from North Korea and Xinjiang, China (Cockayne, 2022). The 2017 Countering America's Adversaries through Sanctions Act (CAATSA) and the 2021 Uyghur Forced Labour Prevention Act (UFLPA) impose a reverse onus on importers who must prove that goods sourced from these regions were not produced with forced labour. The evidence on the effectiveness of the UFLPA "appears mixed, at best, so far" (Cockayne, 2022).

Consequently, we can observe a trend in the legislative approach shifting from voluntary measures and self-commitments to mandatory regulations (Thoms & Fischer, 2022). Thus, global supply chains are under increasing pressure due to recent geopolitical events, as well as the increasing number of legislative requirements for complying with regulations (Thoms & Fischer, 2022). To comply with these regulations supply chain traceability matters because it helps to determine under which conditions goods were produced. If these conditions are poor, then it must be considered. To cope with these risks, companies need to have more visibility and control over their supply chains and therefore companies need to adopt traceability solutions that are tailored to their specific context and objectives (Figures, Gilbert, McAdoo, & Voigt, 2021).

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One of the important elements of traceability is the origin of goods. Origin of goods refers to the country or region where a product or its inputs were produced or manufactured. Thus, the origin of goods is a critical aspect of supply chain traceability, as it provides important information about the source of raw materials, as well as compliance with regulations and industry standards. By tracking the origin of goods, companies can ensure that they are sourcing materials from ethical suppliers, as well as complying with social, and governance regulations (Saenz, Hinkel, & Bysong, 2021). Further, companies can identify any potential risks and take appropriate action to address them, such as implementing new supplier standards, improving supply chain transparency, or working with suppliers to improve working conditions (Razak, Linda C., Stevenson, & Hendry, 2021). Thus, we can define supply chain traceability as the ability to track and trace products or materials through the various stages of the supply chain, from the origin of raw materials to the destination of the finished product (Bateman & Bonanni, What Supply Chain Transparency Really Means, 2019). This process involves capturing and recording information at each stage of the supply chain, such as the origin and sourcing of raw materials, manufacturing, transportation, distribution, and retail (Norton, 2019). Traceability allows companies to identify the source of problems that arise in the supply chain and take corrective action quickly.

In this thesis I will be concentrating on textile, fashion and clothing industry and its requirements for supply chain traceability. The argument presented in this thesis is applicable to larger fashion, textile, and clothing companies. The arguments made in the thesis will not apply to small fashion and clothing manufacturers who may not have the capacity, technological expertise, and the need for implementing a complex supply chain traceability system. Also, larger fashion and clothing brands have their reputation at stake and are impacted by boycotts due to issues related to labour practices and human rights (Mariachiara Colucci, 2020,). Thus, larger fashion and clothing industry players are compelled to invest in solutions that are robust and verifiable through the supply chain.

As a result of the foregoing, we have recognised the problem in terms of compliance concerns, and this thesis conducts a literature review to analyse the issues regarding traceability within the supply chain. It also investigates the problems experienced in monitoring the cotton supply chain, which tries to prevent cotton farmed in Xinxiang using forced labour from being purchased. Furthermore, the thesis will analyse the role blockchain technology can play in enhancing traceability based on results inferred from interviews with experts and industry people (Stouffer, et al., 2022).

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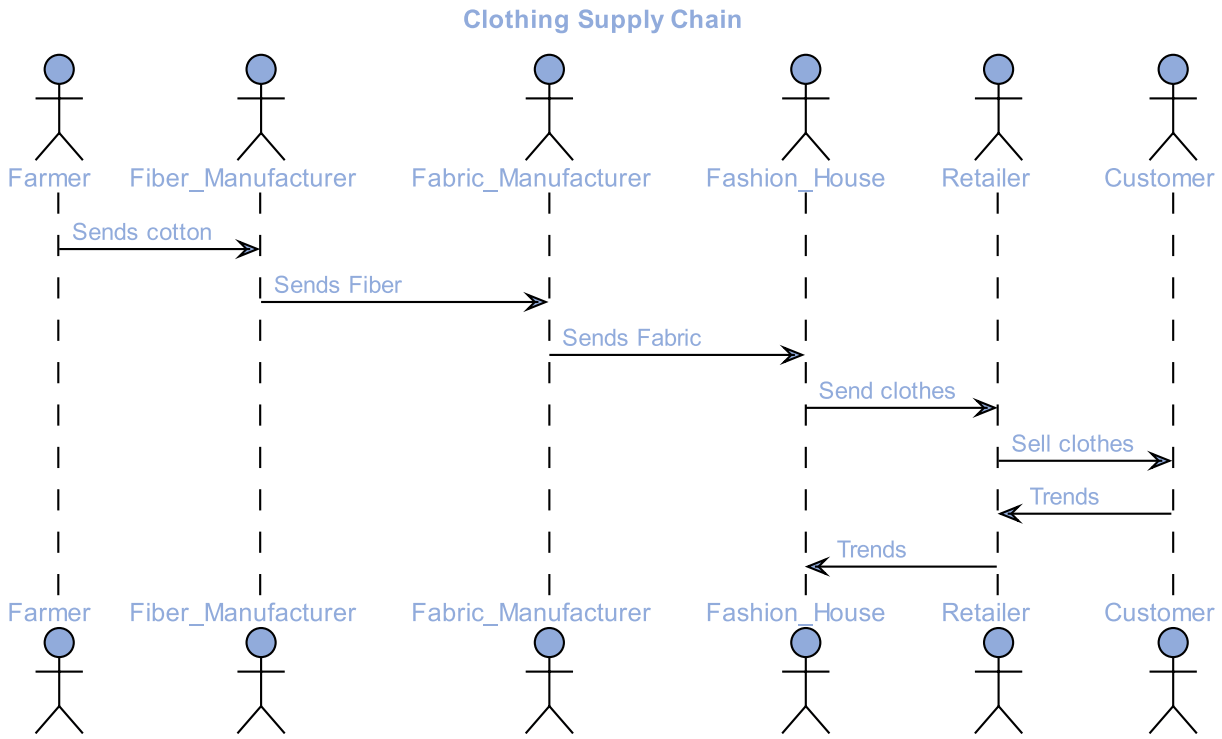
Understanding the cotton supply chain

Let's start by understanding the supply chain for the textile and clothing industry. It can be said that the supply chain is complex with many parties involved in the entire supply chain. The following diagram is a simplistic view of the supply chain, in the real world each step is more complex and involves many parties, that is one among the many reasons for lack of supply chain transparency within the textile and clothing sector.



The figure above shows the flow of goods, trends, and information within the supply chain.

Current challenges

Unfortunately, poor information exchange is among the main reasons for challenges with traceability, while no single method will comprehensively address these challenges, efforts are being made to improve traceability of goods by exchanging traceability records using secure industry wide data sharing platforms that can collect reliable information on responsible suppliers and eliminate auditing redundancies without compromising business confidential details. As this requires companies to collect data across their entire supply chain, new technologies are being explored to make this change happen.

Currently, supply chain traceability and origin of goods can be achieved by using various methods and technologies, such as barcodes, QR codes, RFID tags, sensors, blockchain, and artificial intelligence. These tools can help capture, store, share, and analyse data on products

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and processes along the value chain. However, they also pose challenges and barriers, such as data quality, security, privacy, interoperability, scalability, and governance. Therefore, supply chain traceability and origin of goods are not only technical issues, but a collaborative one (Betti, Hinkel, & Saenz, 2021). They require alignment and coordination among value chain partners and stakeholders, as well as common standards and protocols for data collection and exchange. They also entail continuous monitoring, evaluation, feedback, and adaptation of traceability systems as the business environment evolves and new technologies emerge (Betti, Hinkel, & Saenz, 2021). Currently, there are various technologies and tools available to support supply chain traceability, such as barcodes, RFID (radio-frequency identification) tags, and blockchain. These technologies enable companies to capture and store data about the movement of products through the supply chain, and to share this information with suppliers, customers, and other stakeholders. Further, Distributed ledger technologies (DLTs) such as blockchain have emerged as a hopeful tool for improving supply chain traceability. DLTs are decentralized digital ledgers that enable secure, transparent, and tamper-proof recording and sharing of data across a network of participants. This makes them particularly well-suited for supply chain traceability, which requires the recording and sharing of data across multiple parties in a secure and transparent manner (Oliver Bischoff, 2021).

Thus, the key questions to answer are:

- What is the promise of DLT? What properties are claimed to be delivered by the DLT?
- What is the level of transparency needed to ensure compliance with demands for supply chain traceability?
- In the context of Supply chain traceability which actors would be entering data and which actors would need access to the data?
- What are the advantages of using distributed ledger technology in supply chain traceability over other IT systems?
- Is DLT as a solution feasible from the perspective of political, legal, economic, and technical aspects for supply chain traceability?
- Does DLT based on the research in this thesis, suffice the needs of the actors?

Problem definition and research questions

The research will identify the challenges faced in supply chain traceability and it will explore the positives and negatives of technologies like distributed ledgers to understand if such technologies can help to improve the supply chain traceability. The suggestion made in this research is to evaluate whether use of trusted decentralized information sharing technologies like blockchain, which enables stakeholders to share traceability information across supply chain, help resolve some of the challenges faced in supply chain compliance. So, the question we are asking is “Can utilization of distributed ledger technologies help resolve the compliance challenges with supply chain traceability?”

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Chapter 2 Review of research literature and research approach

This thesis identifies compliance problems coming from recently imposed forced labour legislation and proposes enhancing supply chain traceability to better compliance with the regulation through a literature study and desktop research. For example, it investigates the difficulties in monitoring cotton supply networks that attempt to avoid cotton from Xinxiang (Stouffer, et al., 2022).

Furthermore, the literature study is guided by answers to the main issues raised earlier in the introduction under the heading "key questions." Answering these questions will help understand the challenges of supply chain traceability and the role blockchain technology can play in improving traceability.

Later, in the chapter titled "Lesson from implementation of DLT," I cover successful attempts of implementing supply chain traceability solutions using DLT. This will help draw learnings from such implementations.

Furthermore, I will conduct interviews with industry leaders and experts to acquire better knowledge of the industry's supply chain traceability challenges, as well as their worries and DLT experiences. I spoke with experts and industry professionals to learn about the challenges that have arisen because of the implementation of forced labour regulations, whether supply chain traceability can assist in overcoming the challenges of complying with forced labour regulations, and whether DLT as a technology can assist in improving supply chain traceability. As a result, I attempted to interview various supply chain stakeholders, including individuals responsible for the development and management of information systems, technology platform operators offering traceability solutions as a service, logistics service providers delivering services using the platform developed for providing traceability solutions in China and Singapore, and clothing aggregator and trader, to learn how they have managed to comply with the recommendations. Unfortunately, all supply chain stakeholders cannot be asked the same questions because they each approach the problem from a unique perspective and with specialist knowledge. As a result, the questions have been designed so that by the end of the interview, I will be able to draw conclusions and identify the key challenges in interpreting the regulation, setting appropriate expectations, whether traceability can support regulatory compliance, and what it may entail to implement a DLT-based solution.

Finally, the thesis will analyse whether blockchain technology might aid in traceability by drawing conclusions and summing the findings from interviews with industry experts and professionals. Based on the results of the interviews, I will identify potential issues with the use of blockchain technology for supply chain traceability and give recommendations on how to proceed. Based on the information I've gathered; I'll draw conclusion on whether DLT-based supply traceability has matured sufficiently and whether the market is ready for DLT-based solutions to address compliance concerns. The figure below shows the diagrammatic representation of the research methodology.

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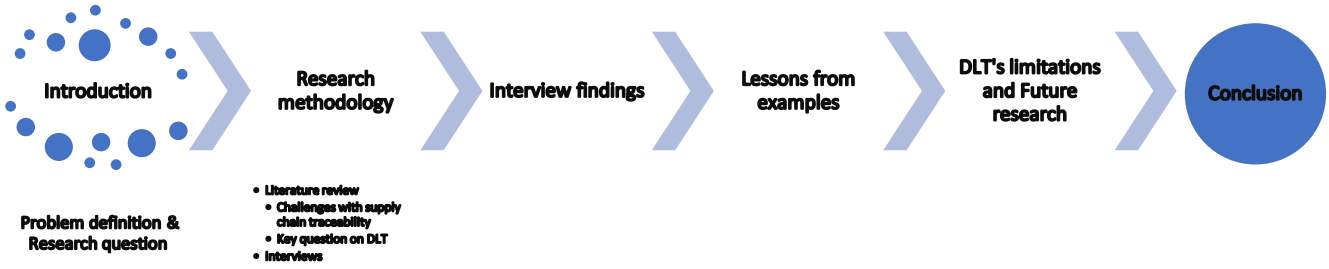
Figure 2 Research methodology



Desktop research & Literature review

There is literature on both supply chain traceability and distributed ledgers technology (DLT) or blockchain, unfortunately though very less is written on resolving the challenges faced in supply chain traceability using blockchain technology. As mentioned earlier, it is being recognized that blockchain could be a potential solution for supply chain traceability (Laaper, 2022). The literature review is driven by answering the key questions stated below, answering these questions will help in thoroughly understanding the challenges in supply chain traceability such that a solution can be developed for traceability and transparency needs of the supply chain, these key questions are.

- What is the promise of DLT? What properties are claimed to be delivered by the DLT?
- What is the level of transparency needed to ensure compliance with demands for supply chain traceability?
- In the context of Supply chain traceability which actors would be entering data and which actors would need access to the data?
- Advantages of using distributed ledger technology in supply chain traceability?
- Is DLT as a solution feasible from the perspective of political, legal, economic, and technical aspects for supply chain traceability needs?
- Does DLT based on the research in this document, suffice the needs of the actors?

Following that I will review certain traceability implementation for ‘Examples of successful implementation of distributed ledger technology in supply chain traceability’.

Interviews with experts and industry professionals

As mentioned earlier, I will conduct interviews with experts to better understand the industry's supply chain traceability difficulties, as well as their concerns and experiences with DLT. By

developing results from interviews with industry experts and professionals, the thesis will investigate whether blockchain technology can aid in traceability.

A diverse set of experts and industry professionals were chosen for the interview, including the head of information systems, the Director of Global Engineering, and the Director of Digital Transformation, who were both chosen to understand the industry's perspective on implementing a DLT-based supply chain traceability system. A Regional Head of TradeLens at Maersk was chosen because TradeLens has extensively used DLT in the implementation of its supply chain platform, a Director at the international logistics firm that collaborated with TradeLens on implementing DLT supply chain system and the challenges they faced, including understanding why the implementation did not go as planned, and finally a clothing aggregators and trader engaged in clothing trade between Asia and the US for understanding the challenges in complying with recently enacted Forced Labour Act.

Thus, based on the findings from the literature research, interviews with experts, a specific proposal will be provided which will be the ‘Recommended action to overcome future hurdles for application of blockchain technology for supply chain traceability’.

Finally, data from the aforementioned sources will be examined and triangulated to arrive at a conclusion.

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Chapter 4 What is supply chain traceability?

Before conducting research on the compliance challenges of supply chain traceability, it is essential to define supply chain traceability. But in order to comprehend what constitutes supply chain traceability and which actors are crucial to the data transfers, the following questions must be answered.

1. What is supply chain traceability?
2. Which actors would be entering data?
3. Which actors would need access to the data?

What is supply chain traceability and transparency?

Traceability refers to the ability to track the movement of a product or item from its origin to its destination. This can include information about the source of raw materials, the suppliers and manufacturers of intermediate products, and the logistics involved in transporting products from one point to another (Bateman & Bonanni, What Supply Chain Transparency Really Means, 2019). Traceability is important for various industries to ensure the safety of products, compliance with regulations and to track the product in case of recall or other issues, whereas transparency refers to the ability to access and view information about a product or item (Bateman & Bonanni, What Supply Chain Transparency Really Means, 2019). This can include information about the origin of raw materials, production processes, and logistics. Transparency is important for ensuring compliance with regulations and for providing customers and other stakeholders with information about the products they are buying. Thus, together, traceability and transparency can provide a complete view of the supply chain and the movement of a product from its origin to its destination. Traceability ensures that products can be traced back to their source in the event of a recall or other issue, while transparency allows for real-time tracking and verification of transactions and provides customers and other stakeholders with information about the products they are buying (Bateman & Bonanni, What Supply Chain Transparency Really Means, 2019).

Who would be entering data?

Stakeholders in the supply chain will be entering data and contributing to the data pipeline based on their role and the value that they add to the supply chain. Also, it is important to remember that technology solutions deployment is always in the digital dominion, whereas goods are in the physical dominion and thus linking digital to physical dominion is important to keep track of the goods in the supply chain. This is possible by linking physical objects to digital records. Thus, validation of authenticity of a physical goods requires that the goods are inspected to detect a unique characteristic or signature which can be linked to digital records. Currently for associating physical goods with digital records, techniques such as radiofrequency identification (RFID), barcode, serial numbers, QR Codes, near field communication (NFC), and IOT (Internet of things) devices are used to link to physical goods, IOT devices allow computing devices such as sensors to connect and talk to each other, modern sensors are already advanced enough to track items, containers, and pallets across the supply chain. Linking of physical goods to digital records must occur at two levels, the first is an actual physical marking

and the second is a trusted data layer (Stouffer, et al., 2022). However, to ensure flow of information, all steps of the supply chain will have to be tagged digitally for transparency and traceability. Such technological solutions might require significant changes to the current system architecture and thus might cost significantly to deploy. Also, improving transparency and traceability may require a significant change in the culture of working and that may be a showstopper too. Further it is also important to check whether the technology connecting the physical goods to the technology solutions is tamper proof.

Who would need access to the data?

In the context of Supply chain traceability depending on the role and requirements stakeholder must have access to the data. In the next chapter I have explained which actors would be entering data and which actors would need access to the data.

But, for end-to-end traceability, it must be feasible to share data records among parties in the supply chain, while at the same time participants in the supply chain must have high confidence in the existence of robust data protection measures and must have satisfactory processes and procedure for sharing their business information. Participants' confidence in data safeguards must be high enough to enable them to participate in shared technology platforms such as distributed ledgers and blockchains, that create transparency within the supply chain and reduce all parties' exposure to supply chain risks (Stouffer, et al., 2022). Thus, the technology solution must have many characteristics like easier information exchange, transparency, authenticity, availability etc. to overcome the challenges of ensuring traceability and origin of good in international trade (Buist, 2020). Databases are the underpinnings of traceability systems tying all the pieces together (Betti, Hinkel, & Saenz, 2021). Blockchain or distributed ledger technology is considered as a tamper evident and tamper resistant distributed ledger, which stores all the details of a supply chain network's activity (Buist, 2020). This enables the data to be trusted by blockchain participants. Further in the research we will explore whether blockchain as a technology is suitable to overcome the challenges of ensuring traceability and determining preferential and non-preferential origin of goods in international trade.

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Chapter 5 Current challenges

In the context of Supply chain traceability some of the promises made by Distributed ledger technology stated earlier in the introduction seem ideal at the onset for implementing a DLT based supply chain traceability system. But it is important to understand the challenges such that the solution developed using DLT does indeed help the Cotton and Textile industry.

Based on the literature review, it can be inferred that compliance challenges in supply chain traceability can be broadly classified into three categories (Bateman & Bonanni, What Supply Chain Transparency Really Means, 2019).

1. Lack of transparency
2. Inadequate record-keeping
3. Falsifying records.

Lack of transparency

The absence of visibility and clear information about the many phases and actors engaged in the supply chain process is referred to as a lack of transparency. As a result, it becomes more difficult to verify the validity and origin of items, as well as monitor and enforce compliance with legislation and standards. Companies may find it difficult to analyse and manage the risks connected with their supply chains, as well as demonstrate compliance with legislation and standards, if there is a lack of transparency. This can lead to difficulties such as unethical practises and worker exploitation. In brief, a lack of transparency can jeopardise the supply chain's integrity and make it impossible to ensure compliance with regulations and standards, posing several issues for businesses.

While the critical data elements for designing a digital traceability solution include unique identification, origin, and location information of goods throughout their supply chain journey, these data elements alone may not suffice; supply chain traceability necessitates additional information and inputs from various stakeholders involved in the supply chain that either supports or cross validates the various data points and information of the goods. One of the primary issues in existing traceability systems is identifying suppliers when materials have been blended or paper trails have been lost. Liability for paperwork inconsistencies can result in fines, additional tariff, and duty assessments, and, in cases of fraud, criminal prosecution in addition to fines and penalties.

As supply networks become more complicated, an effective and cost-effective method of tracing components used in the end product is critical for increasing confidence among all stakeholders involved in the supply chain. However, trust can only be established if the information presented with the stakeholder is transparent. Thus, it can be claimed that the problem of supply chain traceability can be handled by increasing supply chain transparency, however supply chain transparency has two aspects (Bateman & Bonanni, What Supply Chain Transparency Really Means, 2019).

- Visibility: Accurately identifying and collecting data from all process steps in the supply chain

- Disclosure: Communicating this information, internally and externally, at the appropriate level of detail

Increasing the visibility of origin information throughout the supply chain has the potential to reduce administrative costs by relieving importers of the burden of relying on information and paperwork provided by their foreign suppliers, as well as to aid in the prevention of fraud and mis-declaration in some cases. If the goal is to identify the country or region of origin and verify production conditions along the supply chain, as well as potentially the chain of custody of a product, then some traditional approaches to managing information through chain of transport documents, which are part of any company or industry effort to establish traceability, may be insufficient (Lehr, 2020).

While visibility and disclosure are important aspects of supply chain transparency, the foundation is a reliable and tamper-proof audit trail of information flow between various stakeholders (Lehr, 2020). Furthermore, major stakeholders interacting in the supply chain, including external parties such as government authorities, must be able to access and process the information in the supply chain. Access to such information may be restricted based on the requirements and function of the supply chain actor. Authorities and stakeholders would be more confident if they could view supply chain traceability information about the flow of commodities between different parties that is tamperproof and has an audit trail. To address the issue of supply chain transparency, the system must be constructed on the main pillars of a tamper-proof audit trail, transparency, and disclosure at the right level of information to the relevant set of stakeholders (Lehr, 2020).

Inadequate record-keeping

Inadequate record-keeping by supply chain participants, like lack of transparency, refers to insufficient or erroneous documenting and recording of supply chain actions and information (Lehr, 2020). This can lead to compliance issues in supply chain traceability as it becomes more difficult to follow the movement of items, verify the declared authenticity of origin, and monitor compliance with legislation and standards.

For example, incorrect or inadequate data may pose traceability issues, such as the difficulty to authenticate a product's origins if authorities raise concerns and seek information. This can have serious consequences for enterprises, including reputational damage, legal liability, and income loss. Inadequate record-keeping can also make it difficult for enterprises to demonstrate compliance with laws governing worker rights. This can result in sanctions, punishments, and negative news, all of which can harm the company's reputation and stakeholder relationships. In short, inadequate record-keeping can imperil the integrity and compliance of the supply chain, providing a plethora of issues for firms, regulators, and consumers (Lehr, 2020).

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Current traceability frameworks are, to an extent, still paper-based and often utilize assorted, unconnected systems to manage the supply chain (Lehr, 2020). The traditional approach towards origin traceability has been in two ways.

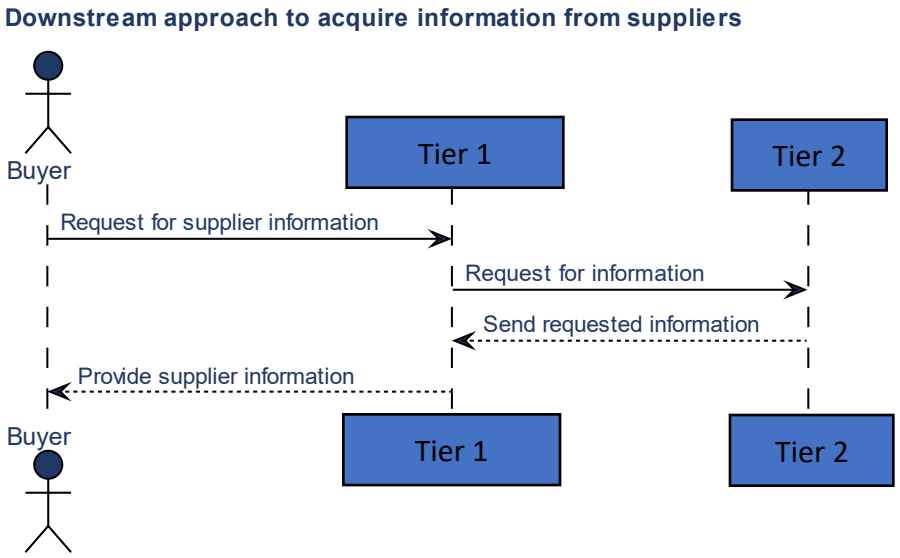
1. Downstream approach
2. Upstream approach

Downstream approach

To trace their products back to their origin, companies adopting the downstream method rely on agreements with downstream suppliers, such as Tier 1 and Tier 2 suppliers. Outside of Tier 1, where they frequently have a direct relationship, this can be challenging. Some companies can communicate with their Tier 2 suppliers if they have direct communication with them or if their Tier 1 provider has agreed that they must purchase from their preferred Tier 1 supplier. Companies may lack leverage to compel answers farther up the supply chain, especially if they only purchase a small percentage of a Tier 1 or Tier 2 supplier's manufacturing. Companies try to track down the sources of their products by questioning factories about their suppliers and progressively working their way up the supply chain. It is a time-consuming process, and those who have tracked a small number of downstream items recognise that doing so for every product line would be prohibitively expensive. If suppliers are aware that sourcing from specific sources is restricted, they may supply deceptive information. Even with this manual approach, most organisations have limited visibility beyond Tier 2 because pinpointing the origin of raw materials without identifying the entire chain of suppliers is practically impossible (Lehr, 2020).

Companies rely on relationships with downstream suppliers to acquire information. In this scenario enforcement is coming from the fashion house. Following figure shows the flow of information in the downstream approach.

Figure 3 Downstream approach for flow of information



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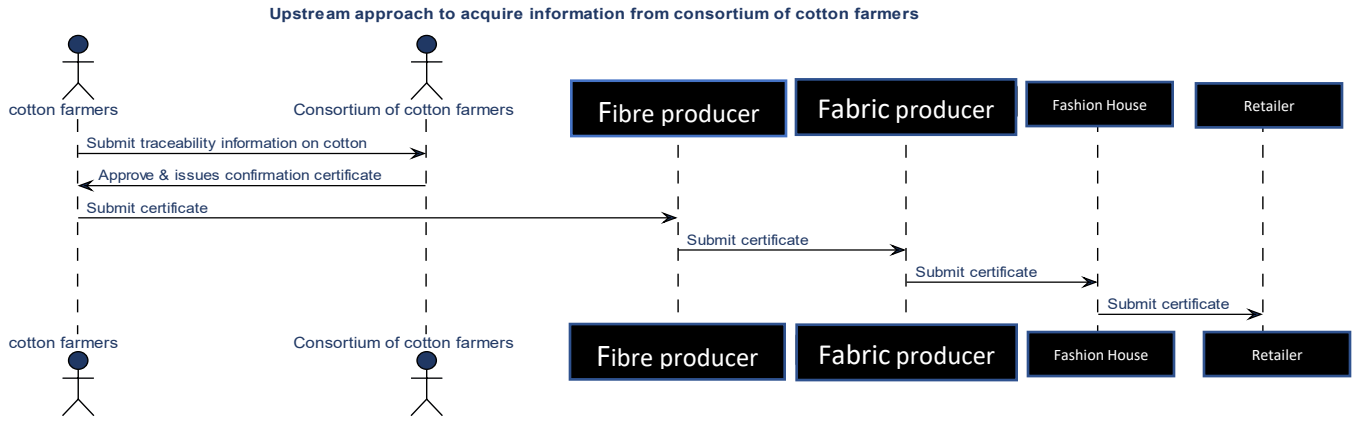
Upstream approach

In this strategy, industry organisations begin at the source, such as the farm in the case of cotton. Thus, they build certification standards in collaboration with farming societies and growers that focus on defining specific production circumstances, such as verifying accurate claims of cotton production without the use of forced labour or responsible sourcing. They are often not focused on giving very specific information about geographic origin or intermediaries along the whole supply chain and are meant to provide some sort of guarantee to the end user regarding the conditions under which cotton is produced at the farm level. For instance, if it is less interested with the specific farms or factories in its supply chain and just wants to ensure that none of these suppliers use forced labour. Thus, these systems identify certain, well-known farms that are accredited to specified production parameters, the output of which can theoretically be traced along the supply chain (Lehr, 2020).

However, this technique limits the number of suppliers, and in a highly competitive market with supply chain concerns, it is tough to confine yourself to a small number of farmers and their certification criteria (Lehr, 2020). Following figure shows the flow of information in the upstream approach.

Figure 4 Upstream approach to acquire information from consortium of cotton farmers



Similar issues arise at each point of the supply chain. Whether a corporation wishes to track cotton from the field or yarn from a spinner, upstream methods include auditors visiting locations to check labour practises, which is not always practical. Furthermore, maintaining traceability across the supply chain is difficult, and approaches are either costly or ineffective to prevent goods generated through forced labour from entering the supply chain. Similarly, upstream approaches are unstable and resource demanding. The inadequacy of both upstream and downstream techniques necessitates the development of new, stringent traceability systems (Lehr, 2020).

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Falsifying records

The deliberate alteration, falsification, or tampering of information in supply chain records and systems is referred to as data manipulation. This can pose substantial compliance difficulties in supply chain traceability by undermining the accuracy and reliability of data used to track the flow of items and monitor compliance with regulations and standards. For example, data manipulation might result in the development of fraudulent records, making determining the origin and validity of products in the supply chain difficult. As a result, counterfeit or substandard items may enter the market, putting consumers at danger and harming the reputations of the companies involved. Furthermore, data tampering can make demonstrating compliance with legislation and standards, such as those governing labour rights, environmental protection, and product safety, difficult. Companies may face legal liabilities, fines, and unfavourable publicity as a result of this, which can impact the company's reputation and relationships with stakeholders. In brief, data tampering can have major consequences for the integrity and compliance of the supply chain, posing a number of issues for businesses, regulators, and consumers.

Instead, IT systems can aid in the development of transparency and traceability; the problem is in creating a trusted and tamperproof audit trail of information flow between diverse stakeholders. If all stakeholders are using the same IT platform, it may be easier to create a reliable and tamper-proof audit trail of the information flow. To be effective, we would obviously require not only global corporations, but also the different vendors and distributors with whom they collaborate, to apply the same methods. However, it is nearly impossible for all players to be on the same platform because overhauling the global economy's digital infrastructure would be a mammoth task. However, the first step in managing records such as supply chain events or transaction data, responsible sourcing information, and tracing technology is to digitise this information. Because digitalization is crucial to maintaining the security and accessibility of these records (Lehr, 2020).

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Chapter 6 What is blockchain or DLT?

Before we moved further, we must understand what is blockchain or distributed ledger technology. A Blockchain is a database that is shared across a network of computers. Thus, it is a form of database or a storage structure that uses blocks and chaining to store data. As new data is received, it is entered into a new block and then chained to the previous Blockchain Once a record has been added to the chain it is very difficult to change. To ensure all the copies of the database are the same, the network makes constant checks. Blockchains have been used to underpin cyber-currencies like bitcoin, but many other possible uses are emerging (Murray, 2018). Blocks have specific storage capabilities, and when they are filled, they are linked to the previous filled block, establishing a data chain known as a ``Blockchain.'' Satoshi Nakamoto, an anonymous individual, or group of individuals originally built the Blockchain in 2008, a peer-to-peer network, and solved the double-spending problem. A year later, Bitcoin, a cryptocurrency, was created based on Blockchain technology serving as the distributed ledger (Agarwal, et al., 2022). Thus, Blockchain is a technology that can allow authenticated data communication between each player in a supply chain without the intermediation of a trusted central organization. By verifying and adding data in real time, blockchain can increase transparency across a supply chain. According to Bank of England, a blockchain is “a technology that allows people who don’t know each other to trust a shared record of events (Laaper, 2022).

The following figure 5 explains the blockchain model in our context. In our case, when blockchain recordkeeping is used, assets such as inventory, orders, packing lists, and bills of lading are given unique identifiers. Participants in the blockchain are assigned unique digital signatures, which they use to sign the blocks they add to the blockchain. Every step of the transaction is then recorded on the blockchain as a transfer of the corresponding data from one supply chain participant to the next. This allows an importer to track the product from the factory floor to the port and shipment for export, thereby ensuring the correct country of origin and minimizing the risk of illegal transhipment, circumvention, or evasion of duties (Ludwikoski & Salaheldin, 2022).

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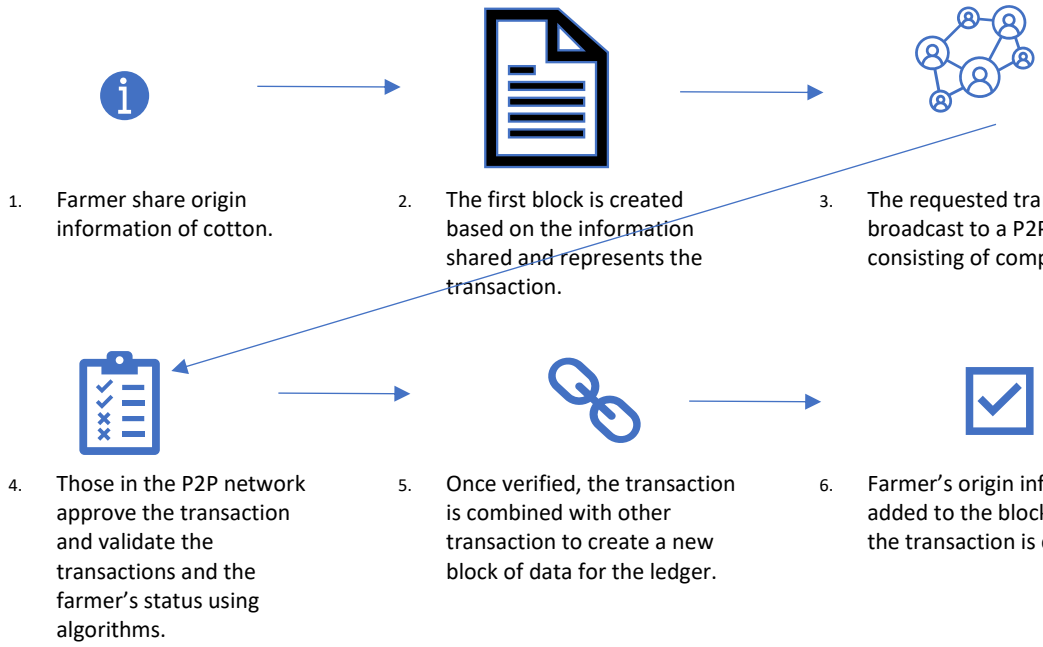
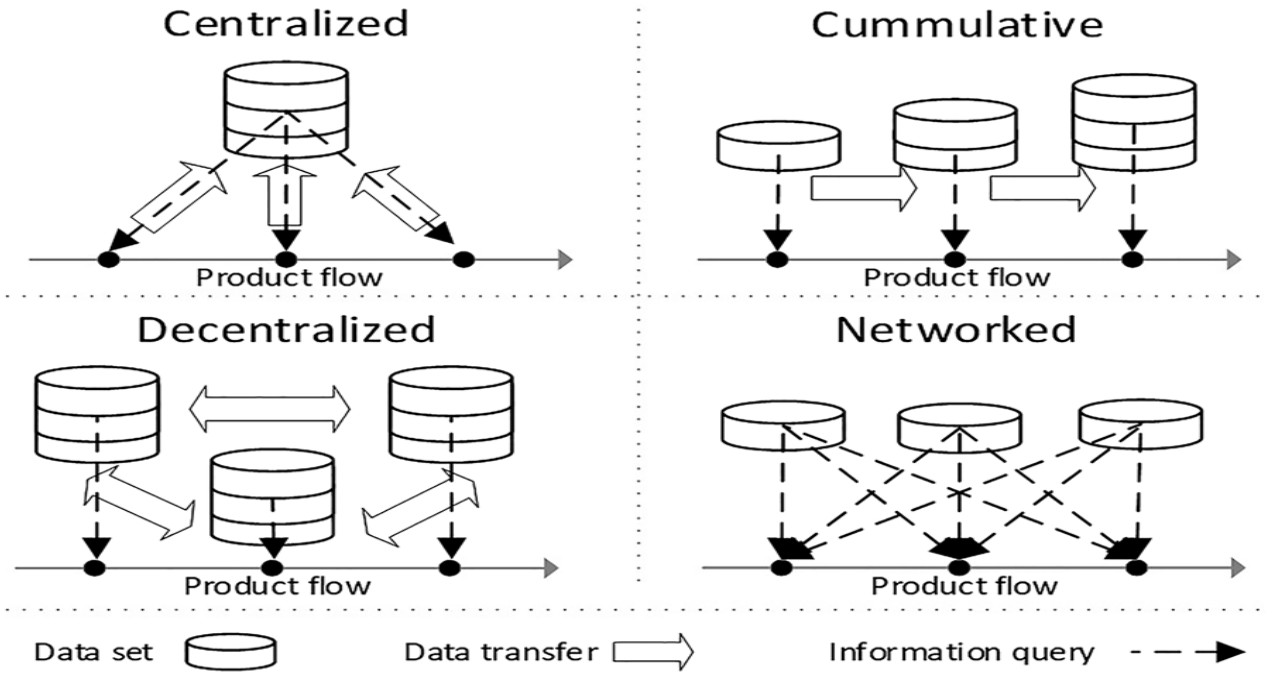
Figure 5 Blockchain model



But we must understand what centralised database is and how is Distributed ledger technology, or blockchain based database addresses the challenges of centralized database model.

Figure 6 Database model and flow of traceability data



(Oliver Bischoff, 2021)

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The above figure 6 explains the various types of databases, thus in centralized database model, all parties share their information in a central repository. The central database holds the complete set of its systematically enhanced traceability data at one point. However, access rights might be set individually for all parties. The central node might therefore become a bottleneck for communication and processing in the networked model, to avoid this bottleneck, the participating parties keep their individual data in local systems, providing supply chain partners with query access to relevant information. In the cumulative model, traceability data are enhanced as they move together with the material downstream along the supply chain from one partner to the next. Here, data are only shared with downstream partners. In the decentralized model, as used in the distributed ledger technology, all data are systematically enhanced and shared with all supply chain partners. Elimination of central processing and maintenance of a local copy of the complete set of traceability data by each partner ensures high resilience. While centralized and decentralized models both provide a single traceability dataset, the cumulative scenario provides only local and upstream information from the individual dataset. To achieve traceability in the networked scenario, multiple distributed datasets of the various partners need to be queried (Oliver Bischoff, 2021).

Now, that we understand the blockchain or distributed ledger technology, we must ask ourselves the key questions on how distributed ledger technology can help resolve compliance challenges related to supply chain traceability?

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Chapter 7 Key questions

Based on our literature review and desktop research, I have inferred the pertinent questions to ask about how distributed ledger technology can help mitigate compliance concerns so that a DLT-based solution for supply chain traceability can be developed, these questions are as follows

1. What is the promise of DLT? What properties are claimed to be delivered by the DLT?
2. What is the level of transparency needed to ensure compliance with demands for supply chain traceability?
3. Which actors would be entering data and which actors would need access to the data?
4. What are the advantages of using distributed ledger technology in supply chain traceability over other IT systems?
5. Is DLT as a solution feasible from the perspective of political, legal, economic, and technical aspects for supply chain traceability needs?
6. Does DLT with the certain identified properties based on the research in this document, suffice the needs of the actors?

What is the promise of DLT?

Despite potential efficiencies, corporations have historically struggled to communicate supply chain data; in theory, distributed ledger technologies such as blockchain might help address this difficulty. Blockchain is a digitally distributed ledger or database of records, transactions, or completed events that are shared among participants. Distributed ledger technology (DLT) is a decentralised and distributed system for recording and verifying transactions. As a result, distributed ledger technology is a decentralised ledger used "for electronic transactions without relying on trust" (Nakamoto, 2008). To generate a secure and immutable record of transactions, distributed ledger technology (DLT) can be employed. A DLT-based system could be used to follow the movement of items along the supply chain, from the source to the end user, in the context of supply chain traceability. This would create a transparent and traceable record of the supply chain, which could be used to verify the authenticity and provenance of items as well as to comply with legislation governing the tracking and tracing of commodities. Furthermore, because DLT is a decentralised technology, it may enable multiple supply chain partners to interact and share information in a secure and transparent manner. Blockchain, which is used for cryptocurrencies such as Bitcoin, is the most well-known example of DLT. DLT's key promise is that technology enables the construction of secure and transparent systems for recording and validating transactions without the necessity for a centralised authority (Emma, 2022).

Each transaction in this system is time stamped and confirmed by a majority of system members. A blockchain database stores the whole history of all assets and instructions executed since the beginning. 'Because each participant has their own copy of the blockchain, any party may monitor the status of a transaction, discover problems, and hold counterparties accountable for their conduct. No one can erase previous data since doing so would need rewriting all subsequent blocks on all shared copies of the blockchain (Gaur & Gaiha, 2020). Thus, blockchain facilitates authenticity by ensuring that each user's copy of the blockchain

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matches all of the others. Data integrity and transparency are enhanced by the distributed verification method. Because each participant has a copy of the ledger, blockchain does not have a single point of failure, making it more resilient than a centralised system. Furthermore, Blockchain may be written with embedded instructions like if-else and if-then statements to perform activities when certain criteria are satisfied. These instructions can be used to programme smart contracts, which link the information in a blockchain to consequences if the agreed-upon terms are not met. Lines of computer code use data from the blockchain to verify when contractual obligations have been met and the next course of action can be taken to fulfil the contractual obligation. Thus, smart contracts can be configured to evaluate the state of a transaction and perform actions such as recording ledger entries and indicating exceptions that require user intervention (Gaur & Gaiha, 2020).

The promise of DLT, or distributed ledger technology, is that it allows for the creation of secure, decentralized databases that can be used to track and verify transactions without the need for central authority. In the case of supply chain traceability, DLT could be used to create a transparent and verifiable record of the movement of goods and materials throughout the supply chain, making it easier to track and verify the authenticity of products and ensuring that they have been sourced ethically and sustainably. This could help improve trust and transparency in the supply chain and could also help to reduce the risk of fraud and counterfeiting.

The distributed ledger technology functions as an immutable ledger that allows for transactions to occur directly between anonymous parties in a decentralized fashion. The information is stored transparently, chronologically, and securely. While distributed ledger technology ensures persistent storage and consistency of public data, the technology does not provide interfaces for retrieval, update, evaluation or management of users, data structure or the data itself. In summary, the distributed ledger technology is characterized by the main properties that are claimed to be delivered by DLT namely disintermediation, decentralisation, immutability, and transparency (MacCarthy & A.H. Ahmed, 2022).

What is the level of transparency needed?

The level of transparency needed to ensure compliance with demands for traceability depends on the specific regulations and requirements that a particular industry or organization must adhere to. In general, traceability refers to the ability to track the movement of a product or item from its origin to its destination. In the context of supply chain management, for example, traceability is important for ensuring compliance with regulations such as those related to food safety, product recalls, and anti-counterfeiting (Oliver Bischoff, 2021). In such cases, a high level of transparency is needed to enable end-to-end visibility of the supply chain and allow for the tracking of products at each step of the process. To achieve this level of transparency, organizations may need to implement systems that can collect and store detailed information about each step in the supply chain process. This might include data on the origin of raw materials, the suppliers and manufacturers of intermediate products, and the logistics involved in transporting products from one point to another. Additionally, data would need to be easily

accessible and shareable across the supply chain, allowing all relevant parties to view and verify information this may include detailed information on the origin of raw materials, production processes, and logistics, as well as the ability to trace products back to their source in the case of a recall or other issue. In such a case, the distributed ledger technology (DLT) like blockchain can be a useful tool as it allows for a tamper-proof record of transactions that can be easily accessed and audited by relevant parties. In other cases, the level of transparency required may not be as high. For example, for digital identity, the transparency needed may be limited to the verification of identity and not personal information. Overall, the level of transparency required for traceability will vary depending on the specific regulations and requirements of the industry or organization.

As discussed in the earlier part of this thesis, disintermediation is an important aspect of the blockchain transparency model, by which the mediator is replaced by the consensus mechanism. Also, the decentralisation of blockchains reflects the governance of supply chains, as supply chains are decentralized in the real world so is the DLT's approach toward supply chain data collection. But each entity contributing traceability information to the blockchain like producers, firms, and governments are key stakeholders in supply chain traceability and have an interest in administering the system, these entities can provide resources and processes to fulfil the role of the mediator, on the other hand a traditional traceability systems is in most cases envisaged as closed groups of users with permissioned access rights to the traceability system, thereby introducing an administrative authority, such an authority has complete visibility to the entire system and its users and thus users on such system cannot remain anonymous, similarly presence of centralised mediating authorities can impact anonymity in the blockchain too. But due to lack of a central mediating authority, identities are protected, still transactions are detectable and confirmable. Therefore, transparency is dependent on the concept of anonymous identities to preserve overall confidentiality. Thus, data transparency under the blockchains transparency model supports the need of supply chain traceability. But origin and custody information are important activities, and this information is critical for supply chain traceability, but blockchains' anonymity requirement restricts the possible linkages. The fully decentralized approach necessitated by the absence of a central administrative authority is at the core of the blockchain or DLT's approach toward supply chain data collection. However, supply chains, with heterogeneous capabilities and interests of supply chain partners, present challenges for the decentralisation of data. Specifically, companies' financial and technical resources to distribute, store, validate, analyse, or otherwise exploit large amounts of traceability data might differ greatly. Additionally, while supply chain traceability requires constant participation of all partners in the supply chain, the blockchains' peer-to-peer approach allows participants to join or withdraw from the network without impacting the blockchain. The blockchain's approach to chaining and validating data records strengthens the immutability of information. This supports the demand of supply chain management for trustworthy, immutable information (Oliver Bischoff, 2021).

Flow of Goods from Left to right, each entity in the supply chain contributes data to the Data pipeline as block chain.

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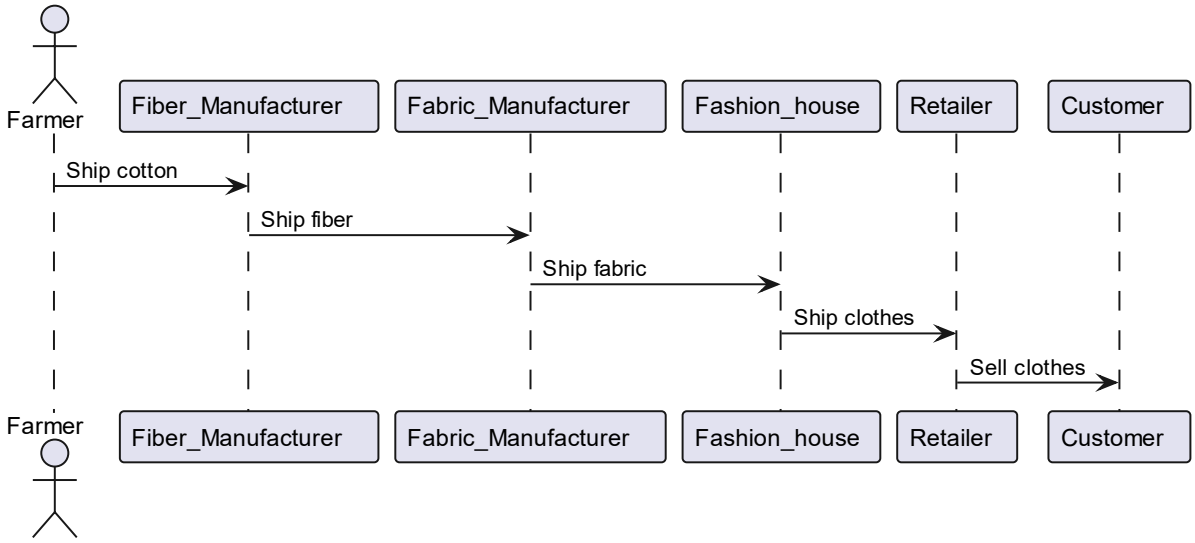
Figure 7 Clothing & Textile supply chain



Thus, there are four essentials for supply chain traceability, they are as follows.

(1) Unique identification of products, logistic units, and locations, such that all goods are uniquely identifiable.
(2) Data capture and recording, thus data is expected to be captured and their structure is defined throughout the supply chain.
(3) Linking process and data, by which transformational and custody information are linked to objects.
(4) Data communication, thus communication and reporting data requirements regarding communication are defined (Oliver Bischoff, 2021).

Which actors would be entering data and need access to the data?

Digital traceability requires data and a well-designed data model (Betti, Hinkel, & Saenz, 2021). Priorities of the company will shape the data model and the analytics capabilities. But data alone does not create insight. Insight comes from advanced analytics applications, prediction modelling, decision-making support, and automated data exchange. A more effective approach is to first define the company's objectives, then use them to determine which data is most valuable. That means thinking ahead about future and possible regulatory requirements. As part of this process, it is important to identify the required data at a granular level and map the data required across the target traceability applications. The resulting matrix quickly helps identify synergies between application areas and data requirements. It also suggests which traceability information to focus on first. This strategic approach eliminates the risk of gathering data that does not lead to insights (Betti, Hinkel, & Saenz, 2021).

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In the context of clothing and textile supply chain, it is important to know the location of production, the details of the producer, quantity, and material or component input by supplier in each stage of processing.
In the context of clothing and textile multiple actors may enter and access data along the supply chain, including:

- Cotton farmer: Location of the cotton farm, details of the cotton grower and date of harvest.
- Fibre Producers: They may enter data about the origin and quantity of raw materials they provide.
- Yarn and Fabric Producers: They may enter data about the production process, including the raw materials used and production dates.
- Clothing Manufacturers: They may enter data about the production process, including the raw materials used, production dates, and quality control measures, as well as information about the location of production, labour standards.
- Brands and Retailers: They may enter data about the distribution of goods, including the quantities and destination of products.
- Logistics providers: They may enter data about the transportation and storage of goods, including the dates, locations, and conditions of shipping and storage.
- Retailers and distributors: They may enter data about the distribution of goods, including the quantities and destination of products.
- Regulators and auditors: They may need access to data to monitor compliance with regulations and standards, such as those related to labour rights, and verify the authenticity of declaration.

Table 1: Data elements contributed by each actor.

	Production location	Producer details	Quantity	Labour standards	Destination	Production date
Cotton farmer	Yes	Yes	Yes	Yes	Yes	Yes
Fibre Producers	Yes	Yes	Yes	Yes	Yes	Yes
Yarn and Fabric Producers	Yes	Yes	Yes	Yes	Yes	Yes
Clothing Manufacturers	Yes	Yes	Yes	Yes	Yes	Yes
Brands and Retailers	No	No	Yes	No	Yes	No
Logistics providers	No	No	Yes	No	Yes	No
Retailers and distributors	No	No	Yes	No	Yes	No
Regulators and auditors	No	No	No	Yes	No	No

Table 2: Data access rights.

	Production location	Producer details	Quantity	Labour standards	Destination	Production date
Cotton farmer	Yes	Yes	Yes	Yes	Yes	Yes
Fibre Producers	Yes	Yes	Yes	Yes	Yes	Yes
Yarn and Fabric Producers	Yes	Yes	Yes	Yes	Yes	Yes
Clothing Manufacturers	Yes	Yes	Yes	Yes	Yes	Yes
Brands and Retailers	Yes	Yes	Yes	Yes	Yes	Yes
Logistics providers	No	Yes	Yes	No	Yes	No
Retailers and distributors	No	No	Yes	No	Yes	Yes

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Regulators and auditors	Yes	Yes	Yes	Yes	Yes	Yes

In short, different actors along the supply chain may enter and access data to ensure the traceability and compliance of the supply chain, and to protect the interests of companies, regulators, and consumers.

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What are the advantages of DLT over other IT systems?

Following are some of the current technologies utilised for supply chain traceability, most of these technologies aid in capture, identify and by that contribute data to a database or supplement and therefore can potentially enhance the Distributed ledger technology, which acts are the repository for the information.

- Radio Frequency Identification (RFID) Technology: RFID technology uses radio waves to identify and track products as they move through the supply chain. It provides real-time tracking information and can be used for a wide range of applications, but it can be more expensive than other technologies. RFID tags can be attached to products, enabling real-time tracking of their movement along the supply chain. This technology can help to reduce the risk of fraud and counterfeiting, as well as improving inventory management. For example, the apparel company Levi's uses RFID tags to track its products from the factory to the store (RFID in Manufacturing and Supply Chain, 2020).

- Internet of Things (IoT) Technology: IoT devices such as sensors and cameras can be used to monitor the movement of products along the supply chain, providing real-time data on factors such as temperature, humidity, and location. This technology can help to ensure that products are stored and transported in optimal conditions, reducing the risk of spoilage or damage (Newman, 2018).

- Artificial Intelligence (AI) Technology: AI can be used to analyse data from various sources along the supply chain, such as IoT devices and transaction records, to identify patterns and anomalies that could indicate potential issues. For example, AI-powered algorithms can be used to detect fraud or counterfeit products (Muhammad Khan, 2022)

- Barcodes and QR codes: Barcodes and QR codes are widely used for tracking products and shipments through the supply chain. They are inexpensive and easy to scan, but they can be limited in terms of the amount of information they can hold.

- GPS and geolocation tracking: GPS technology can be used to track the location of shipments and products as they move through the supply chain. This can provide real-time tracking information, but it can also be limited by the availability of GPS signals and the need for batteries.

- Electronic data interchange (EDI): EDI is a computer-to-computer exchange of business documents between trading partners. It enables the electronic transfer of data such as purchase orders, invoices, and shipment notices, but it can be limited in terms of its ability to provide real-time tracking information.

- Cloud-based platforms: Cloud-based platforms can provide real-time visibility and analytics across the entire supply chain. They can integrate data from multiple sources,

including sensors and IoT devices, to provide insights into product flow and inventory levels (Slocum, 2018).

While these technologies are useful in supply chain traceability applications, general adoption and implementation are frequently hampered by challenges such as cost, scalability, and data security. Furthermore, while the majority of the technologies listed above contribute data to a centralised database, distributed ledger technology, or blockchain, is emerging as a promising solution for addressing the challenges of the centralised database model and improving supply chain traceability. As a result, these present technologies supplement and enhance Distributed ledger technology, or blockchain (Agrawal , Kumar, Pal, Wang, & Chen, 2021).

Further, the Distributed Ledger Technology (DLT) is preferred over current supply chain traceability technologies for several reasons as listed below.

- Decentralized: DLT is a decentralized system, which means that there is no single point of failure or control. This eliminates the need for intermediaries, such as banks or government agencies, to verify or authenticate transactions, reducing the risk of delays, errors, or fraud (Thomas K. Dasaklis, 2022). DLT distributes data across a network of computers, making it difficult for any single party to control or manipulate the data. This helps to enhance transparency and accountability.

- Streamlined processes: DLT can automate and streamline a wide range of supply chain activities, including payment settlements, inventory management, and product tracking, hence reducing the need for manual intervention and paperwork. This can help save costs, improve efficiency, and enhance the overall client experience. By cutting costs and increasing transaction speed and accuracy, this can serve to build trust between parties (Yingli Wang, 2018). By offering real-time access to information, DLT enables stakeholders to view data in real time. Because all stakeholders have access to the same information at the same time, better decision-making and openness are possible. DLT generates a secure and tamper-proof record of all transactions, reducing the possibility of data errors or abnormalities. This can assist boost operational efficiency by reducing the need for manual reconciliation and data verification. By offering real-time access to information, DLT enables stakeholders to view data in real time. Because all parties can access the same information at the same time, better decisions can be made, and transactions can be completed more quickly. DLT can improve supply chain management by providing a transparent and secure platform for tracking and tracing commodities. This can help firms avoid delays and boost supply chain efficiency by offering real-time visibility of inventory and shipping status. DLT can facilitate collaboration by providing a centralised platform for transactions and data sharing. This can assist boost operational efficiency by reducing the need for human data entry and communication.

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- Immutable and tamper-proof: DLT provides an immutable and tamper-proof record of transactions and events, ensuring the integrity and authenticity of the data stored on the ledger. This makes it difficult for bad actors to manipulate or alter the data, ensuring transparency and trust among the various stakeholders involved in the supply chain. DLT creates a permanent and unalterable record of all transactions, which ensures that all parties have access to the same data. This helps to prevent disputes and enhances accountability (S. Menon, 2021). DLT creates an immutable and tamper-proof record of all transactions, making it easier to identify and hold accountable any party that engages in fraudulent or unethical behaviour. This can help to build trust between parties by ensuring that everyone is held accountable for their actions.

- Enhanced security: DLT provides enhanced security features, such as encryption and digital signatures, that can protect sensitive information from unauthorized access or breaches (Agarwal, et al., 2022). This can help to increase trust by providing a secure platform for transactions and reducing the risk of fraud or cyber-attacks.

- Audit trails: DLT generates an audit trail of all transactions that may be used to track asset movement and verify regulatory compliance. This enhances accountability by keeping a detailed record of all activities carried out by all parties. Disputes are settled faster. DLT creates an auditable and transparent record of all transactions, making it easier to resolve disputes promptly and fairly. You can help to create confidence between parties by offering a clear and effective procedure for resolving conflicts. DLT allows all supply chain actors to see the same information in real time, increasing transparency and reducing the likelihood of misunderstandings or arguments. By ensuring that all parties have access to the same information, trust can be built between them (Yingli Wang, 2018).

Overall, distributed ledger technology (DLT) has various advantages over current supply chain traceability methods. As a result, blockchain can help supply chain players by providing a detailed, transparent, and tamper-proof history of information and inventory flows in transactions. Records like inventory units, orders, origin, and bills of lading are granted unique identifiers that operate as digital tokens when employing blockchain record keeping. In addition, blockchain participants are given unique IDs, or digital signatures, which they use to sign the blocks they add to the blockchain. The blockchain then records each step of the transaction as a token transfer from one participant to another (Gaur & Gaiha, 2020).

Thus, by combining IoT and blockchain, businesses may gain comprehensive end-to-end visibility across all stages of the supply chain, as well as across other countries and organisations with which they work. Using IoT devices, we can track items as they move through the supply chain and share this data through a blockchain-based architecture that allows all players to access the data. IoT devices can employ sensors to record various factors, which is helpful in areas where product traceability is critical, such as cotton, to evaluate if the

cotton procured has authentic origin information and prevent cotton grown using forced labour from Xingjian. This amount of transparency will increase trust of the authorities.

Blockchain may ensure the dependability and security of this data, proving that a corporation is adhering to legislation and responding to government concerns. Stakeholders, including customs officers, may have access to the information and be able to watch the status of the supply chain in real time (Wattanajantra, 2020). As a result, Distributed Ledger Technology (DLT) has the potential to dramatically improve transparency and accountability, making it more transparent and secure (Ahmed, Mosa, Abualigah, & A. Abohany, 2022). As a result, Distributed Ledger Technology (DLT) has the potential to boost supply chain trust by providing a visible, tamper-proof record of all transactions as well as a secure platform for transactions (Ahmed, Mosa, Abualigah, & A. Abohany, 2022). DLT has the ability to improve operational efficiency in supply chain management by streamlining operations, decreasing mistakes, improving supply chain management, and facilitating stakeholder collaboration (Ahmed, Mosa, Abualigah, & A. Abohany, 2022).

While Distributed ledger technology (DLT) has the potential to enhance supply chain traceability by enabling real-time tracking of products, improving transparency, and reducing falsification of data. However, there are also several challenges and limitations to consider when using DLT in supply chain traceability (Rejeb, A., Rejeb, K., Simske, S., & Treiblmaier, H, 2021).

1. Interoperability and Integration with existing systems: One of the main challenges of using DLT in supply chain traceability is interoperability. Different organizations and supply chain actors may use different DLT platforms, which can create compatibility issues when trying to share data. This can hinder the adoption and effectiveness of DLT for traceability in supply chains.

2. Data quality and standardization: DLT relies on accurate and standardized data to provide reliable traceability. However, supply chain data is often complex and fragmented, making it difficult to ensure data quality and consistency across the supply chain. Ensuring the accuracy and consistency of data inputs into DLT systems is essential for effective traceability (Zhang & Ling, 2022).

3. Scalability: DLT systems can be slower and less scalable than centralized systems, which can be a limitation for supply chains that require real-time data and high transaction volumes. This may require additional investment in infrastructure and technical expertise to ensure that DLT systems can handle the demands of large-scale supply chains (MacCarthy & A.H. Ahmed, 2022)

4. Cost of implementation and complexity: DLT systems can be costly and complex to implement and maintain. This can be a barrier to adoption for smaller organizations or those with limited resources.

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5. Governance and confidentiality: DLT systems require governance structures to ensure the integrity and security of the data stored on the network. Ensuring confidentiality while maintaining transparency is also a key challenge for DLT in supply chain traceability.

6. Technical skills and knowledge requirement: Using DLT for various stakeholders with the supply chain will require some level of technical skill and training. Stakeholders may not be motivated enough to learn such skills, also such training may need frequent update and revision depending to changes made in the implementation. Thus, without a robust technical support team it may be challenging to implement any technology solution, but this is not unique to DLT technology.

Is DLT as a solution feasible?

While the preceding paragraph seems to assume that DLT is a technically viable solution for supply chain traceability demands, since it can provide a secure and tamper-proof system for recording and verifying transactions across the supply chain. However, various political, legal, technological, and economic issues must be considered when analysing the practicality of DLT for supply chain traceability. Thus, the question is whether DLT as a solution for supply chain traceability is practical in terms of political, legal, economic, and technical considerations.

Political perspective

A lack of regulatory clarity or political support from the government may hinder the adoption of DLT for supply chain traceability. Depending on the jurisdiction, legal obstacles to the use of DLT may exist, such as data privacy rules or intellectual property rights issues. Unfortunately, transparency of traceability information cannot be the primary purpose of supply chain information systems; rather, it can be a result of the process of acquiring supply chain information. This is because each stakeholder has an incentive to be transparent about the origin information. In the case of textiles and cotton from China's Xingang province, the cotton producer has no incentive to reveal the origin and location information. In such cases, fashion companies and retailers must approach the issue from the top down, insisting on traceability information to ensure transparency throughout the supply chain in order to comply with regulatory requirements in other jurisdictions where they operate and want to sell their products. Also, trust is one of the various challenges, so who implements the solution is critical; parties prefer a neutral organisation as the implementer who has no interest in the data that is published to the platform and is compliant with all data sharing regulations and laws that exist around the world. As a result, if an American or Chinese corporation implements the traceability system, parties may lack trust and hence decline to join such a platform. This is due to present political tensions.

Economic perspective

Economically, DLT for supply chain traceability may be too expensive for small and medium-sized businesses. DLT implementation necessitates major investments in technology, staff, and infrastructure, as well as adjustments to existing business processes. Furthermore, the cost of

operating a DLT network might be substantial, which may be difficult for certain organisations to accept (Betti, Hinkel, & Saenz, 2021).

Legal perspective

From a legal perspective, DLT's immutability and transparency may generate legal problems concerning data confidentiality and intellectual property rights. Furthermore, there is no guarantee that blockchain will constitute a legal contract. The legal status of blockchain contracts in many jurisdictions is yet to be determined; hence, a paper version must be available to back them up. Also, it is unclear if regulators will approve blockchain-based traceability systems to provide assurance that corporations will complete their broad obligations regarding their own supply chain as well as those of their direct and indirect suppliers (Thoms & Fischer, 2022). We can also see that the authorities continue to place an emphasis on supporting documents to demonstrate the countries of origin of the raw cotton as well as where the purchase, manufacture, and transportation of the various inputs occurred throughout the supply chain (Office of Trade, US Customs and Border Protection, 2022). Thus, one of the most significant roadblocks is the legal position of blockchain-based traceability solutions. Thus, while DLT-based traceability solutions can give internal assurance in the current situation, the organisation will still be required to recreate physical documents to show provenance. As a result, the legal recognition of smart contracts, a major component of DLT, will vary between jurisdictions, creating ambiguity and legal concerns for organisations.

Technical perspective

From a technical perspective, there are several limitations of distributed ledger technology (DLT) that may impact its adoption and implementation. Some of the main limitations include:

- Scalability: DLT networks have scalability issues as the number of transactions and users on the network increases (Abdurrashid Ibrahim Sanka, 2021,). For example, the throughput of Bitcoin and Ethereum blockchains are 3 to 4 and 15 transactions per second respectively (Abdurrashid Ibrahim Sanka, 2021,). This can lead to slow transaction processing times and high fees. To quantify the problem, consider the maritime industry, which shipped 1.85 billion metric tonnes in 2020 (Statista Research Department, 2021). As a result, the average transaction ranges from 31 million to 93 million every day, whereas with the current technology the daily transaction limit for Bitcoin is 360,000.
- Interoperability: DLT solutions need to be integrated with existing systems and processes, which can be challenging and time-consuming. Different DLT networks and platforms may have difficulty communicating and interacting with one another, which can create barriers and make it difficult for different organizations to work together, making it difficult to create a seamless and integrated system.
- Energy consumption: Some DLT networks, such as Bitcoin, require a significant amount of energy to maintain the network and validate transactions, which can be environmentally damaging (Abdurrashid Ibrahim Sanka, 2021,).

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- Regulation and standardization: The regulatory environment for DLT is still evolving, and there is a lack of standardization across different DLT platforms and networks. This can make it difficult for organizations to comply with legal and regulatory requirements.
- Data confidentiality and security: despite the security features offered by the DLT, data confidentiality and security can be a concern. There is a need to find a balance between preserving data confidentiality and allowing for the transparency and traceability required for certain use cases. “Though one of the essential principles of DLT is transparency, distributed ledger technology does not connect the transaction to real-world objects, as this could break anonymity (Oliver Bischoff, 2021).”
- Efficiency: Latency in the blockchain is introduced through block building, validation, and network distribution. This latency may hinder blockchain adoption when supply chain traceability requires real-time information. The correction of erroneous data and removal or archiving of expired data from fast-growing traceability data pools are limited.
- Lack of understanding and expertise: DLT is a relatively new and complex technology, and many organizations may not have the necessary knowledge and expertise to fully understand and implement it. Further, DLT can be complex to implement and maintain, requiring specialized knowledge and expertise. This can create barriers to entry for organizations that are not familiar with the technology, and this can make it difficult to identify the right use cases, design appropriate solutions, and manage the implementation process.
- Adoption: The adoption of DLT can be slow, as it requires buy-in and cooperation from all parties involved, including suppliers, customers, and other stakeholders.

Overall, while DLT has the potential to transform supply chain traceability, these limitations must be considered and addressed to fully realize the technology's potential. While DLT is a technically feasible solution for supply chain traceability, the political, legal, and economic considerations must be considered to fully evaluate the feasibility of DLT for our use case.

Does DLT suffice the needs of the actors?

As discussed above, Distributed ledger technology (DLT), such as blockchain, has the potential to suffice the needs of supply chain traceability by providing a secure, transparent, and tamper-proof way to record and verify transactions across the supply chain. DLT allows for real-time tracking and verification of transactions, which can provide end-to-end visibility of the supply chain and allow for the tracking of products at each step of the process. This can be useful for ensuring compliance with regulations such as those related to tracing supply chains within the fashion industry. DLT can also provide a tamper-proof record of transactions that can be easily accessed and audited by relevant parties. This can be especially useful for supply chain traceability as it allows for the tracking of products back to their source in the case of a recall or other issue. However, DLT alone may not be sufficient to meet all the needs of supply chain traceability. The data stored in the DLT needs to be accurate and up to date, which may require additional systems and processes to ensure data quality. Additionally, there are several other challenges to consider when implementing DLT for supply chain traceability such as scalability,

interoperability, adoption, data privacy, and cost. These challenges related to political, legal, economic, and technical aspects for supply chain traceability are discussed in detail in the next part of this thesis.

Furthermore, the advantages and disadvantages of public DLT-based supply chain traceability are that DLT designed for business and supply chain applications are private blockchain and quite different from that of the public blockchain, such as bitcoin blockchain or those for cryptocurrency applications. As compared to the public bitcoin network, blockchain for supply chain needs to have confidentiality of business data and restricted access to ensure limited and authorised set of participants can access the data. Thus, it should be private with authorized and identifiable partners. Besides, there may be a requirement of different levels of visibility and accessibility for each partner. At system level, the blockchain would record and secure essential data to ensure traceability. However, depending on the accessibility level, each partner may only have access to a certain set of information. This structure would ensure a technology-based trust among partners, transparency in the supply chain and visibility that can enable easy implementation of the government rules and policies. Similarly, each partner can maintain their competitive advantages without disclosing all information and strategies to the competing firms (Agrawal , Kumar, Pal, Wang, & Chen, 2021) for example price of the cotton producer will be available only to the buyer and not to the manufacture of the fabric who has bought the cotton from the buyer, but location of the cotton farm in which the cotton was cultivated would be available to all the stakeholders.

Overall, DLT has the potential to be a powerful tool for supply chain traceability, but DLT with the certain identified properties based on the research in this document may not be sufficient on its own and needs to be integrated with other systems and processes to fully meet the needs of the supply chain traceability to suffice the needs of the actors. Further ahead in the thesis we will discuss the challenges and propose certain workaround to overcome the challenges.

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Chapter 8 Research analysis and results

DLT is a distributed ledger technology that enables the construction of secure, decentralised databases that can be used to track and authenticate transactions without the need for a central authority. Disintermediation, decentralisation, immutability, and transparency define it. For supply chain traceability, numerous technologies are utilised, including RFID, IoT, AI, barcodes, QR codes, GPS, geolocation tracking, and EDI exchange of business documents between supply chain partners. Distributed ledger technology, also known as blockchain, is emerging as a promising solution for addressing the challenges of the centralised database model and enhancing supply chain traceability. DLT is decentralised and disseminated across a network of computers, making it difficult for a single entity to manipulate or control the data. It can automate and expedite supply chain activities, facilitate collaboration, and create an immutable and tamper-proof record of transactions and events. However, there are a few obstacles and limitations to consider when using DLT for supply chain traceability, including interoperability and integration with existing systems which hints towards standardization for the growth of blockchain as a technology and for interoperability, data quality which hints towards verifiable audit trail, scalability which hints towards simpler consensus protocols to ensure larger data can be processed faster, cost of implementation and complexity, confidentiality and security to ensure long term trust which hints towards private blockchain to build trust and protect propriety information, the need for technical skills and knowledge and finally legal recognition for blockchain records. Further, DLT for supply chain traceability may be hindered by regulatory clarity or political support, transparency of traceability data, cost, and trust.

In addition, it has technical limitations including scalability, interoperability, energy consumption, regulation and standardisation, data confidentiality, latency, and a lack of understanding and expertise. DLT has the potential to transform the traceability of the supply chain, but political, legal, and economic considerations must be considered. It must be incorporated with other systems and procedures to meet the requirements of the actors. In the following chapter we will discuss these issues and propose solutions briefly mentioned above.

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Chapter 9 Lessons from DLT implementations

In this chapter we look at implementations of supply chain traceability using distributed ledger technology to gain insight into factors of success and drawing learning for our case.

1. International Trade Compliance

Customs authorities throughout the world are becoming interested in blockchain's potential to improve efficiency, transaction transparency, and reliability in risk management and trade facilitation. At the time, CBP, for example, conducted research on the use of blockchain in the submission method for entrance summary statements under the North American Free Trade Agreement (NAFTA) and Central America Free Trade Agreement (CAFTA). The study found that using blockchain improved interactions between CBP and merchants, improved receipt paperwork, and faster processing while eliminating manual documentation requirements and duplicative data entry (Ludwikoski & Salaheldin, 2022).

Further, to enforce compliance with the Uyghur Forced Labour Prevention Act (UFLPA), which is intended to counter China's alleged human rights violations in the Xinjiang Uyghur Autonomous Region (XUAR), the United States Customs and Border Protection (CBP) has increased its enforcement through Withhold and Release Orders (WROs), which authorise CBP to stop a shipment containing goods suspected of being made with forced labour and allow for its release only when the importer proves otherwise. WROs are having an impact on products such as clothing and cotton. The usage of Blockchain aided in the tracking of materials and goods from source to end-use, as well as providing corporations with real-time, verifiable data that was critical to the success of their Environmental, Social, and Governance (ESG) programmes. It has resulted in determining and reporting their performance on social issues, such as whether items are sourced ethically, resulting in conformity with set norms and regulations, thanks to the automation of data gathering and the deployment of blockchain. Thus, blockchain has contributed to responsible and ethical sourcing by enabling supply chain transparency and reliability, traceability through tamper-proof records, data immutability, decentralised data storage, and a verifiable audit trail (Ludwikoski & Salaheldin, 2022). Thus, Blockchain has been used for customs compliance to minimize sourcing risk and it can help monitor the risk of labour exploitation in the supply chain.

2. Textile industry

The Organic Cotton Traceability Pilot is a collaboration between Fashion for Good, the Laudes Foundation, and the Organic Cotton Accelerator (OCA) that aims to trace organic cotton digitally and physically from farm to retail by combining blockchain with on-product identifiers. There is a need to connect the dots at the beginning and conclusion of a product's existence, particularly in light of the Xinjiang cotton issue. As a result, real-time visibility of supply chain journeys has become increasingly important (Emma, 2022). The textile and garment industries are conscious that they must return to tiers 2 and 3 in order to sustain openness. The project's goal is to increase transparency and visibility across the fashion supply chain. The study

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concentrated on the cotton industry and the issue of forced labour in the global supply chain. To achieve visibility and transparency, the project collaborates with partners to understand the process and supporting documentation, as well as collect the data needed to evaluate the solution properly. The usage of blockchain for data recording opens up new avenues for addressing some of these issues. The goal of the project is to provide a comprehensive solution to establish a more transparent, efficient, and long-lasting end-to-end fashion supply chain. It is about being able to demonstrate where that cotton came from; the project's attraction is that it considers both product traceability and concerns about forced labour (Sustainable Supply Chain Optimisation: Proof of Concept, 2021).

UNECE and FAO are adopting blockchain tracing technologies in Latin American cotton supply chains. In 2020, a blockchain trial application for cotton was developed. The study's blockchain system is an open-source Ethereum blockchain that supports smart contracts and the use of Cotton DNA markers. Its goal is to safeguard data confidentiality in compliance with applicable legislation. It is offered in both web and mobile editions to ensure that all value chain players, particularly farmers and producers in emerging economies, have access to the project. The goal was to examine important data identification and coding at key supply chain data points to establish an interconnected and immutable record of origin and composition. Consumers want improved traceability of the sources of their products, but in countries like Peru, family farmers still produce 99% of cotton. The project demonstrates the potential of the transparency and traceability framework and system, which were put in place to improve customers' visibility into the products they buy while connecting local sustainable rural producers to global value chains and marketplaces. FAO and UNECE are implementing a UNECE-developed traceability strategy and standard. Through the +Cotton Project, FAO is already implementing the UNECE-UN/CEFACT standard and methodology in Latin America, as well as working on a blockchain pilot with Costach Cooperative and Creditex. Costach recently pledged to increase the traceability and openness of fibre manufacturing processes, woven yarn, and garment manufacture, with the goal of tracing cotton fibre from field to shelf. The next step of the project will see FAO apply its approach, which is delivered through its global and regional network of partnerships, to reproduce at scale this initial validation at a granular level with local actors and technology providers. Over 250 academics, activists, government officials, and industry insiders participated to the recommendations and standards, which resulted in an agreed-upon standard for their implementation (UNECE and FAO join forces on cotton traceability to connect sustainable rural producers in Latin America to global value chains, 2021).

Learnings from the cases

In the above examples we can conclude that, Customs authorities have utilised blockchain to increase efficiency, transaction transparency, and reliability in risk management and trade facilitation, as well as to ensure compliance with the Uyghur Forced Labour Prevention Act. DLT is a promising solution for enhancing supply chain traceability, as it offers enhanced security features, audit traces, and a transparent and efficient method for resolving conflicts. It can automate and expedite supply chain operations and provide access to information in real time.

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DLT has the potential to enhance supply chain management's transparency and accountability, boost supply chain trust, and increase operational efficiency, but it is not without its challenges and limitations. DLT has the potential to transform the traceability of the supply chain, but it must be integrated with other systems and processes to meet the requirements of the actors.

In the case of the Organic Cotton Traceability Pilot, the project seeks to trace organic cotton digitally and physically from farm to retail using blockchain and on-product identifiers. The objective is to establish a more transparent, efficient, and durable end-to-end fashion supply chain, considering both product traceability and concerns about coerced labour. The blockchain system utilised in the study is an open-source Ethereum blockchain that supports smart contracts and Cotton DNA markers. The objective is to investigate crucial data identification and coding at key supply chain data points to create a connected and immutable record of origin and composition.

Based on the implementations described above, I conclude that distributed ledger-based supply chain traceability solutions have been successful. In these use cases, the emphasis is on using traceability information to aid in the tracking of materials and goods from source to end-use, as well as providing corporations with real-time, verifiable data that was critical to the success of their Environmental, Social, and Governance programmes; for example, in the case of organic cotton, the goal was to study critical data identification and coding at key supply chain data points in order to generate a connected and immutable record of origin and composition. These examples are analogous to our use case, in which we are investigating if a DLT-based solution might be effective in tracking cotton grown in high-risk areas for forced labour. These examples demonstrate characteristic on how DLT-based systems can improve supply chain transparency, reliability, and traceability by enabling tamper-proof records, data immutability, decentralised data storage, and a verifiable audit trail with the use of an on-product identifier.

In the following chapter we will be interviewing experts and industry professional to understand the challenges and to learn whether DLT-based supply traceability solution is appropriate for supply chain traceability.

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Chapter 10 Summary of finding from interviews.

While a review of the research and case studies suggests that a DLT-based supply traceability solution is an ideal system, it does not emphasise the difficulties that must be overcome in order for the solution to be mature and powerful enough for the industry to use effectively. Furthermore, the literature review reveals an academic viewpoint that may be biased towards technology being able to provide a solution to the compliance challenge demanded by the regulation on forced labour, whereas the case studies point to the possibility of transforming the traceability of the supply chain if the implementation is done correctly.

To understand the challenges and to learn whether DLT-based supply traceability solution is an ideal system, I have interviewed experts and industry professionals to gain their perspectives on the challenges faced because of the implementation of forced labour regulations, whether supply chain traceability can assist in overcoming the challenges of complying with forced labour regulations, and if DLT as a technology can support in improving supply chain traceability. Thus, I tried interviewing various stakeholders in the supply chain, including individuals responsible for the development and management of information systems, technology platform operators providing traceability solutions as a service, logistics service providers delivering services using the platform developed for providing traceability solutions in China and Singapore, and clothing aggregator and trader, to learn how they have managed to comply with the receivables requirements. Unfortunately, same queries cannot be addressed to all supply chain stakeholders because each one contributes a unique viewpoint to the problem and is tackling it with their specific expertise. Thus, the questions have been tailored so that at the end of the interview, I can draw conclusions and identify the key challenges in interpreting the regulation, setting appropriate expectations, can traceability support regulatory compliance, and what it might entail to implement a DLT-based solution.
Interviews were conducted with the following experts.

- Ms. Michelle Moore (Interviewee A)
    - Head of information system for Global Trade @ Henkel (for blockchain based supply chain traceability solution) (Structured)
- Mr. Wolfgang Weber (Interviewee B)
    - Director Global Engineering and Digital Transformation @ (For understanding traceability challenges at Henkel and what is the future for supply chain traceability) (Structured)
- Mr. Varun Kulshreshtha (Interviewee C)
    - Regional Head of TradeLens at Maersk (For understanding how blockchain based technology solution was implemented by TradeLens and the learnings on supply chain traceability from the implementation (Structured interview)
- Mr Ajay Shukla (Interviewee D)
    - Director @ Mainfreight Singapore Pte (For understanding implementing challenges with TradeLens and why it failed?) (Structured interview)
- Mr Praveen Mathur (Interviewee E)

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- CEO @ Tadashie (For understanding the perspective of a clothing aggregators and trader due to recent implementation of Forced labour Act in the USA) (Structured interview)

Key questions asked in the interviews were as follows.

Question asked to Mr. Varun Kulshreshtha (Regional Head of TradeLens at Maersk (Structured interview) and Ms. Michelle Moore, Head of information system for Global Trade @ Henkel (for blockchain solution) (Structured)

1. What are the key challenges to achieving traceability in the supply chain, and how can distributed ledger technologies help address these challenges?
2. What are the most important benefits of using blockchain technology for traceability?
3. How do you think blockchain traceability solutions can be used to improve supply chain transparency?
4. How would you describe the current state of blockchain based supply chain traceability solutions?
5. What challenges do you think you may face when implementing blockchain based supply chain traceability solutions?
6. What do you think are the most important considerations when designing a blockchain traceability solution?
7. What advice would you give to companies looking to use blockchain traceability solutions?

Question asked to Mr. Wolfgang Weber, Director Global Engineering and Digital Transformation @ Henkel (Structured)

1. Can you explain your company's current traceability system and how it is implemented throughout the supply chain?
2. How does your traceability system ensure compliance with regulations and industry standards?
3. How does your traceability system help with product safety and risk management?
4. How does the traceability system improve efficiency and transparency in the supply chain?
5. Can you give an example of a time when the traceability system helped to identify and resolve a problem in the supply chain?
6. How does your company plan to improve or update its traceability system in the future?
7. How does your traceability system handle and track sub-tier suppliers and their products?
8. Can you discuss any challenges your company has faced with implementing or maintaining a traceability system?
9. How does your traceability system integrate with other systems such as inventory management or logistics?

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10. How does the traceability system handle the traceability of sensitive items?

Question asked to Mr Praveen Mathur, CEO @ Tadashie on managing supply chain traceability and compliance with forced labor Act in clothing industry.

1. Can you describe the steps you take to ensure that your supply chain is free from forced labour, and how do you monitor compliance with these standards?
2. How do you vet and select suppliers to ensure that they are also committed to ethical and legal labour practices, and how do you communicate these standards to them?
3. How do you identify and assess potential risks of forced labor in your supply chain, and what measures do you take to mitigate those risks?
4. Do you conduct any independent audits or assessments of your suppliers' labour practices, and how often do you review and update your supplier policies and procedures?
5. How do you ensure that your suppliers are transparent about their own supply chains and labour practices, and what measures do you take to encourage or enforce this transparency?
6. Can you describe any challenges or obstacles you have faced in trying to maintain supply chain traceability and compliance with forced labour Acts, and how have you overcome them?
7. How do you communicate your commitment to ethical and legal labour practices to your customers, and how do you respond to any concerns or complaints they may have about your supply chain practices?
8. How does your current traceability system ensure compliance with regulations and industry standards?

Question asked to Mr Ajay Shukla, Director @ Mainfreight Singapore Pte on logistical challenges with blockchain based traceability solution (Structured)

1. What are the current challenges you face with supply chain traceability, and how do you think a blockchain-based solution could address these challenges?
2. How do you plan to integrate the blockchain solution with existing supply chain systems and processes, and what are the potential obstacles to integration?
3. How do you plan to integrate the blockchain solution with existing supply chain systems and processes, and what are the potential obstacles to integration?
4. How did you ensure the security and privacy of the data stored on the blockchain, and what measures are in place to prevent unauthorized access or tampering?
5. What are the legal and regulatory considerations you need to consider when implementing a blockchain-based solution, and how will you ensure compliance with these requirements?
6. How will you educate and train your team and partners on the use of the blockchain-based solution, and what resources will be available to support adoption and use?

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7. How will you measure the success of the blockchain-based solution, and what metrics will you use to evaluate its effectiveness in improving supply chain traceability?
8. What are your thoughts on the success of the blockchain-based supply chain solution?

These questions have helped to understand whether the industry is indeed ready for deploying DLT based traceability system. To understand their perspective, it is necessary to interview experts and industry professionals, from the interview I inferred the following.

As per Michael Moore (Interviewee A), Blockchain is still a relatively new technology, and it's important to plan for the long-term when implementing a DLT based traceability solution. The current state of blockchain-based supply chain traceability solutions is still in its early stages, with a few successful projects implemented but still relatively few at scale. Thus, as per her, first steps if to identify the purpose and scope of the traceability solution, specific purpose and scope will determine the technical requirements and the design of the system. Second steps if to clearly define the problem statement. Then data structure used in the blockchain must be carefully designed to ensure that it can track the desired information in a secure and efficient manner. Further the solution should be designed to prevent unauthorized access to the blockchain and ensure that only trusted parties have access to the data. The solution should also include measures to prevent tampering with the data and ensure the integrity of the blockchain. Also, important as per her is that the blockchain traceability solution must be designed to handle large volumes of data as the number of transactions recorded on the blockchain grows. The solution should be designed to work seamlessly with other systems and be capable of interoperating with a variety of different technologies. The blockchain traceability solution should be easy to use and understand for all users. The solution should be designed to comply with any relevant laws and regulations to avoid any legal or regulatory issues. She also emphasised on, onboarding all the stakeholders engaged in the supply chain. Further, there must be safeguards in place to ensure the data is true and accurate. Checks and balance are in place as logic can be programmed in the blockchain system. Whereas in the typical ERP solution such a solution will be complex Integrating blockchain-based traceability solutions with existing systems can be a significant technical challenge. Ensuring that data is accurate, complete, and consistent across all stakeholders can be a significant challenge.

As per Praveen Mathur (Interviewee E), steps taken to ensure a supply chain is free from forced labour typically include conducting due diligence on suppliers, requiring suppliers to sign contracts that commit to ethical and legal labour practices, and conducting regular audits to monitor compliance. Monitoring also involved engaging with workers and labour organizations, using third-party auditors, and implementing technology solutions to improve supply chain transparency. Currently to ensure compliance with regulations and industry standards, stakeholder collect information about our suppliers' labour practices and conduct risk assessment of suppliers and their facilities to identify potential areas of non-compliance. stakeholder also conduct audits and assessments of suppliers' labour practices. If we encounter any potential noncompliance, we immediately take remediation by addressing the issues and

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suggest corrective action plans and follow-up assessments. Overall, our program is designed to provide visibility throughout the supply chain, enabling our customer to reply on our assurance that our supply chain is free of forced labour practices and potential non-compliance issues while ensure compliance with regulations and industry standards.

As per Ajay Shukla (Interviewee D), the current logistic and supply chain solutions lack transparency, accuracy, and interoperability. Blockchain technology can provide a transparent and tamper-proof record of transactions, ensure data accuracy and integrity, enable interoperability, and provide real-time visibility into the supply chain. However, challenges such as the cost of development, deployment, and maintenance, and the need for standardization of data fields must be addressed. Blockchain-based solutions are being implemented to address these challenges, but it requires a complete understanding of the supply chain to configure programmable logic. Integrating a blockchain solution with existing ERP systems and operational processes requires careful planning and execution. Identifying current systems and processes, defining the scope of the integration, developing APIs and other integration tools, and testing the integration are all important steps to ensure a successful implementation. Cost was the biggest factor, the cost of implementing the system did not equate to the results we had set for ourselves at the start. We did not see significant benefits in terms of achieving any of the objectives during the 19 months we had deployed the system. Thus, we cannot say that the benefits materialized fully, also TradeLens is about to stop supporting as the platform is closing in March 2023.

As per Varun Kulshreshtha (Interviewee C), there is lack of standard based approach for such system to thrive, each implementation sets a unique standard and that becomes a roadblock as API must to developed for interoperability across platforms and therefore it defeats the purpose. Thus, an industry-wide standard must be developed for supply chain data to be shared in the lines of information exchanges that take place in the finance and banking sectors. For such standards to be developed independent industry and trade bodies must play a significant role. Further he also stated that the question about traceability is not a technology question the question is more around collaboration and how can you incentivize companies to be part of it. If traceability was to be pursued as a cradle to grave approach, then it is going to be challenging and it depends on different sort of scenarios, for example a big retailer as a part of its contract, requires them to sign up to this platform and publish this information then the supplier will align and share the information at a cost. He also highlighted some of crucial questions that must be answered for blockchain to be a viable solution in the future. The first question is around trust and who is implementing the solution, parties prefer a neutral organization as the implementer who does not have any interest in the data that is being published to the platform and is compliant to all the data sharing regulations and laws that exist all over the world. Second as highlighted earlier, was on the challenge is around creating common standards. That common standard cannot be only for traceability. Traceability needs to be a by-product. The main push needs to be around digitization of the supply chain and all the records. And finally, legal recognition of the records in the block chain, especially contracts, currently these are not

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legally viable, so, a law must be there to formally recognize digital records to be legally valid, as currently this does not exist and therefore there is no incentive to digitise the supply chain.

As per Mr. Wolfgang Weber (Interviewee B) while implementing blockchain-based traceability solutions can bring significant benefits in terms of improved transparency and efficiency in supply chains, there are several challenges that need to be addressed, including integration with legacy systems, cost and scalability, data accuracy and consistency, regulatory and legal considerations, and adoption and collaboration. Also, it is only as strong as the number of parties in the block chain and using it. The future of blockchain is in increased adoption, also widespread adoption is likely to lead to greater standardization, with common data formats and protocols emerging. Currently traceability is based on paper-based approach, which in some cases is audited, in this case you have certain authority publishing or giving you certificates. Such situation can be improved with the help of blockchain based traceability solution. Blockchain has been made to solve some problems like this, the fact that all the parties in a distributed Ledger are authenticated is democratization of information, records cannot be changed once published, unless if the record is validated through consensus and it has audit trail maintained.

From the above we can conclude that the concerns of the industry professional and experts can be broadly classified under the following buckets. Standardization for the growth of blockchain as a technology and for interoperability, private blockchain to build trust and protect propriety information, Simpler consensus protocols to ensure larger data can be processed faster, Traceability and audit trail of physical goods and finally security as a fundamental aspect of Blockchain to ensure long term trust in the technology.

Table 3 Interview summary (commonalities mentioned by all, individual findings mentioned by some)

Common findings	**Individual findings**
Identification of the purpose and scope, clearly define the problem statement	Private blockchain to build trust and protect propriety information
Integration with legacy systems and interoperating with different technologies.	Simpler consensus protocols to ensure larger data can be processed faster
Compliant with data sharing regulations and laws	Standardization for the growth of blockchain as a technology and for interoperability,
Cost of development, deployment, and maintenance	Verifiable audit trail
Designed to handle large volumes of data.	Confidentiality and security to ensure long term trust
	Legal recognition for blockchain records

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Thus, it is recommended that further research is done for overcoming the challenges identified above. As a preview to explain the challenges and propose certain solutions the next chapter devolves into these briefly.

Chapter 11 DLT's limitations and directions for further research

We recognised several limitations during the interviews and in the case studies, therefore, we will investigate them more in this section and provide directions for further research. We will look at how standards-based approaches might help with blockchain adoption and why private blockchain may be necessary in some circumstances. We will also investigate simpler approaches to overcome the difficulties of building consensus to add records to the blockchain, as well as how to ensure physical items and digital data accurately mirror each other. As a result, we will investigate measures for physical items tracking and audit trail. Also, during the interviews, concerns were made about the security and confidentiality of commercial and proprietary information, thus the issues with security as a core feature of Blockchain to maintain long-term trust will be investigated. Finally, legal recognition for DLT-based supply chain records is a significant barrier, as there is no motivation to digitise supply chain data without it.

While we can envision blockchain and the Internet of Things (IoT) combining to improve supply chain traceability in novel ways, widespread adoption of blockchain for supply chain traceability of goods in international trade requires that the distributed ledger be based on standards agreed upon by industry stakeholders. While private blockchain implementation may be preferred in some cases to protect access to proprietary and confidential information and to build trust among all stakeholders involved in the supply chain, companies may need to make portions of their blockchain records public in the future. This can help with public monitoring as well as accountability to consumers and stakeholders (Roshan, 2022). But a true representative of transparency is a decentralized, public blockchains as opposed to private ones (Emma, 2022).

1. Standards based approach for interoperability.

Companies are much more likely to develop proprietary digital solutions with the assistance of a few trustworthy and well-known partners. This non-collaborative method enables for the faster creation of a system adapted to the specific needs of the company. The difficulty in establishing a new standard in any industry-wide initiative is the source of the interoperability dilemma. Obtaining buy-in from a critical mass of organisations and competitors takes a significant amount of time and work. Though private technologies are useful for business operations, their incompatibility makes data sharing difficult. This difficulty is exacerbated by differences in the types of data collected and how it is stored. When businesses implement some of the most complicated data systems, resolving these differences becomes much more difficult. If data exchange is needed in the future, industry standards for the creation of private systems must be developed to assure interoperability. This would allow a corporation to maintain its own database while also communicating and exchanging data with other systems (Lehr, 2020).

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To allow widespread implementation of blockchain-enabled smart contracts, a standards-based approach is required. The standard must provide specified supply chain data items that multiple parties may communicate across smart contract parties or inside a single supply chain without disclosing proprietary, business-sensitive, or secret information. The advantage of such sharing would be that parties involved in all tiers of the supply chain would be assured of product origin and provenance through supply chain transparency. While smart contract practises will continue to mature in the future and may benefit from standards, a taxonomy for smart contracts should be proposed in the absence of standards (Stouffer, et al., 2022).

To produce and read traceability records, there must be collaboration across the supply chain, as well as adoption of technology, procedures, and means to mark and check items and services for linkage with digital records. To reach a Minimum Viable Ecosystem for traceability information, there must be sufficient incentives to generate traceability records, as well as a critical mass of early adopters. The Minimum Viable Ecosystem is an initial starting point for later growing involvement and confidence in the supply chain to ensure that incentives for supply chain players are sufficient to stimulate adoption of blockchain and similar technologies (Stouffer, et al., 2022).

In the figure below, for example, stakeholders separated by various tiers can write and read traceability records as goods migrate towards integrators and end operating environments. Additional data records, such as logistics operators, could be written to attract stakeholders far from the integration and end operational settings. This may encourage widespread engagement and allow for the establishment of a Minimum Viable Ecosystem. Measures must be used to monitor progress and close gaps as the ecosystem establishes the need for traceability. The flow of goods and services in the figure below can include traceability markers, which can subsequently be associated with traceability data records across the ecosystem. Traceability records may not be understood outside of the ecosystem due to semantic and other deficiencies (Stouffer, et al., 2022).

Figure 8 Flow of goods and services along with traceability data

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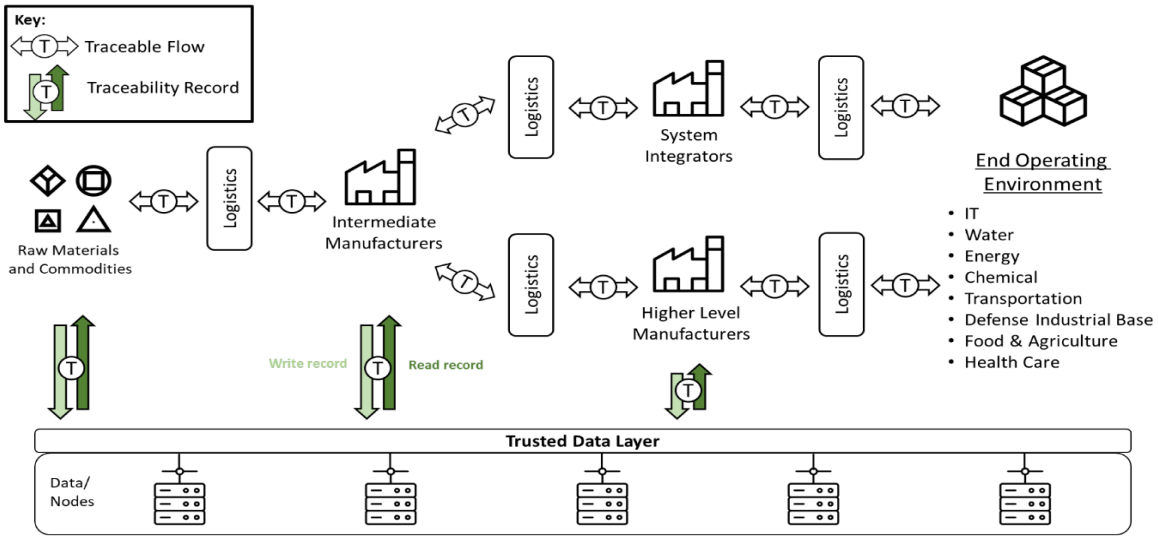

(Stouffer, et al., 2022)

An industry association could make certain types of traceability mandatory for membership, either specifying the precise methodology or setting minimum standards for what must be traceable while enabling flexibility as to how that is achieved (Lehr, 2020). The UNECE, the regional UN body for Europe and North America, is in the early stages of exploring what such a standard could look like using blockchain systems for apparel and textile companies (Lehr, 2020).

2. A case for private blockchain.

Various measures can be used to address the issue of protecting confidential information. Blockchains that are permissioned, and access regulated prohibit unauthorised data access. Other possibilities could include businesses storing information on many interoperable blockchains. A corporation may wish to demonstrate that it uses responsible certification requirements for suppliers without disclosing the identity of such suppliers. Some of these issues may be addressed by advances in the field of zero-knowledge proofs. Zero-knowledge proofs allow you to prove claims about your data without revealing the data itself (Lehr, 2020). To provide an example, in the real world, someone who wishes to establish their age would need to present an ID that also indicates their full date of birth. Zero-knowledge proof could allow another party to validate the ID holder's age without forcing them to reveal their private date of birth. In summary, if two parties agree that the underlying data, the information stored on the ID, is correct, zero-knowledge proofs let them to make and verify assertions about the data without showing it or contacting a trusted third party. If zero-knowledge proofs are successfully integrated into traceability databases, they have the potential to enable a new type of data exchange, one that transmits relevant information without disclosing confidential details and alleviates concerns about confidential information leakage (Lehr, 2020).

Further the following figure below explains the various block-based privacy models.

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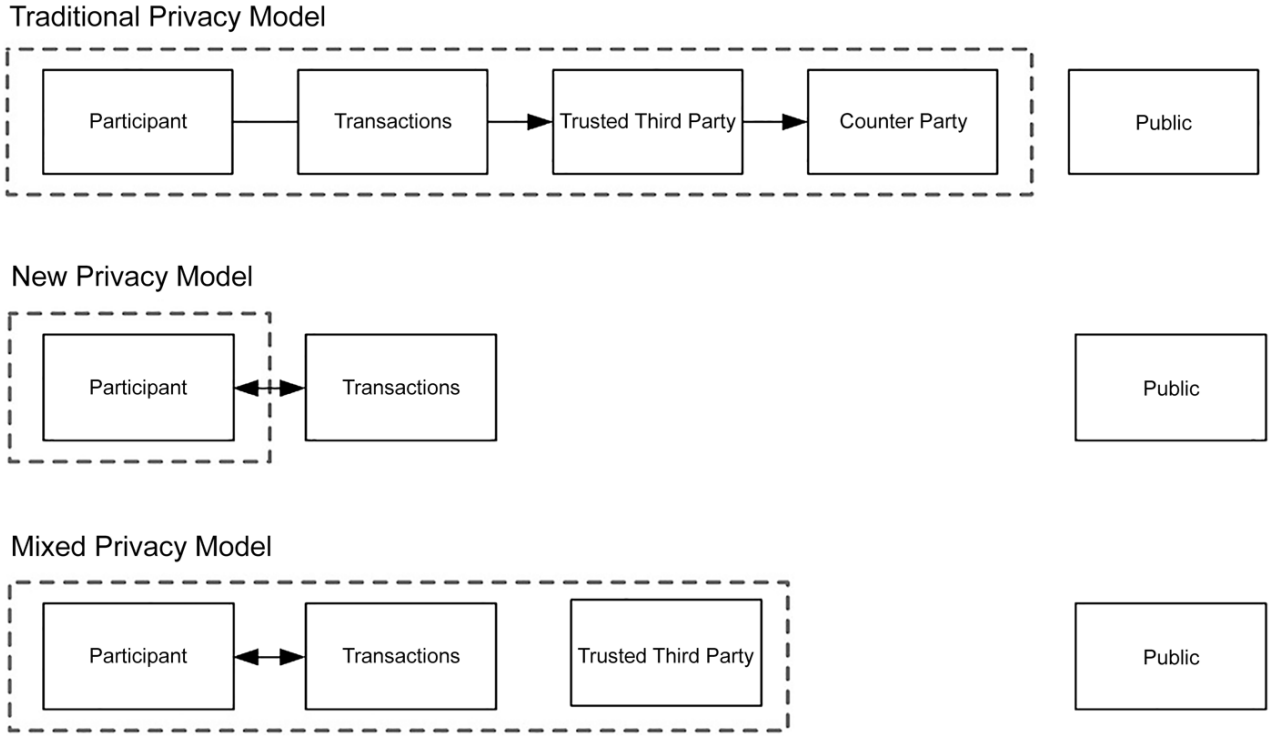
Figure 9 Blockchain privacy models (Nakamoto, 2008)



Therefore, it is suggested that private blockchains between known parties, and not open blockchains between anonymous users, should be the starting point (Lehr, 2020). So that members of a supply chain can determine the origin and quality of their inventory, each item must be securely associated with its owner's identity at each step. Consequently, only known parties can be permitted to participate in such a blockchain, meaning that corporations must be granted access to the system. In addition, permission must be granted selectively because blockchain's open and decentralised structure poses a danger to data privacy. When businesses record transactions on a blockchain, any participant can access those records. As the quantity of data increases, it may be abused to obtain competitive intelligence. Therefore, the blockchain participants must be vetted and approved for security purposes. Creating a group of trustworthy companions with whom to share data on a blockchain will require overcoming several obstacles. One is the requirement for a governance mechanism to determine the system's norms, such as who can be invited to join the network, what data is shared, how it is encrypted, who has access, and how disputes will be resolved, as well as the scope of IoT and smart contracts. Another difficulty is determining how to mitigate the impact that blockchain could have on pricing and inventory allocation decisions by increasing the transparency of information regarding the quantity or age of products in the supply chain.

For these reasons, it is prudent for businesses to concentrate on limited applications, such as product traceability, that are supported by well-defined use cases or regulatory mandates. To reduce the risk to data privacy and make the system more acceptable to supply chain partners, businesses restrict the types of information recorded on the blockchain.

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While I have made a case for private blockchains, the true representatives of transparency will likely be decentralised, public blockchains rather than private ones, as it is impractical to rewrite the blockchain if copies of it exist in different locations, on computers belonging to different parties. Therefore, if provenance information is not made public, it may not serve its intended purpose. Thus, private blockchains may be preferred for widespread adoption, but regulatory information such as origin must be accessible to the public. Future evaluations will be required to determine how well this method could function in the context of interoperable but private blockchains or public blockchains. Further, because these solutions are private, it is possible that they would not be standardized, and hence each company will need to implement many solutions. This will be especially challenging for second and third tier suppliers. But the choice here is between confidentiality, available of traceability throughout the supply chain and trying to find a one stop solutions for traceability needs. A public blockchain can resolve the issue of not duplicating the process multiple times but may fail to instil the confidence in the participants on confidentiality of data available on the public platform and thus the recommendation of this research is to go ahead with the private blockchain.

Table 4: Summary of types of blockchain and their differences.

	Public blockchain	Private blockchain
Overview	Fully decentralized with no central authority; “proof-of-work” or “Proof-of-ownership” is used to ensure record authenticity.	A central authority acts as a trusted intermediary to control and ensure record authenticity.
Permission	Permissionless anyone can read and write	Write permissions are centralized to one entity
Transaction verification	Records are verified by the majority of the “miners” reaching consensus. on the authenticity	Central authority verifies. transactions
Data storage	Records are distributed, a copy of the entire record is available to all users of the peer-to-peer network	Records are stored by the central authority
Transaction cost	Low cost for transactions	Transaction cost dictated by one. entity

(Laaper, 2022)

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3. Simpler consensus protocols for faster processing and execution

Blockchain necessitates a consensus protocol, a mechanism for sustaining a single version of the transaction history that is accepted by all parties. Since peer-to-peer cryptocurrency networks lack a central authority, they employ a complex method known as proof of work. It ensures that all network transactions are accepted by the majority of network participants, but at the expense of limiting the rate at which new blocks can be added. Therefore, it is too sluggish to accommodate the velocity and volume of transactions in supply chains.

Consider the shipping industry, in 2020, about 1.85 billion metric tons of cargo were shipped globally (Statista Research Department, 2021). Over 31 million twenty-foot equivalent units (TEU) of cargo are expected to be transported across the Pacific Ocean in 2021 (Statista Research Department, 2021). Each unit is handled three to five times, on average. That translates to roughly 31 million to 93 million transactions a day, on average. The Bitcoin network, in contrast, allows only about 360,000 transactions a day.

Fortunately, if a blockchain is permissioned and private, the proof-of-work consensus method is not required. To determine who has the right to add the next block to the blockchain, simpler methods are available. A round-robin protocol is one such method, in which the ability to add a block rotates among the participants in a predetermined order. Since all participants are known, a malicious actor who used its turn to modify the chain in a detrimental or illegitimate manner would be discovered and disputes can be readily resolved by validating previous blocks by participants (Lehr, 2020). Thus, simpler consensus protocols can aid in faster processing and execution (Gaur & Gaiha, 2020).

4. Traceability and audit trail of goods

Even if a blockchain record is secure, there is still the possibility that a non-confirmatory or uncertified product could be identified and introduced into the supply chain, either by accident or by a malicious actor. Inaccurate inventory data resulting from errors in scanning, labelling, and data entry is a further risk.

These dangers can be mitigated in three ways. First, perform rigorous physical examinations when products are first introduced into the supply chain to ensure that shipments match blockchain records. Second, build Distributed-Apps that can track products throughout the supply chain, verify data integrity, and communicate with the blockchain to prevent mistakes and deception. If a non-confirmatory product or error is identified, its origin can be determined by tracing the transactions for that asset on the blockchain. Thirdly, companies can make the blockchain more robust by employing IoT devices and sensors to automatically scan products and contribute records to the blockchain without the intervention of a human, as we have discussed previously (Gaur & Gaiha, 2020).

Some companies may not be prepared to rely on an audit conducted by another entity because they have their own audit standards. Compliance with various types of audits may still be reflected in the system, even if not all businesses elect to utilise them. A shared platform could

also potentially assist in mapping which suppliers have relationships with entities further upstream, thereby bolstering efforts to improve traceability (Lehr, 2020). Thus, inventory audit may be necessary to ensure that the blockchain records match with the physical inventory.

5. Security & confidentiality as a fundamental aspect.

Additionally, security concerns complicate the adoption of a platform for data sharing. A centralised database for the industry would create a single point of failure and a large attack surface for those seeking to gather data. In addition, businesses are reluctant to disclose confidential information regarding their supply chains with rivals. To address these concerns, blockchain technology may be the optimal solution. As previously mentioned, blockchain is a long chain of digital documents to which new data is appended. It is a type of distributed ledger technology in which the database is not maintained in a single location, but rather on multiple devices, known as nodes. These nodes, which are typically controlled by numerous distinct entities, must concur on all database alterations. Decentralised systems are those that function through a network of dispersed nodes. A further characteristic of blockchain technology is its permanence, or immutability. After data has been submitted to a blockchain, it is typically impossible to modify or delete it. Together, decentralisation and immutability resolve some of the security concerns of businesses. In a decentralised system, there is no longer a singular point of failure because copies of the data are stored on numerous nodes. Centralised authorities, which could potentially access or be stolen from, are no longer required. Due to blockchain's immutability, it is impossible for attackers to alter system data. This includes suppliers who may attempt to alter historical data to misrepresent compliance with government regulations. While such methods provide assurances of security once data has been entered into the system, they do not guarantee the accuracy of the data. If unreliable actors can submit falsified or altered data to the blockchain, the database will be rendered useless even if its storage is secure. To mitigate this risk, some traceability systems have eliminated the need for manual data submissions by capturing the data electronically via IoT devices (Gaur & Gaiha, 2020). Thus, it is strongly recommended that security & confidentiality is a fundamental aspect of the design to ensure long term trust.

Further research is required to ensure that blockchain based supply chain traceability systems are secure and tamper proof or at minimum tamper evident. Security is the cornerstone of supply chain transparency and getting this wrong will jeopardize the trust of a nascent and promising technology like DLT.

6. Legal recognition for blockchain records

Legal recognition is critical for DLT-based supply chain records because, in most geographies, only physical documents and records such as Bills of Lading, country-of-origin certificates, and so on are legally recognised, and thus blockchain-based systems are not viable because physical documents and certificates, in addition to digital records, must be maintained and presented to authorities. As a result, legislation must be in place to publicly recognise digital records that have been certified as legally valid based on agreed-upon common standards for supply chain data interoperability; otherwise, there is no incentive to digitise the supply chain. Furthermore,

English law, like many other trade regimes across the world, currently does not consider intangible items to be possessable. This means that electronic forms of business papers, which are considered intangible, cannot be held and, as a result, cannot be utilised in the same way as paper counterparts (Department for Digital, Culture, Media and Sport, Goverment of UK, 2023). Given the extent to which international trade transactions, even those not involving the UK, are based on English and Welsh law, it is widely accepted that UK legal reform would serve as a significant catalyst for global legal reform and the development of an electronic trade document ecosystem (Department for Digital, Culture, Media and Sport, Goverment of UK, 2023). As a result, explicitly accepting digital records on the DLT platform in English law may set a precedent for other countries to follow (LegalUK, 2021). The House of Commons is currently debating a draft Bill to make provisions for electronic trade documents. The primary goal of the Bill is to provide the international logistics sector with a legal framework that allows the use of electronic trade documents without the need for complex and often time-consuming processes (Department for Digital, Culture, Media and Sport, Goverment of UK, 2023).

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Chapter 12 Conclusion

Distributed ledger technology (DLT) has the potential to play a significant role in resolving challenges related to supply chain traceability. By providing a secure and transparent way to track and verify transactions and data across the entire supply chain, DLT can enhance transparency, improve data accuracy, and increase trust and accountability among stakeholders. DLT can also enable the automation of compliance checks and the verification and certification of suppliers, providing additional assurance of compliance with ethical and legal standards. While there are challenges to implementing DLT-based solutions for supply chain traceability, the potential benefits in terms of enhanced compliance, transparency, and trust are significant, making it a promising option for clothing and fashion industry seeking to improve their supply chain practices and complying with risk of forced labour. Within the context of monitoring for potential labour exploitation, one potential limitation is that blockchain places a priority on the tracing of the product itself rather than on addressing the labour conditions involved in the manufacturing process. Also, the data that is traced through the supply chain may be fraudulent from the beginning, thus those entering the data may input fraudulent information. So, while blockchain can confirm that a commodity is "clean" because the data along the supply chain reads as such, there need to be certain safeguards in place to ensure the data is true and accurate. On-site inspections and/or third-party certifications may aid in remedying this deficiency and ensuring reliability of the data.

From my interactions with the industry insiders and experts and through the interviews I have realised that the promise made by the distributed ledger technologies need realistic evaluation. I learnt that the challenges in implementing a distributed ledger technology-based traceability solution must be addressed. Among the various challenges is around trust and who is implementing the solution is critical, parties prefer a neutral organization as the implementer who does not have any interest in the data that is being published to the platform and is compliant to all the data sharing role laws that exist all over the world. So, if an American or a Chinese entity, there are lot of parties in the world who do not trust and so may not sign up on such a platform due to geopolitical risks and being constrained by competing regulatory requirements and interests (Cockayne, 2022). Blockchain based solution will only work if everyone engaged in the supply chain network is part of the platform, the entire supply chain ecosystem including all stakeholder must subscribe to the platform. Second challenge is creating common standards for supply chain data, such that the data is interoperable, thus it is important to develop standardization for the growth of blockchain as a technology and for interoperability. That common standard cannot be only for traceability, traceability needs to be a by-product, the main push needs to be around digitization of the supply chain records. Third is the legal recognition of digitised supply chain records. Currently only physical documents and records like Bill of Lading, country-of-origin certificate, traceability data etc are legally recognised in most geographies and thus blockchain based systems are not viable, as along with digital records, physical documents and certificate must be maintained and presented. So, a law must be there to formally recognize digital documents identified to be legally valid based on

agreed common standards for supply chain data interoperability, as currently this does not exist there is no incentive to digitise the supply chain. At the onset if the English law formally recognize digital documents, then that may set a precedent for other jurisdictions to follow, as significant international trade is governed by English law (LegalUK, 2021). For addressing the concerns around confidentially, it is recommended that private blockchain as a solution is explored which may help to build trust and protect propriety information. Simpler consensus protocols must be developed to ensure larger data can be processed faster. Also important is the aspects of verifiable audit trail of records in the blockchain corresponding with the physical goods and finally security and confidentiality must be a fundamental feature of blockchain based supply chain traceability system to ensure long term trust in the technology.

Based on my research, it can be concluded that, of all the current technologies mentioned in Chapter 5 on page 20, DLT is best suited to and has the potential to improve supply chain traceability, thereby supporting compliance with ethical labour practises and identifying the risk of forced labour or other non-compliance issues in the supply chain. It is crucial to emphasise, however, that implementing DLT necessitates significant investment and coordination among supply chain parties. As a result, using distributed ledger technology (DLT) to increase supply chain traceability can be costly and time-consuming, making it difficult for companies with minimal resources. Working with third-party providers can also help to reduce some of the initial costs and technological hurdles. Companies can consider partnering with a third-party vendor that provides DLT-based supply chain traceability solutions rather than developing their own system from the ground up. This can help to decrease initial expenses and technical obstacles while still giving the benefits of improved supply chain transparency and compliance. Companies could also start with a pilot project to investigate the feasibility and possible benefits of DLT-based supply chain traceability on a smaller scale. Before committing to a larger-scale implementation, this can assist identify any issues or restrictions. However, the cost and viability of implementing DLT will be determined by a variety of factors, including the supply chain's complexity, the level of data integration required, and the specific DLT platform chosen. Finally, the business entity should carefully weigh the costs and benefits of implementing DLT-based supply chain traceability, as well as if it is consistent with their business goals and values. However, it is crucial to emphasise that DLT is not a panacea for all compliance issues. To maintain its effectiveness, it requires coordination and collaboration among supply chain stakeholders, as well as ongoing monitoring and maintenance. Furthermore, DLT should be utilised in conjunction with other supply chain traceability best practises and tools, such as risk assessments, audits, and supplier engagement programmes.

Finally, consider the relevance of distributed ledger technology in resolving compliance issues. While blockchain can help with transparency, dependability, traceability, and efficiency, it is not a cure-all. One potential drawback in the context of monitoring for potential labour exploitation is that blockchain prioritises the tracking of the product itself above resolving the labour conditions involved in the production process. Furthermore, the data that is traced through the supply chain may be fraudulent from the start, so those providing the data may provide false information. As a result, while blockchain can affirm that a commodity is "clean" since the data

along the supply chain indicates such, certain controls must be in place to verify the data is real and correct. On-site inspections and/or third-party certifications may help to correct this flaw and ensure the data's veracity. This is just one illustration of how blockchain technology adoption in the supply chain is still in its early stages. Users' lack of expertise, the requirement for standards, and existing legacy systems are all barriers to deployment (Ludwikoski & Salaheldin, 2022).

Finally, as discussed in the previous chapter, these are the recommendations for further research to overcome challenges in implementation of blockchain technology for supply chain traceability.

- Standards based approach for interoperability.
- Private blockchain to build trust and protect propriety information.
- Simpler consensus protocols
- Traceability and audit trail of physical goods
- Security as a fundamental aspect of Blockchain
- Legal recognition for blockchain records

But if an organisation were exploring the potentials of a blockchain based traceability solution then, following aspects must be considered before they embark on the journey (Agrawal , Kumar, Pal, Wang, & Chen, 2021).

Begin with a small-scale pilot project to test the technology and iron out any bugs before building it up. Collaboration with other organisations in your business can aid in the development of a more comprehensive and successful traceability solution. You can also learn from other people's mistakes when designing other types of systems. Use blockchain technology and supply chain management professionals to assist you in developing and implementing your traceability solution. Maintain regulatory compliance by ensuring that your solution complies with all applicable rules and regulations, especially those concerning data protection and intellectual property. Ascertain that the solution can be integrated with current systems. Monitor and analyse the solution's performance on a regular basis, making changes as appropriate to optimise efficiency and effectiveness. Participate in the blockchain ecosystem of experts, developers, and technologists to stay up to date on the newest advances in the area. Instead, of attempting to adapt the solution to the use case, learn about it and tailor the solution to it. Ensure that the solution targets the entire supply chain, not just a section of it, from raw materials to the end user.

Overall, adopting blockchain traceability solutions requires a clear understanding of the problem, and a well thought out strategy to implement it.

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Appendix

Interviews

Question asked to Ms. Michelle Moore, Head of information system for Global Trade @ Henkel (for blockchain solution) (Structured

1. What do you think are the most important considerations when designing a blockchain traceability solution?

The first and foremost important aspect is the purpose and scope of the traceability solution, thus the first step in designing a blockchain traceability solution is to identify the purpose and scope of the system. Is it intended to track the supply chain of a particular product or to track the movement of assets or financial transactions? The specific purpose and scope will determine the technical requirements and the design of the system. The second important aspect is the problem statement, what is the use case to build around the problem statement. Requirements must be stated clearly, what do you want to do, how can blockchain support in realizing the exercise. What information do I need, what does the law say. Further it is important to focus on the following aspects when designing a blockchain based traceability solution. The data structure used in the blockchain must be carefully designed to ensure that it can track the desired information in a secure and efficient manner. This includes determining what data will be recorded on the blockchain, how it will be formatted, and how it will be linked together to create a complete picture of the transaction history. Security is critical in blockchain traceability solutions. The solution should be designed to prevent unauthorized access to the blockchain and ensure that only trusted parties have access to the data. The solution should also include measures to prevent tampering with the data and ensure the integrity of the blockchain. The blockchain traceability solution must be designed to handle large volumes of data as the number of transactions recorded on the blockchain grows. This includes designing the blockchain to handle high transaction volumes and ensuring that the solution can be scaled up as needed. In many cases, blockchain traceability solutions will need to integrate with existing systems and processes. The solution should be designed to work seamlessly with other systems and be capable of interoperating with a variety of different technologies. The blockchain traceability solution should be easy to use and understand for all users, including those who may not be familiar with blockchain technology. This includes designing a user-friendly interface and providing clear documentation and support for users. There may be legal and regulatory requirements that must be met when designing a blockchain traceability solution. The solution should be designed to comply with any relevant laws and regulations to avoid any legal or regulatory issues.

2. What are the key challenges to achieving traceability in the supply chain, and how can distributed ledger technologies help address these challenges? What do you think are the most important considerations when designing a blockchain traceability solution?

The first and foremost aspect is to define the use case and requirements for designing the blockchain based solution for achieving traceability in the supply chain. If the use case and

requirements are not clearly defined, then we are setting ourselves for failure. It is also important to define the data element and requirements for traceability, it is important to define What type of data is required? It is also critical to define what are the legal requirements that govern that data. Thus, developing the scope is important and what are you looking to control or to view and how, who should be involved and as per the data requirements determine which partners need to provide that. Overall, it is only as strong as the number of parties within your use case/process that are using the blockchain. I understand from you that you are writing you thesis on Issue of human rights / forced labor in China Xinjiang in the production clothing.

Another critical aspect is onboarding all the stakeholders engaged in the supply chain. Supplier, transporter, different parties involved, these suppliers would provide a validated legal document, this is loaded to the blockchain for example long term vendor declaration, each of the parties can have different license and they could be providing their information to the block chain.

As the data travels through the supply chain, it is possible that it is fraudulent from the start, and the individuals entering the data may input false information. While blockchain can confirm the authenticity of a data entered, there must be safeguards in place to ensure the data is true and accurate. The problem may be remedied by on-site inspections and/or third-party certifications.

3. What are the most important benefits of using blockchain technology for traceability?

Checks and balance are in place as logic can be programmed in the blockchain system. Whereas in the typical ERP solution such a solution will be complex.

Blockchain could do the validation check for origin information. What type of information you have can be checked and validated, Roles, what information would need to be provided, crossed checked by the information provided transporter and the supplier, so location information from the transport and supplier declaration can be verified. Define what is that you want to have, what type of data is required, what are the legal requirements that cover that data.

4. How do you think blockchain traceability solutions can be used to improve supply chain transparency?

Blockchain traceability solutions can improve supply chain transparency by providing a secure and transparent record of all transactions and events along the supply chain. But it can improve if all the parties are going to play their assigned role. For example: blockchain can help in improving logistics, thus Blockchain can be used to track the movement of goods through the supply chain, providing real-time visibility into the location and status of products. This can help improve logistics and reduce the risk of delays or disruptions. Enhancing trust and accountability: By providing a transparent and tamper-proof record of transactions, blockchain can enhance trust and accountability throughout the supply chain. This can help prevent fraud,

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counterfeiting, and other forms of malfeasance. Increasing efficiency: By automating many supply chain processes and reducing the need for intermediaries, blockchain can help increase efficiency and reduce costs. This can benefit everyone engaged in the blockchain based traceability solution by improving the overall value proposition of the supply chain.

5. How would you describe the current state of blockchain based supply chain traceability solutions?

The current state of blockchain-based supply chain traceability solutions is still in its early stages, with a few successful projects implemented but still relatively few at scale. However, there is growing interest and investment in this area, as more companies recognize the potential benefits of blockchain technology for improving supply chain transparency and accountability. One of the most notable blockchain-based supply chain traceability solutions that have been implemented to date is the IBM Food Trust which is a blockchain-based platform that allows food suppliers to track the origin and movement of their products from farm to table. It has been successfully used by companies like Walmart to improve food safety and reduce waste.

6. What challenges do you think you may face when implementing blockchain based supply chain traceability solutions?

Implementing blockchain-based supply chain traceability solutions can pose several challenges, many companies already have complex supply chain management systems in place that may not be compatible with blockchain technology. Integrating blockchain-based traceability solutions with existing systems can be a significant technical challenge. Implementing a blockchain-based traceability solution can be expensive, particularly for smaller companies. Furthermore, as the volume of data being recorded on the blockchain increases, scalability can become an issue. While blockchain technology can provide a tamper-proof and transparent record of transactions, it is only as accurate as the data being recorded. Ensuring that data is accurate, complete, and consistent across all stakeholders can be a significant challenge. There may be regulatory and legal requirements that need to be considered when implementing a blockchain-based traceability solution. These requirements may include data privacy, security, and compliance with industry-specific regulations. Implementing a blockchain-based traceability solution typically requires collaboration with multiple stakeholders, including suppliers, customers, and regulatory agencies. Ensuring widespread adoption and collaboration can be a significant challenge, particularly in industries with a history of low trust and transparency. Overall, while implementing blockchain-based traceability solutions can bring significant benefits in terms of improved transparency and efficiency in supply chains, there are several challenges that need to be addressed, including integration with legacy systems, cost and scalability, data accuracy and consistency, regulatory and legal considerations, and

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adoption and collaboration. Also, it is only as strong as the number of parties in the block chain and using it.

7. What advice would you give to companies looking to use blockchain traceability solutions?

Clearly define the problem you're trying to solve: Before implementing a blockchain traceability solution, make sure you have a clear understanding of the problem you're trying to solve and how blockchain can help. Identify the specific pain points in your supply chain and determine whether blockchain is the best solution to address them. Choose the right blockchain platform, there are many different blockchain platforms to choose from, each with its own strengths and weaknesses. Do your research and choose a platform that is best suited to your needs, considering factors such as scalability, security, and interoperability. Ensure data accuracy and integrity, as Blockchain technology is only as good as the data that is stored on it. To ensure that your blockchain-based traceability solution is effective, it's important to ensure that the data being recorded is accurate, complete, and up to date. This may require changes to your existing supply chain processes and systems. Focus on collaboration, implementing a blockchain-based traceability solution typically requires collaboration with multiple stakeholders, including suppliers, customers, and regulatory agencies. Focus on building strong relationships and fostering collaboration to ensure that everyone is aligned and invested in the success of the solution. Thus, here onboarding of various stakeholders to the platform is critical. Do not underestimate the preparedness of the suppliers to provide the information to the block chain solution. Stakeholders may require training and handholding during the implementation of the solution. Always plan for the long-term. As Blockchain is still a relatively new technology, and it's important to plan for the long-term when implementing a traceability solution. Consider factors such as future scalability, evolving regulatory requirements, and ongoing maintenance and support to ensure that your solution remains effective over time.

8. What is the incentive for the stakeholder participating in a blockchain based traceability solution to provide the correct and accurate information?

The incentive for stakeholders to provide correct and accurate information in a blockchain-based traceability solution is that it can ultimately benefit their business. By providing accurate and transparent information about their products and supply chain, stakeholders can improve customer trust, increase efficiency, reduce costs, and mitigate risk. Also, participating in a blockchain based traceability solution can reduce cost and time for the parties because the information will be shared electronically, thereby reducing managing paperwork for tracking traceability.

For example, by providing accurate information about the origin of a product, a supplier can demonstrate that the produce is and ethically sourced and does not involve forced labor, which can be an important selling point for consumers who value ethical business practices. Similarly,

by providing accurate information about the quality and safety of a product, suppliers can reduce the risk of product recalls, improve customer satisfaction, and avoid legal and reputational damage.

Furthermore, in a blockchain-based traceability solution, stakeholders are incentivized to provide accurate information because the technology is designed to be tamper-proof and transparent. If stakeholders provide inaccurate or misleading information, it will be easily detectable, and the reputational and legal consequences can be significant.

Overall, the incentive for stakeholders to provide accurate and transparent information in a blockchain-based traceability solution is that it can ultimately benefit their business by improving customer trust, increasing efficiency, reducing costs, and mitigating risk.

9. What do you think the future of blockchain based traceability solutions may look like?

I think in the future there is bound to be Increased adoption of Blockchain based technologies and thus may lead to standardization and interoperability. Also, as more companies recognize the benefits of blockchain-based traceability solutions, adoption is likely to increase in various industries. This increased adoption is also likely to lead to greater standardization, with common data formats and protocols emerging.

I believe that for Blockchain to mature it must integrate with other technologies, thus we can expect that blockchain-based traceability solutions will likely integrate with other technologies, such as IoT sensors, artificial intelligence, and cloud computing. This integration can enable real-time tracking and monitoring of products and supply chains, as well as predictive analytics and other advanced capabilities.

Another area that blockchain based traceability solutions will play a critical role is in providing greater emphasis on sustainability and ethical sourcing, we as consumers are more aware of the environmental and social impact of their purchasing decisions, blockchain-based traceability solutions are likely to play an increasingly important role in enabling companies to demonstrate the sustainability and ethical sourcing of their products.

Increased focus on data privacy and security: As the use of blockchain-based traceability solutions becomes more widespread, there is likely to be greater focus on ensuring data privacy and security. This may include the use of encryption, secure access controls, and other advanced security measures.
I believe blockchain will expand into new industries and applications, while blockchain-based crypto currencies have been primarily focused, there is potential for their use in other industries and applications too in the future.

Question asked to Mr Ajay Shukla, Director @ Mainfreight Singapore Pte on logistical challenges with blockchain based traceability solution (Structured)

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1. What are the current challenges you face with supply chain traceability, and how do you think a blockchain-based solution could address these challenges?

Currently our logistic and supply chains solutions are complex, with multiple stakeholders involved in the process. This makes it difficult to track the movement of goods and ensure their authenticity and thus results in a lack of transparency across the supply chain. Currently most of the traceability is based on paperwork, the paperwork is difficult to manage and must also be transported along with the goods to ensure original documents are received for verification when required. Another problem we face currently is the accuracy of the data in the supply chain, the accuracy can be compromised due to manual data entry errors or intentional data manipulation. It is difficult for us to check and ascertain the accuracy of the information shared by various actors in the supply chain. Any inaccurate or manipulated data related to traceability can result in loss of confidence by the authorities and thus resulting in delays.

Current technologies have limited interoperability, our customers, stakeholders, and supply chain participants use different systems and processes, making it difficult to share information and track products across the entire supply chain. Sharing of information thus requires complex solutions and developments of APIs. Adding a new participant to the supply chain network is complex, it requires that the participant has access and has expertise in utilizing certain technologies for them to share the data as may be required.

Another problem we face is that limited visibility into the supply chain makes it challenging to detect and address issues such as unethical practices like forced labor unless this is verified and authenticated by a third party. Thus the third party can then confirm the findings and upload the information to the blockchain. Here again the block chain is only acting as the medium to share information.

Another important factor is the aspect of the cost of development, deployment, and maintenance of a traceability solution. This is a massive limiting factor and even a solution like blockchain may not be able to easily resolve this issue. As any new technology has a learning and adoption curve. Unless blockchain as a technology is widespread and standardized, such that any technology platform can and will support, it is difficult to keep the cost of development, deployment, and maintenance low and I don't think blockchain can solve that problem now. Thus, unless there are viable use cases adopting the technology is challenging. We partnered with TradeLens from Maersk to implement the solution.

But some of the challenges I have stated above are being addressed as follows.

The main premise for implementing a Blockchain technology-based supply chain solution is that it can provide a transparent and tamper-proof record of all transactions and activities across the supply chain. Thus, it can address the issue of most traceability solutions being based on paperwork. The information can be shared by multiple partners across the supply chain and thus with the help of programmable logic built into the blockchain, the information shared can

be verified and the accuracy can be authenticated, also because the information shared on the platform is transparent and tamper-proof, it helps in building confidence among all the stakeholders and authorities.

As for the problem of data accuracy, the use of smart and programable contracts in blockchain-based solutions help ensure the accuracy and integrity of the data on the supply chain. Like in our case we have implemented location based traceability, thus the pick up location is captured using a GPS device and thus helps us to identify the origin of the produce like fish. So, if the fish is caught off the Japanese coast and is being shipped from Japan then the GPS coordinate data can corroborate the origin data with the help of programmable logic built into the blockchain. But such uses cases are few and require complete understanding of the supply chain to configure programmable logic.

Blockchain technology can enable interoperability by providing a common platform for all supply chain participants to share information and track products. Thus, even if the stakeholders are on different platforms. It is possible to share data on the blockchain and thus support interoperability, But this requires standardization of data fields. Thus, as blockchain grows more in popularity these data elements could become standards across various technology platforms and thereby ensuring largescale adoptability.

Blockchain-based solutions provide real-time visibility into the supply chain, enabling us to detect and address issues quickly, like the case mentioned earlier of fishing. If the origin data does not match with the location data as programmed to check and match then it helps us to flag possible manipulation or inaccuracy.

2. How do you plan to integrate the blockchain solution with existing supply chain systems and processes, and what are the potential obstacles to integration?

We first spent significant time and resource in identifying current systems and processes, thus the first step is to identify the current systems and processes used in the supply chain. This can help determine which processes can be improved by integrating the blockchain solution. It was also important to determine the architecture of the blockchain solution that we wanted to implement. As stated earlier we partnered with TradeLens from Maersk to implement the solution, the participation to join the platform and share data was based on invitation only, this was because we had to ensure that the data was access controlled and secured, such that participant were assured that the information shared was not free to be accessed by anonymous users. Also, defining the scope of the integration is important, including which stakeholders will be involved in the process and which data will be shared. After wish we set out to develop APIs and other integration tools, APIs and other integration tools need to be developed to connect the blockchain solution with existing ERP systems and finally we set out to test the integration, as before rolling out the integration, it's important to test the integration. Such tests helped us to identify issues and bugs. We also had partners who cooperated with us to complete the tests.

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We faced many obstacles during integration, the first among them was resistance to change. Some of our stakeholders were resistant to change and were not willing to adopt the new technology. There was paucity of technical expertise within our organization, as Integrating a blockchain solution requires technical expertise, and we found it difficult to find the necessary skills and knowledge and were dependent on TradeLens for most of the activities. As stated earlier the cost of implementation was high and it did prove to be expensive, we had to carefully consider the costs involved. Also, there were security concerns about the security of the blockchain solution from our supply chain stakeholders, and we had to ensure that the data on the blockchain is secure.

Overall, integrating a blockchain solution with existing ERP systems and our operational processes required careful planning to overcome the obstacles. We had to identify the current systems and processes, determine the blockchain solution architecture, define the scope of the integration, develop APIs and other integration tools, and test the integration.

3. How did you ensure the security and confidentiality of the data stored on the blockchain, and what measures are in place to prevent unauthorized access or tampering?

To ensure security and privacy of the data stored on the blockchain, several measures were taken, including implementing strong encryption techniques, access control mechanisms, and multi-factor authentication protocols. Additionally, consensus mechanisms and smart contracts also help to prevent unauthorized access or tampering of data by ensuring that all transactions are verified and approved by the network participants. Regular security audits and updates can also help maintain the integrity of the blockchain and protect against potential vulnerabilities or attacks.

4. What are the legal and regulatory considerations you need to take into account when implementing a blockchain-based solution, and how will you ensure compliance with these requirements?

To ensure compliance with legal and regulatory requirements when implementing a blockchain-based solution, we worked with legal experts and consulted them on the legal requirements, we implemented appropriate privacy, security measures, maintained proper records, conducted regular compliance reviews.

5. How will you educate and train your team and partners on the use of the blockchain-based solution, and what resources will be available to support adoption and use?

To train the team and our partners on the use of the solution, we had to develop and deploy various resources, including training sessions, workshops, documentation, and online resources such as videos. Additionally, providing access to a test environment also helped the team and partners become familiar with the solution and its features. Further, ongoing support continues to be provided through dedicated support teams, our colleagues can contact them through email, chat, and phone, to help address any questions or issues that may arise. Regular updates

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and communication also help the team and partners to be informed of any new features, updates, or best practices related to the solution.

6. How will you measure the success of the blockchain-based solution, and what metrics will you use to evaluate its effectiveness in improving supply chain traceability?

The objective we had set at the start to measure the success of the solution was, first, will the solution help in reduction in the time it takes to trace a product through the supply chain? Second, will it improve in the accuracy of product tracing and ability to identify the source of issues? Third will there be improvement in supply chain efficiency, such as reduction in inventory levels, lead times, or transportation costs? Fourth, will it increase trust and transparency among supply chain partners? Thus, we have been regularly monitoring and analyzing these metrics to determine the success of the supply chain solution and it has been a mixed bag till date.

7. What are your thoughts on the success of the blockchain-based supply chain solution?

In my opinion the main factors that may have caused the solution to fail are as follows.

Cost was the biggest factor, the cost of implementing the system did not equate to the results we had set for ourselves at the start. We did not see significant benefits in terms of achieving any of the objectives during the 19 months we had deployed the system. Thus, we cannot say that the benefits materialized fully, also TradeLens is about to stop supporting as the platform is closing in March 2023.

Further, there is lack of standard based approach for such system to thrive, each implementation sets a unique standard and that becomes a roadblock as API must to developed for interoperability across platforms and therefore it defeats the purpose. Thus, an industry-wide standard must be developed for supply chain data to be shared in the lines of information exchanges that take place in the finance and banking sectors. For such standards to be developed independent industry and trade bodies must play a significant role.

Thus, in all I could say, we tried and experimented with the solution but did not result in the desired outcome. We may have succeeded if we had given more time for the platform and the stakeholder to mature and we were willing to do that but as stated earlier TradeLens is about to close its operations and we were dependent on them for the technology and expertise.

Question asked to Mr. Wolfgang Weber, Director Global Engineering and Digital Transformation @ Henkel (Structured)

1. Can you explain your company's current traceability system and how it is implemented throughout the supply chain? How does your traceability system ensure compliance with regulations and industry standards?

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Currently there is no need for us to provide full traceability of our standard ingredients, neither is trade requesting that from us. Normally our trade and business partners would do is that they seek certificates on traceability and that in most cases suffice the requirements. As an example, we run business with Tesco in the UK, and they audited us against a standard of the British Retail Consortium, which had excess incremental requirements on traceability compared to our standard ISO 9001 requirements. Tesco is strict when it comes to consumer products that don't follow strict traceability requirements and they let us pass the audit and they testified our current traceability systems are appropriate.

Further, some Non-governmental organizations having particular focus on very specific type of raw materials. An example we use pine can oil as an alternative to crude oil, having appropriate visibility of the supply chain of pine can oil for us is of rising importance to make certain that the farmers providing us with that raw material cultivate their land, in an appropriate manners, and the whole supply chain is managed in an ethical way is of highest relevance because they would touch upon the credibility and the ethical standards of a company, and particular emphasis is placed to make certain that company standards are met and procurement happens in an ethical way. Another example is one of our crude oil suppliers has implemented a blockchain based traceability solution, the capability this technology has brough to them currently exceeds the requirements associated with crude oil supply from the traceability perspective. But they saw significant improvement on contractual agreements done in electronic way, they saw significant advanced advantages in the area of invoicing, invoice and payments control

We investigated blockchain technology a couple of times relatively aware what this technology can bring to us and our business partners. We also explored to check if blockchain technology if it can support us in better control of our long-haul transportation supply chains. We realised that it wouldn't require the full bandwidth of capabilities of blockchain would bring us, but we realised that it could bring proper processes and so I'm still happy to invest in the interest of an overall organizational improvement. What keeping us from doing this are costs considerations because running a blockchain is an expensive thing. Also, we are afraid that we would over engineer the problem that we wish to address with blockchain technology and traditional ways of communication still are good enough for us, unless we wish to solve two other problems as discussed earlier of invoicing, invoice and payments control and even payment steering and appropriate visibility of the supply chain for certain raw materials.

2. How does the traceability system improve efficiency and transparency in the supply chain?

I think traceability system improve efficiency and transparency in the supply chain in a completely different way. It's not directly related to traceability, but I think overall transparency can improve invoicing challenges that the blockchain helps to resolve. It is important to remember that the product that you bring market must come with a minimum value threshold.

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Such the effort and the cost associated with Blockchain is proportional to the value of your product.

I believe payment is an area where blockchain technology could be used, blockchain technology gives a significant different level of security that your payments will, if you fully automate and make this non correctable on distributed Ledger type of technology with certainty at the that at the end of the day you will get your money.

3. How does your company plan to improve or update its traceability system in the future?

We will act immediately if a client or customer of ours would request that from us, as an example we are seeing that customer is scanning with their iPhones in stores, product by product to get a good understanding of the ingredients. This dynamic may transfer from the customer to us and that would be our trigger to invest in much more on traceability. Further I would expect significant requirements from some quarters of the industry in the future and they will even be forced to look into that for customer requirements reasons.

4. How does your traceability system handle and track sub-tier suppliers and their products?

There are certain raw materials for which you need the appropriate specification of a product when you receive it, which the buy cannot automatically measure but must rely on suppliers' data. We can only weigh a certain quantity of that product, which does not tell us exactly the correct specification of the raw material, in such use cases some background supplier data would help us to address that point. As we must rely on the supplier. As just by weighing or measuring a quantity of something we may not know exactly about the activity level.

5. Can you discuss any challenges your company has faced with implementing or maintaining a traceability system?

First we need a robust IT architecture and infrastructure data platform to do this to accommodate those type of data and there I believe we still need to further invest and work on that one and you need to define the interface also to get external data sources and allow them in so you have an interface to be managed between your environment and the external environment which meets IT, security requirements. Finally, you need to be capable to process the data you receive from outside to make them somewhat useful.

6. Is there anything that you think will add to my research on supply chain traceability?

Most of the people would spontaneously tell you, yeah, that's super, that's important and we should have that and that is always good to invest in having more accuracy on traceability, but at the end of the day it always boil down to the business case and it is important to get a profound understanding of how such an invest on supply chain traceability will the company benefit either in complying with regulatory requirements or improving the supply chain performance. In principle you are in a business environment where traceability would be a

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good thing, but you will have to come upon an upfront significant infrastructure investment to build the platform, and then with all your use cases can you hook up to that platform. Finally, it would be difficult to expect first use case in the company to already to pay back immediately.

Question asked to Mr Praveen Mathur, CEO @ Tadashie on managing supply chain traceability and compliance with forced labor Act in clothing industry?

1. Can you describe the steps you take to ensure that your supply chain is free from forced labor, and how do you monitor compliance with these standards?

At the onset I wish to mention that it is challenging for us to comply with the requirements due to cost pressures, but we are being supported by our customers who are larger retailers and fashion houses, therefore to ensure that we do not jeopardize their reputation we have taken steps to ensure our supply chain is free from forced labor, thus we conduct due diligence on our suppliers, we mandate our suppliers to sign contracts that they commit to ethical and legal labor practices, we conduct regular audits to monitor compliance. Monitoring involves engaging with workers using third-party auditors, and we have implemented technology solutions to improve supply chain transparency. Further all our suppliers must declare their goods are not sourced from locations considered to be engaging in forced labor practices.

2. How do you vet and select suppliers to ensure that they are also committed to ethical and legal labor practices, and how do you communicate these standards to them?

To vet and select suppliers committed to ethical and legal labor practices, we conduct due diligence, we mandate requiring contracts, we use certification programs or audits, and engaging in ongoing dialogue with suppliers. To communicate these standards to our suppliers, we include standards in contracts, provide training, regular communication, and provide feedback to suppliers.

3. How do you identify and assess potential risks of forced labor in your supply chain, and what measures do you take to mitigate those risks?

As stated earlier, to identify and assess potential risks of forced labor in the supply chain, we conduct risk assessments that analyze factors such as supplier location, country risk, and industry risk. We conduct audits or assessments of suppliers' labor practices. We engage with workers to identify potential risks. We monitor news reports and other sources to identify potential risks. To mitigate these risks, we have developed policies and procedures that address forced labor risks for our organization with the help of our customers who are lager fashion houses and retailers. As much as we can we use technology solutions to improve supply chain transparency and traceability. Further we provide training and support to suppliers and employees to help them understand and comply with labor laws and ethical standards. Finally, we monitor and audit suppliers on a regular basis to ensure ongoing compliance.

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4. Do you conduct any independent audits or assessments of your suppliers' labor practices, and how often do you review and update your supplier policies and procedures?

To ensure compliance with ethical and legal labor practices, we conduct independent audits or assessments of suppliers' labor practices. The frequency of these audits varies depending on factors such as the risk level of the supplier and the nature of our relationship. Additionally, we review supplier policies and procedures and update them on a regular basis to ensure ongoing compliance with changing laws and ethical standards.

5. How do you ensure that your suppliers are transparent about their own supply chains and labor practices, and what measures do you take to encourage or enforce this transparency?

To ensure supplier transparency about their own supply chains and labor practices, we take measures such as: Requiring suppliers to provide detailed information about their supply chains and labor practices. Conducting audits or assessments of suppliers' supply chains and labor practices. Engaging with suppliers to encourage transparency and collaboration. Further we take measures such as, Including requirements in supplier contracts or agreements. We request certificates from 3rd parties or 3rd party audits to verify supplier compliance. suppliers who fail to meet the requirements are met with consequences such that barred from supplying or even blacklisted, we even terminate the supplier.

6. Can you describe any challenges or obstacles you have faced in trying to maintain supply chain traceability and compliance with forced labor Acts, and how have you overcome them?

Some of the challenges or obstacles that we face in maintaining supply chain traceability and compliance with forced labor Acts can include Lack of transparency and visibility in the supply chain, particularly in lower-tier suppliers. Limited resources for conducting audits or assessments. Resistance from suppliers to change their labor practices or provide information about their supply chains. Difficulty in tracking and verifying compliance across a large and complex supply chain. To overcome these challenges, we have taken the measure as stated earlier. Also, by engaging with suppliers we have managed to build trust. We also provide training and support to help them to meet labor standards.

7. How do you communicate your commitment to ethical and legal labor practices to your customers, and how do you respond to any concerns or complaints they may have about your supply chain practices?

To communicate our commitment to ethical and legal labor practices to customers, we have taken the following measures, including information about our labor practices and supply chain transparency in our website. We have demonstrated our program to our customers including the method by which we conduct audits or assessments of suppliers' supply chains and labor

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practices. We have welcomed our customers to engage with our suppliers to encourage transparency and collaboration. Further we have demonstrated measures such as, Including requirements in supplier contracts or agreements. The certificates requested from our suppliers to verify supplier compliance. And finally, the consequences that our supplier face if they fail to meet the requirements, such as being barred from supplying or even blacklisted and terminated. We have in the past conducted investigations into any allegations of non-compliance and provided transparent communication about the results. Thus by engaging with customers and other stakeholders in a transparent and collaborative manner to address concerns and build trust.

8. How does your current traceability system ensure compliance with regulations and industry standards?

To ensure compliance with regulations and industry standards, we collect information about our suppliers' labor practices, we conduct risk assessment of suppliers and their facilities to identify potential areas of non-compliance. We conduct audits and assessments of suppliers' labor practices. We request 3rd party certification to verify compliance with industry standards. If we encounter any potential noncompliance, we immediately take remediation by addressing the issues and suggest corrective action plans and follow-up assessments. Overall, our program is designed to provide visibility throughout the supply chain, enabling our customer to reply on our assurance that our supply chain is free of forced labor practices and potential non-compliance issues while ensure compliance with regulations and industry standards.

Question asked to Mr. Varun Kulshreshtha (Regional Head of TradeLens at Maersk (Structured interview)

1. What are the most important benefits of using blockchain technology for traceability?

I will set the context on what we are doing at TradeLens and how traceability came to be one of the offshoot benefits of TradeLens platform. One of the key use cases was Customs. To do customs, we integrated customs, carrier, and our customer through blockchain. The customer used to publish their packing list and shipping invoice directly on TradeLens, the carrier releases the Bill of Lading directly on the platform and thus based on this information the platform created the export declaration automatically and submit to customs, after which the customs would release a hold / release message.

So, one of our customers, Sea Food Tracing, wanted their customers to know when it was caught, and they had huge challenges in terms of mapping their supply chain. So, this was enabled by a QR code on the package. So, we had to keep track of when did it arrive at the port or when it was discharged, the event information that TradeLens provides supported our customer to trace the entire supply chain, especially when it comes to substances like seafood where traceability really matters and the customer could just scan the QR code to know the date on which the sea food was caught and the location of the catch too.

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But the question about traceability is not a technology question, if you imagine a blockchain where most of the world manufacturing in a particular vertical or industry is part of it and are publishing documents that is authenticated and the data can be trusted. It's so easy to trace not only to the supplier, but to multi-tier suppliers too. The question is more around collaboration and how can you incentivize companies to be part of it. Does it need to be mandated by law, which sort of make it mandatory that everything that coming in needs to supply and have maybe at least two or three degrees of data in it. Thus, it needs some push for parties to collaborate, as right not it is fragmented.

As stated in the previous example of sea food, you can trace your seafood, but then they very soon realized that in the market what is considered fresh and what is not considered fresh is a question mark, you could have caught fish a month before in Vietnam and being shipped to the US and still be in a very good shape because of the cold chain facility. But when the customer sees the date, he is sceptical considering the number of days that the fish too to reach the US, then you're sharing information, which is counterproductive. Thus, transparency creates all sorts of issues. In a lot of examples, we wanted our customer to sign up to a custom system because the customs clearance will be faster, but we realized that transparency is also something that they're not after, because it can be counterproductive. They would like to control and have sort of air gap between what they submit to customs and what's in their systems. Initially it's very easy to sell, but when people start going through and then they realize that hey, what I published in by internal SAP system is exactly what the authorities see. while we were able to convince, big companies to be part of this, I could see that to take this to the next level required a lot more.

2. What are the key challenges to achieving traceability in the supply chain, and how can distributed ledger technologies help address these challenges?

It should not be that difficult if you have all the parties are part of this enterprise blockchain and publishing data on the platform. so, party B buys cotton from several entities, all of them are on the blockchain, They are publishing their commercial invoice. You know that party Bs spend is equal to the value of the commercial invoice of all the entities, so there's no room for them to buy from somewhere else, And if there is, you know that, 20% of their sort of supply is not sort of validated through blockchain and then that creates a question mark, So if for people who want to show that they're complying with the law being a part of blockchain is one of the easiest way to do it and it does not place any owners extra administrative hassle on them. Further the data publish could also be verified from multiple sources, like a trucking company can validate the pickup location of the goods.

Another common use case for trade lines is bank discounting or factoring. Say the cargo has been shipped there have no way of identifying whether that's authentic or not, further the same BL can go to multiple banks, however, if they use the EBL facility in trade lens and linked to actual events be rest assured that this is authentic. This way, along its journey, it's departed,

arrived and that gives you a lot more confidence and prevents a fair degree of fraud around invoice discounting or factoring. So in this example traceability also helps the financial institution to know where the cargo is and thus reduce the possibility of fraud.

3. How would you describe the current state of blockchain based supply chain traceability solutions?

There are efforts being made currently, but their main effort is not around traceability right now. If traceability was to be pursued as a cradle to grave approach, then it is going to be challenging and it depends on different sort of scenarios, but I don't think something like that exists right now but if there is a good use case then it can be built on demand. So, a big retailer as a part of its contract, requires them to sign up to this platform and publish this information then the supplier will align and share the information at a cost. For example traceability has a huge impact on coffee, we have a few coffee customers who are using TradeLens in Europe around that to identify single origin, double origin coffee. Thus, of all the available technologies at this point, the answer to how can traceability information be shared across the supply chain while being trusted then that is possible only through blockchain based technology platform, it is tailor made of solving this problem. But the thing is, to get enough people to use it and collaborate.

4. What challenges do you think you may face when implementing blockchain based supply chain traceability solutions?

The first thing is around trust and who is implementing the solution, parties prefer a neutral organization as the implementer who does not have any interest in the data that is being published to the platform and is compliant to all the data sharing role laws that exist all over the world. So, say if it's an American or a Chinese entity, there are lot of parties in the world not trusted and so may not sign up on such a platform. Blockchain based solution will only work if everyone is part of the platform. The entire sort of supply chain ecosystem including all stakeholder must subscribed to the platform.

Second challenge is around creating common standards. That common standard cannot be only for traceability. Traceability needs to be a by-product. The main push needs to be around digitization of the supply chain and all the records.

Third is the legal recognition around these documents and supply chain records that are being digitised. Currently these are not legally viable. So, a law must be there to formally recognize digital documents to be legally valid, as currently this does not exist there is no incentive to digitise the supply chain.

There are many use case for block based traceability, sea food is just one of them, Bangladeshi fish end up being Vietnamese fish, Chilean seabass comes from Oman, Scottish salmon is coming from Japan, such frauds can be eliminated to a significant extent if the supply chain is digitised and thus traceability within the supply chain improves.

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If the sole focus is on traceability, then that may result in negative consequence. So just to do traceability, I think it will be difficult to convince or incentivize firms to be a part of it. if the emphasis on digitization that has positive consequences and like efficiency, speed, lower cost, yeah, transparency, more trust, then traceability can be a sort of tangential benefits out of it and a important one.

5. What advice would you give to companies looking to use blockchain traceability solutions?

If a company is looking for blockchain based traceability solution right now, then I don't think such a solution exists, but traceability can be a by-product of the entire supply chain digitisation platform. They may have to build one or they can borrow parts from some existing blockchain, so they are entities like bolero that are trade finance companies which have some data already. Also, there are solutions in the market offering event management and documentation digitization. All this will require significant investments from all the participants. The biggest hurdle will be around integration, especially as very small companies require IT effort, in addition to the cost It may be beyond the capability of lot of entities.

Also, the entities in the supply chain must be incentives to participate, other benefits around efficiency, productivity, safety, robustness, Sustainability and then traceability needs to be factored as a by-product.

It'd be difficult to for any entity, which is domiciled in any country, any specific government to have an effective traceability solution.

Also, information can be weaponized. Tracing blood diamonds to oil to cotton, people will be inherently suspicious around those motives.

6. What do you think are the most important considerations when designing a blockchain traceability solution?

Its data exchange, so authentication of the parties on the platform, specific types of data do you need to ensure that the data shared in accurate and authentic. whether that can be provided by generally available commercial documents

7. How do you think blockchain traceability solutions can be used to improve supply chain transparency?

Currently traceability is based on paper-based approach, which is audited, in this case you have certain authority publishing or giving you certificates. Such situation can be improved with the help of blockchain based traceability solution. Blockchain has been made to solve some problems like this, the fact that all the parties in the authenticated it's a distributed Ledger is democratization of information, records cannot be changed once published unless if they are changed as audit trail maintained.

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8. What do you think the future of blockchain traceability solution could look like?

Currently, Even the legal requirements around traceability are nebulous. So, it is important to set up global standards, Defining legally the requirement for traceability. Then based on that standard and legal framework providing a platform which becomes the convention and the norm in industry. An industry wide consensus that has been reached upon as we have on many other aspects of global trade is must to envision the future of blockchain based traceability solution.

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