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MASTER'S THESIS

The Role of Blockchain Technology application in Supply Chain Management

Funkce technologie blockchain s důrazem na Supply Chain Management

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Study programme: Innovation Project Management

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MASTER'S THESIS ASSIGNMENT

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Guidelines:

The aim of the thesis will be to present an analysis of the current state and opportunities of blockchain technology from the perspective of a company in the field of Supply Chain Management. The thesis is written in the first person plural. The method of compiling is primarily analytical-synthetic and also inductive-deductive. The individual parts of the work are interconnected. The structure of the work corresponds to the title of the thesis, the aim and the benefit of the work. The thesis consists of the following sub-parts: 1) Introduction, 2) Theoretical part, 2a) Literature review, 2b) Research gap, 3) Empirical part, 3a) Description of three selected Case studies from the field of SCHM, 3b) Own cost benefit analysis of the project , 3c) Discussion of results, Conclusion and recommendations, Literature

Bibliography / sources:

Cole, R., Stevenson, M., & Aitken, J. (2019). Blockchain technology: implications for operations and supply chain management. Supply Chain Management: An International Journal, 24(4), 469-483.
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Abstract

Master's thesis focuses on the transformative potential of blockchain technology within supply chain management. The aim of the thesis is to present an analysis of the current state and opportunity of using blockchain technology from the point of view of a company, from the field of supply chain management. In the theoretical part, the reader is introduced to blockchain's fundamental features, current challenges faced by supply chains, and to the profound impact that blockchain technology has on supply chain operations. The practical part includes analyses of three diverse use cases examining the impact of blockchain technology on supply chain processes. Following expert interviews providing valuable insights from field experience, the paper proceeds with a decision tree analysis, PESTEL analysis, qualitative cost-benefit analysis, and SWOT analysis. These analyses provide diverse perspectives, ensuring a comprehensive evaluation of blockchain technology utilization within a company's supply chain. This thesis serves as a valuable resource for companies in the supply chain sector, as it provides strategic insights for utilizing blockchain to optimize operations and gain a competitive advantage, by enhancing transparency, improving traceability, reducing costs, and facilitating trust among stakeholders.

Keywords

Abstrakt

Diplomová práce se zaměřuje na transformační potenciál technologie blockchain v rámci řízení dodavatelského řetězce. Cílem práce je předložení analýzy současného stavu a příležitosti využití technologie blockchain pohledem firmy z oblasti řízení dodavatelského řetězce. V teoretické části se čtenář seznámí se základními rysy blockchainu, aktuálními výzvami, kterým dodavatelské řetězce čelí, a s hlubokým dopadem, který má technologie blockchain na operace dodavatelského řetězce. V praktické části je provedena analýza tří různých případů použití, která zkoumá dopad technologie blockchain na procesy dodavatelského řetězce. Po rozhovorech s odborníky, které nabízejí cenné poznatky získané ze zkušeností v oboru, je provedena analýza rozhodovacího stromu, PESTEL analýza, kvalitativní cost-benefit analýza, a SWOT analýza. Tyto analýzy nabízejí různé perspektivy, a umožňují komplexní posouzení využití technologie blockchain v rámci dodavatelského řetězce společnosti. Tato práce slouží jako cenný zdroj pro společnosti v sektoru dodavatelského řetězce, protože poskytuje strategické poznatky pro využití blockchainu k optimalizaci operací a získání konkurenční výhody prostřednictvím zvýšené transparentnosti, lepší sledovatelnosti, snížení nákladů a budování důvěry mezi všemi zainteresovanými stranami.

Klíčová slova

Blockchain, dodavatelský řetězec, decentralizace, transparentnost, sledovatelnost, efektivita.

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List of abberviations

SC   Supply Chain

BT   Blockchain Technology

SCM   Supply Chain Management

P2P   Peer-to-Peer

PoW   Proof of Work

PoS   Proof of Stake

4IR   Fourth Industrial Revolution

AI   Artificial Intelligence

IoT   Internet of Things

DeFi   Decentralized Finance

GDPR   General Data Protection Regulation

US   United States

FDA   Food and Drug Administration

RFID   Radio-Frequency Identification

M2M   Machine-to-Machine

IBM   International Business Machines Corporation

OpenSC   Open Supply Chain

H&M   Hennes & Mauritz AB

NFT   Non-fungible Token

EY   Ernst & Young Ltd.

ANSA   National Associated Press Agency

S.D.L   Süddeutsche Leasing AG

ESG   Environmental, Social, and Governance

PPU   Pay-Per-Use

EBS   ELA Blockchain Services a.s

ETD   ETD Transformers Inc.

ROI   Return on Investment

ROI^2 Return on Investment into Innovation

Introduction

In today's interconnected global economy, supply chains (SCs) face numerous challenges that impact their efficiency, and resilience. These obstacles emerge from the management of numerous suppliers, complexity of SCs, a diverse range of products, changing customer preferences, and a growing emphasis on environmentally sustainable product choices. In response to these challenges, blockchain technology (BT) has emerged as a promising solution. With its potential to revolutionize existing systems and processes, blockchain offers a decentralized database structure that extends beyond financial systems, facilitating secure and reliable data sharing among SC stakeholders. This transformative technology has the capacity to fundamentally change how SCs operate across different sectors, by introducing a transparent and decentralized ledger system that securely records and verifies transactions across the entire network.

The objective of this thesis is to analyze the current state and opportunities for leveraging BT from the perspective of companies operating in supply chain management (SCM). Through an exploration of potential applications and implications, this research aims to enhance understanding of how blockchain can improve the efficiency, transparency, and resilience of SCs in today's dynamic business landscape. The thesis begins by presenting key principles and features of blockchain to provide a foundational understanding of its operation. Then it explores the potential applications of BT across various sectors, shedding light on its versatility. Additionally, the thesis addresses current challenges encountered in SCM, and how blockchain can offer solutions to these barriers. Subsequently, three case studies are presented to showcase real-world examples of companies that have successfully implemented BT in their SC operations. Furthermore, insights from expert interviews within the field are incorporated that offer valuable perspectives and practical understanding of blockchain's adoption and implementation. Finally, the thesis concludes with a comprehensive analysis section, which will include a decision tree analysis, PESTEL analysis, qualitative cost-benefit analysis, and SWOT analysis. This analytical framework provides a structured approach to evaluating the potential risks, benefits, and considerations associated with integrating BT into SCM practices. Through the adoption of blockchain, companies stand to improve traceability, streamline efficiency, build trust among stakeholders, enhance customer loyalty, and ultimately, secure a competitive edge within their industries.

THEORETICAL PART

1 Blockchain Technology

This chapter will focus on explaining the fundamentals and the basic principles of the blockchain technology (BT). It will also include the foundational and technical aspects of this technology. At the end of this section, some opportunities and challenges that the BT brings will also be specified.

1.1 The concept of blockchain technology

The origin of this technology goes back to year 2008, when a pseudonymous person called Satoshi Nakamoto introduced a new protocol for a decentralized electronic cash system that operates on a so-called peer-to-peer (P2P) network, utilizing a digital currency named Bitcoin. This protocol formed the base for a distributed ledger that is known now as blockchain. Blockchain was implemented for the first time in 2009 as the underlying technology for cryptocurrency Bitcoin and this is blockchain's most widely recognized implementation. As complicated as it may seem, the idea behind its use is very simple. It basically enabled two individuals to transfer money securely, and directly without the need of any company, bank, or even PayPal, (Tapscott and Tapscott, 2018, p. 5).

Blockchain is an immutable electronic record, that is decentralized. It works as an alternative to the current centralized systems, which have to rely on intermediaries. This open source technology eliminates third-parties, and a collective verification of the entire network, works as the intermediary, (Bradley, 2016). Blockchain is a distributed ledger (database). In essence, it is a chain of interlocked blocks that serves as a digital record for transactions using cloud technology. It is extremely challenging to change, delete or reverse transactions once they have been incorporated into the blocks, (Zheng et al., 2017). A survey that was conducted by the World Economy Forum in 2016, showed that a significant portion of professionals and experts within the information and communications technology sector anticipated that, by the year 2025, at least 10% of the global GDP will be recorded on blockchain platforms. Furthermore, blockchain will transform how individuals and companies engage, how businesses collaborate with each other, it will enhance transparency of organizational processes, and it will also have an impact on the productivity of economy as a whole, (Grewal-Carr and Marshall, 2016).
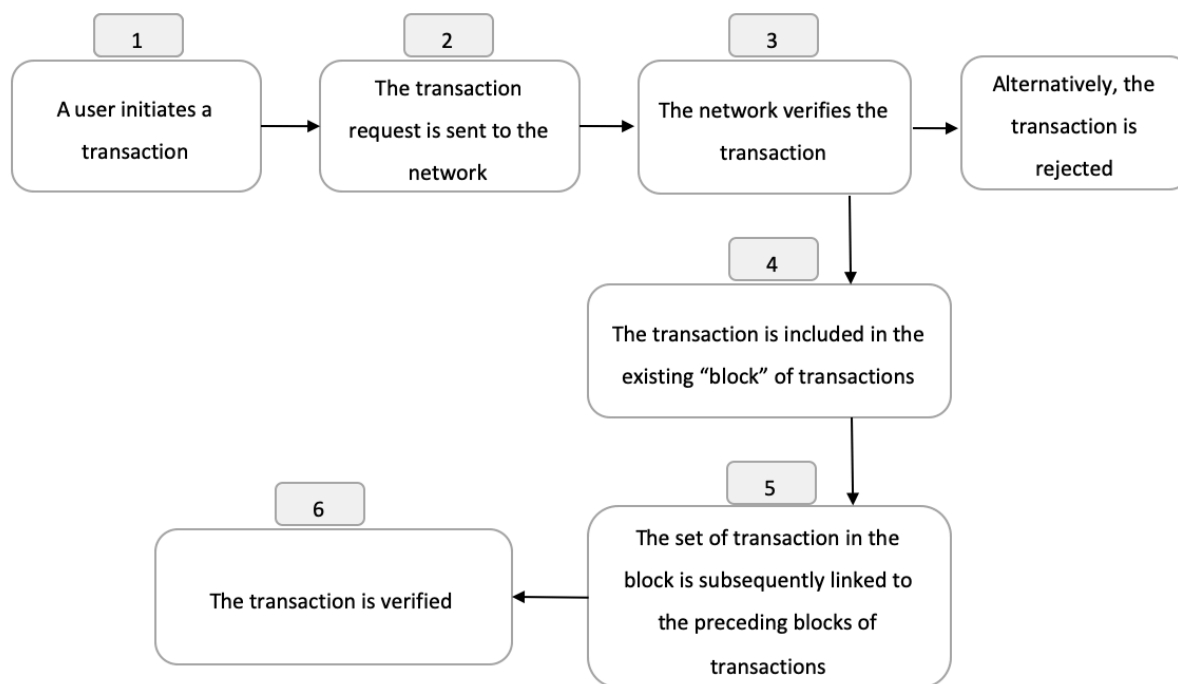
FIGURE 1: TRANSACTIONS PROCESS IN A BLOCKCHAIN, (LAURENCE, 2017); SOURCE: AUTHOR.

1.2 Blockchain's main principals and features

According to Laurence (2017, p. 10), blockchain is created of the following three main parts: blocks, chain, and network. The blocks serve as a place where transactions are logged into a database within a specific timeframe. The dimensions, timeframe and events that trigger the creation of each block are determined based on the blockchain's purpose and these parameters may differ between different blockchains. Additionally, replications of blocks across the whole network is carried out in order to enhance the security and the reliability of the blockchain and also to ensure that all participants have access to the same information. Laurence additionally defines the chain as a link that is created through a process called hashing, which uses data and information from the previous block in order to create a unique fingerprint securing the block in a specific time and order. So basically, hashing could be understood as a digital fingerprint that locks data within the blockchain. Laurence (2017, p. 10–11), further states that the network consists of nodes. In simplified terms, a node is a device such as a computer, or a server that plays and important role in the functioning of a blockchain, and each node holds a full record of all transactions that have ever been documented within a particular blockchain.
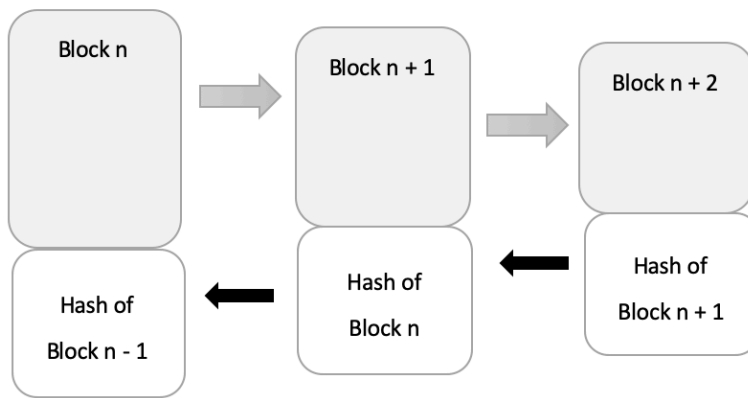
FIGURE 2: BLOCKCHAIN PROCESS THROUGH HASHING, (PAL ET AL., 2021); SOURCE: AUTHOR

1.2.1 Types of blockchain

In accordance with Buterin (2015), blockchains can be categorized into three different groups: public, consortium, or private.

- **Public blockchain**: this type is open to everybody globally for reading the transactions that are taking a place in the network, and everybody can participate in sending transactions or verifying them. Public blockchains for examples serve as the foundation for cryptocurrencies.

- **Consortium blockchain**: this type of blockchain exhibits features from both public and private blockchains. The decision-making regarding the validation and agreement on transactions within this type of blockchain can be managed only by a pre-selected group of nodes, typically representing different organizations or entities.

- **Private blockchain**: is when participants that have the permission to reading the transactions are limited. The permission may even be limited to a single organization, and such blockchains can be applicable in companies' internal processes such as database management or auditing.

1.2.2 Tokenization

According to Arun et al., (2019, p. 70–71), tokenization is the process of transforming assets or rights to an asset into a digital representation (a token) within a blockchain network. Essentially, it is a creation of a digital twin of a physical good or product. While blockchain provides the ability to trust and facilitate exchanges, within a given network, the importance of asset tokenization lies in the digitization of these assets' value. Ownership of anything (or a fraction of ownership) can be tokenized

and stored on the blockchain for example diplomas, medical records, or good moving through the SC. Asset tokenization carries a number of challenges, which include the following:

- Ensuring a smooth and continuous connection between the movement of a physical asset and the its digital twin.

- Ensuring each token's capability to securely transfer of maintain its value.

- Ensuring the confidentiality of tokens.

- Ensuring a securely transfer to other networks without the change of token's value.

- Keeping the token's life span up-to-date

- Effectively managing a token's existence and duration in a business network.

All the above challenges can be effectively resolved by implementing a well-designed solution that incorporates BT, which will secure and guarantee the value, integrity, and individuality of every token in a network.

1.2.3   Opportunities that blockchain technology brings

One of the primary challenges in business that consistently persist is the issue of trust. In numerous scenarios, potential partners lack or possess minimal trust, which plays a crucial role for when two or more parties want to successfully engage in business transactions. The transformative change that is being introduced by blockchain represents a new approach to establish trust among parties. This shift revolutionizes the way people will do business, and blockchain currently presents numerous opportunities for a number of different industries. It opens the door to a collaborative P2P economy, whilst encouraging intermediaries to reevaluate and reshape their business models and business processes, (Arun et al., 2019, p. 19–20).

Furthermore, there five main elements that make BT a game-changer for the business world according to Arun, et al (2019, p. 20–25).

- **Transparency**: blockchain offers a complete visibility into business transactions, utilizing a single, universally accepted source of truth that is duplicated and distributed across the ledger within a network, which provides an access to a complete transactional overview by all parties that have access to the network. Historically, such transparency was absent in business structures that involved numerous participants. Additionally, the transparency of this technology allows a direct P2P connection within complex networks that involve manufacturers, retailers, and distributors.

- **Immutability**: once a transaction is recorded into the blockchain it becomes immutable, and no one has the capability to delete it. Each transaction is recorded into a block, which is linked to the previous block and will be linked to the block that comes after it, and this forms an immutable chain and permanent. This unchangeable history of transactions serves as a shield that addresses the challenges that are for instance related to counterfeiting that businesses commonly face.

- **Security**: each transaction that is documented within a blockchain is protected with a digital signature, which results in providing an exceptionally secure transaction system that is extremely resistant to hacking. Every participant in the network possess a private key that is assigned to each occurring transaction or any updates to existing transactions. This individualized key system provides a better security system for the whole network. Additionally, every transaction is replicated and shared across the network, and as a result, potential hackers would need to examine every ledger in order to locate the exact data report across all ledgers, which is unquestionably a difficult task. Therefore, this multi-layered approach significantly enhances the security and resilience of every blockchain network against unauthorized access or tampering.

- **Consensus**: in order to reduce the dependency on a central authority when validating business transactions, a consensus mechanism is used, and this mechanism refers to a system by which all participants of the network agree on the legitimacy of a transaction without the need of a third-party approval.

- **Smart contracts**: automated and electronic agreements that articulate the juridical and business terms and conditions between partners. They are contracts that are stored on the blockchain and can be programmed to contain predetermined conditions and are automatically executed when these conditions are met, which essentially saves costs, and reduces the contract execution time.

"Smart contracts fuel business process innovation with automation, speed and compliance without hefty costs and risks", (Arun et al., 2019, p. 24). The following chart illustrates the step-by-step process of how a smart contract operates, beginning with its creation and concluding with its execution.
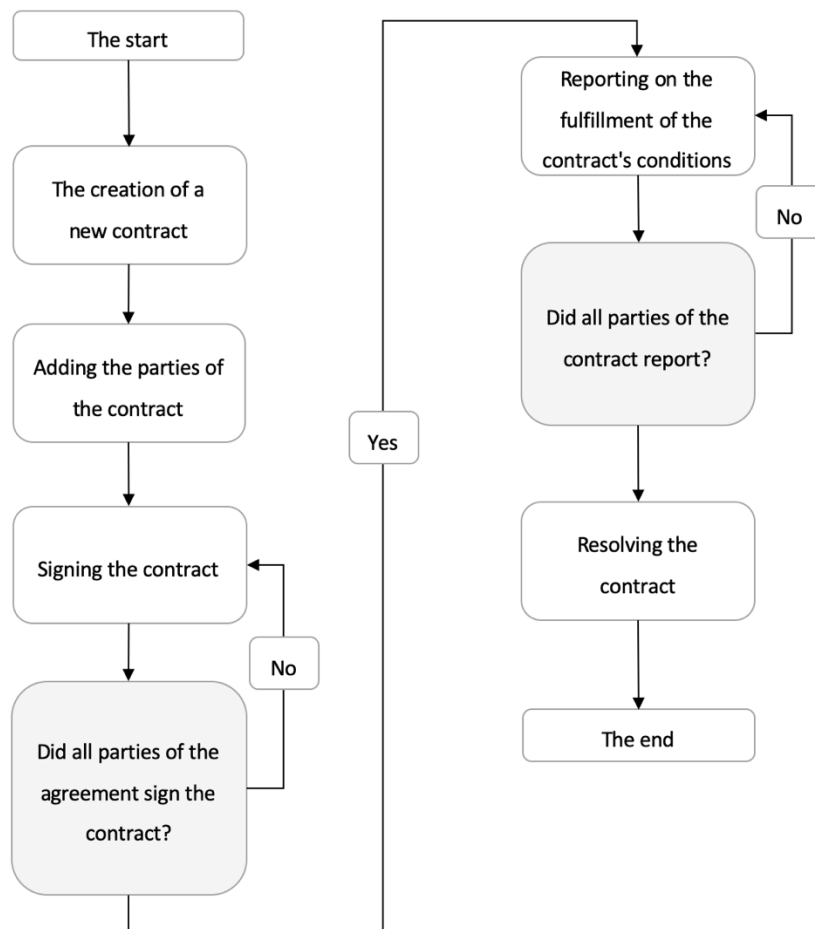
FIGURE 3: FLOW CHART OF A SMART CONTRACT, (ROŽMAN ET AL., 2019); SOURCE: AUTHOR

1.2.4 Consensus mechanism

"Consensus drives fair participation in a business network with democracy", (Arun et al., 2019, p. 23). A consensus mechanism is a core element of BT, ensuring that all members of a network reach consensus or a general agreement on the legitimacy of every transaction and the current status of the ledger. It defines how network participants, known as nodes, reach a collective decision on which transactions are valid and should be added to the blockchain. This mechanism guarantees that every node in the network gains a mutual understanding of the present condition of the blockchain, because nodes communicate with each other in order to preserve the decentralized ledger. There are several approaches to achieving consensus in blockchain networks. Some of the most common consensus mechanisms include Proof of Work (PoW), and Proof of Stake (PoS), (Zheng et al., 2017). For example, in cryptocurrencies that are built on a public blockchain, like Bitcoin, miners validate transactions through a process PoW. Those miners compete to solve complex mathematical puzzles, which require substantial computational power and energy. The competitive nature and effort involved in mining

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makes it exceptionally challenging for anyone to manipulate the history of the blockchain. Doing so would necessitate exceeding the collective computational capabilities of all genuine miners, a task that is highly improbable. Consequently, PoW serves as a foundation for ensuring security and instilling trust within the cryptocurrency network. On the other hand, permissioned blockchains involve trusted participants who validate transactions through consensus algorithms without the need for mining. This results in lower computing power and energy costs compared to public blockchains, (Arun et al., 2019, p. 23). Unlike the PoW system where miners compete to create new blocks, PoS operates differently. In a PoS model, nodes are chosen to validate transactions and generate new blocks based on the quantity of cryptocurrency they possess, which is referred to as their stake in the network. This approach aims to reduce energy consumption by eliminating the need for intensive computational work. Therefore, PoS is often considered a more energy-efficient alternative to PoW, (Laurence, 2017, p. 53).

1.3 Challenges associated with blockchain adoption

Even though BT has the ability to positively influence businesses in many ways, its implementation brings some challenges that need to be taken into account. Understanding the challenges associated with this technology is important in order to mitigate risks and overcome the barriers that they may bring. According to Upadhyay (2020), following are some of the most concerning challenges. The first challenge is the lack of awareness about the actual use of this technology and lack of understanding of how it functions. Not many businesses have adopted blockchain and the ones that did, do not share many of insights and details about the challenges that they have faced for confidentiality reasons, which makes it difficult to fully understand the short-term and the long-term implications that early adopters may face. This lack of certainty also includes the risk that organizations have to take for not having an upfront clear idea about the costs of running this technology. Additionally, it is critical to consider how well this new innovation will interact with the existing systems the company uses. The second part of the challenges is tied to security and privacy. It is crucial to find the balance between transparency and confidentiality. Blockchain's transparency ensures that all transactions are visible to all participants, which can be advantageous for trust and accountability. On the other hand, this transparency also poses challenges for protecting sensitive and confidential information. Another challenge that needs to be addressed is how to deal with end-user errors. Additionally, there is a shortage of skilled people who understand this technology and who are able to utilize its full potential. Also, the legal interpretation of self-executing smart contracts between participating parties are not yet clearly defined. Scalability is also a significant challenge, because some organizations may need a large number of transactions, which exceed the blockchain's capacity, and

this leads to a slowdown in the overall process. For instance, the Bitcoin blockchain can currently handle only seven transactions per second, making it unsuitable for real-time transactions, especially when considering that some organizations may need a million transactions per second.

2 The blockchain revolution

This chapter will delve into the transformative impact of BT within the context of the Fourth Industrial Revolution (4IR) and its potential to disrupt traditional business models across various industries. Blockchain, alongside other innovative technologies driving the 4IR, is positioned to revolutionize how businesses operate in the 21st century. Understanding the role of BT in various industries such as finance, agriculture, and manufacturing is crucial before delving into its specific application in the SC.

2.1 Blockchain and 4IR technologies

According to Schwab (2016, p. 11–12), the 4IR does not only represents a global technological shift, where physical and virtual machines are able to communicate, and flexibly cooperate with each other, but this shift also extends beyond technological advancement, as it is an economic and societal change and a transformation of humankind. This fusion of technologies is going to bring profound development to various industries, and this change is characterized by a number of key technologies including BT, artificial intelligence (AI), Internet of Things (IoT), along with others. He also indicates that the 4IR brings four key influences on businesses across various sectors. Firstly, customer preferences are evolving due to shifts in expectations regarding products and services. Secondly, improved products through data integration. Thirdly, the creation of new partnerships as a result of organizations recognition for the importance of innovative collaborations, and fourthly a transition from traditional operating structures to modern, digitally-driven models that are more effective and efficient, (Klaus, 2016, p. 54–59). BT is related to these changes as it enables transparency by recording SC data, facilitates data integration and improvement through secure storage and sharing of data. It also supports innovative collaborations, by automating and enforcing agreements between partners.

First and second industrial revolutions gave rise to centralized networks, where power was concentrated in specific centers. The third industrial revolution introduced decentralized networks, distributing control among several central hubs. In contrast, the 4IR operates on a decentralized network, where each connection point holds equal power, as illustrated in Figure 4. This decentralized structure leads to increased interconnectedness among individuals and organizations, (Lee et al., 2018).
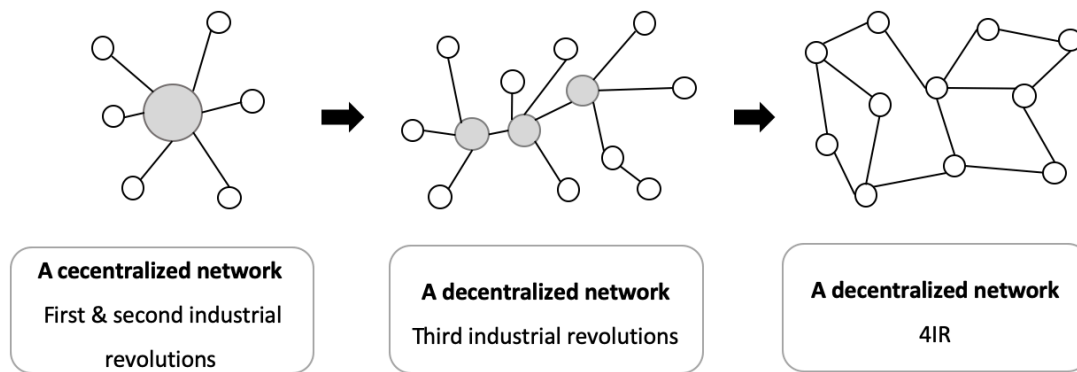
FIGURE 4: NETWORKS THROUGH INDUSTRIAL REVOLUTIONS, (LEE ET AL., 2018); SOURCE: AUTHOR

2.1.1   Blockchain and the Internet of Things

Unlike previous revolutions, the current one is progressing at an unprecedented pace, marked by rapid advancements in technologies such as the IoT and blockchain. Over a billion connected intelligent devices are currently integrated with the IoT and the number of these devices is increasing every day. The progress of the IoT allows industries to capture data from various devices, derive insight from the data and then make decisions based on the gathered and provided information. However, the main deficiency of this process has is that it the origin of the data may not always be transparent or verifiable. Decisions based on unverified data raise concerns about the reliability and accuracy of it. IoT and blockchain together have the potential to bring transparency and instill confidence to the data that is gathered through random devices, (Arun et al., 2019, p. 170–171). Additionally, BT brings people the ability to recognize smart devices carrying essential core information and programming them to operate within specified conditions without the potential for errors, tampering, or shutdowns. Due to the blockchain's incorruptible ledger, users can trust the accuracy of the data, (Tapscott and Tapscott, 2018, p. 152–153). Smart devices are increasingly being used in SCM to improve efficiency, visibility, and decision-making. IoT that is powered by BT bring this new network a number of features according to Tapscott and Tapscott, (2018, p. 154–155):

- **Resilient**: as having the ability to self-correct with no single point of failure.

- **Robust**: being capable of handling very large number of transactions (billions).

- **Real-time**: operational 24/7 with instant data flow.

- **Responsive**: adaptive to change of conditions.

- **Radically open:** being continuously evolving.

- **Renewable**: being multipurposed, reusable, as well as recyclable.

- **Reductive**: minimizes costs while maximizing efficiency and effectiveness.

- **Revenue-generating**: creating new business models and bringing new opportunities.

- **Reliable**: ensuring the security and accuracy of data.

2.1.2 Blockchain and robots

Various industries, including the SC, employ robots for their operations. Studies indicate that robots that get hacked have the potential to be reprogrammed leading to undesired actions, hazardous behaviors, and in this situation, they get the ability to violate the safety feature that they have been equipped with. Therefore, it is very important in the era of technological progress, not only to focus on the positives that the robots bring, but also not to forget about the harm that they could potentially cause, (Ferrer, 2023). Ferrer further states that the above-mentioned issues can be limited by using BT when dealing with robots. Smart contracts can be used to automate transactions, as they are able to effectively secure the coordination of a group of robots. For example, when a smart contract-based robot was programmed with intention to disrupt other robots of the group, this faulty robot ended up becoming neutralized without the need of a human intervention. This demonstrates the capability of smart contracts to enhance security and coordination among robotic systems that are utilized across various industries within the SC.

2.2 Blockchain revolution reshaping industries

This chapter will delve into the profound impact of blockchain on sectors ranging from finance and agriculture to healthcare and beyond.

2.2.1 Blockchain technology and reinventing financial services

Blockchain has prompted a bigger in-depth discussion about how much governments should be involved in keeping an eye on the financial services industry. Retail banking currently revolves around a few key functions. Firstly, it serves as a secure place to store money. Secondly, it offers a platform for conducting financial transactions, a sort of payment utility. Additionally, it extends credit, offering opportunities to grow wealth and generate income. Just as the emergence of internet revolutionized information services, the blockchain is poised to revolutionize financial services, and reinvent people experience with money handling, (Tapscott and Tapscott, 2018, p. 71). The benefits that blockchain brings to the financial industry are numerous and among them are for examples, that transactions can be conducted within seconds instead of minutes or even days as some financial institution require especially for cross-border transactions that may involve several intermediaries.

Additionally, the transaction costs are significantly lower compared to the high fees charged by banks and traditional payment processors, especially in the case of cross-border transactions, (Tapscott and Tapscott, 2018, p. 5). In the rapidly evolving landscape of digital currencies and BT, Bitcoin and Ethereum stand out as pioneers. Each of them introduces distinctive innovations to the decentralized landscape. Bitcoin is the first created cryptocurrency in the world and it operates on the world's first public blockchain. Its fundamental purpose is to allow individuals to receive and send value to anyone in the world by only using internet and computers. It is revolutionary; unlike other methods of transferring money, which require intermediaries. Bitcoin operates without the need for a middleman such as banks or other similar entities. It is public, it operates on a decentralized network of computers, which means that no central authority or government controls it. Unlike traditional fiat currencies, Bitcoin has a maximum supply, and the total number of bitcoins that can ever be created is capped at 21 million, (Tapscott and Tapscott, 2018, p. 5–6).

Ethereum holds the position of the second-largest cryptocurrency, and it was introduced for the first time by Vitalik Buterin in 2014. Ethereum introduced the groundbreaking concept of smart contracts, (Schär, 2021). Smart contracts have a profound impact on the finance industry, introducing transformative changes across various aspects of financial operations. They offer the potential for parties to secure agreements that are automatically executed. In these agreements, parties can, for example, exchange Ethereum as soon as the specified contract terms are met. Through their automated execution of contract terms, smart contracts eliminate the need for intermediaries, which leads to significantly speeding up financial transactions, while reducing operational costs. These contracts operate on decentralized blockchain networks, ensuring a high level of security and transparency in financial operations. The transparency of actions that are recorded on the blockchain result in building trust among parties involved in transactions, (Tapscott and Tapscott, 2018, p. 101–102). This BT has given rise to a new financial infrastructure, that is called Decentralized Finance (DeFi). DeFi is built upon the Ethereum blockchain infrastructure; it utilizes smart contracts to create protocols mirroring traditional financial services whilst offering heightened openness, interoperability, and transparency. DeFi replicates current financial services through the creation of decentralized protocols that mimic traditional financial activities. For example, DeFi platforms allow users to borrow assets or lend their assets and earn interest mirroring activities such as traditional bank loans. Moreover, decentralized exchanges allow individuals to directly trade cryptocurrencies, which replicates the process of buying or selling securities, (Schär, 2021).

2.2.2 Blockchain technology potential use in the healthcare industry

Recently, there have been significant changes in the healthcare industry, especially regarding the management and handling of data. The transition from paper-based records to electronic health records has been a notable development. The internet has played a transformative role in shaping various aspects of healthcare, bringing new advancements in communication, information access, research, and patient care. However, challenges like data interoperability, security, and privacy concerns still persist. According to Alladi et al., (2019), BT has the potential to facilitate an efficient sharing of crucial patient data in the healthcare sector. This could lead to improvements in the delivery of healthcare services, such as minimizing the risk of patient mismatches and decreasing errors in patient care. Furthermore, it can enhance interoperability in the healthcare sector and its applications in providing secure access to patient medical files as well as in managing diseases through the IoT. Alladi et al., (2019), outline the features of BT in healthcare as follows:

- **Enhanced interopretability**: blockchain has the ability to improve the seamless and secure exchange of health-related data and information among various stakeholders, systems, and applications within the healthcare ecosystem.

- **Blockchain-enabled IoT in healthcare**: an example of this is represented by wearable medical devices that are designed to measure certain key physiological signs and provide feedback.

- **Clinical drug monitoring**: blockchain can be utilized for tracking tested medications during examination phases. The adoption of blockchain significantly reduces the risk of manipulated results, establishing a dependable and transparent methodology for assessing the performance of drugs during the investigative phase.

2.2.2.1 Current research initiatives

Current investigative studies in the healthcare sector are currently examining two distinct areas related to BT. Firstly, issues related to healthcare data administration; a notable challenge in handling patient records arises from the tendency of individuals to spread their health information across different healthcare providers. Blockchain plays a crucial role in establishing a framework for sharing data while ensuring the reliability and security of the information. As a result, healthcare providers will be able to collect information from patients, encompassing details such as personal information, prescribed medications that they have been taking, and past medical procedures that they underwent. Patient data is subsequently stored on cloud, which undergoes a cryptographic hashing process, essentially creating a digital fingerprint for that specific set of information, (Alladi et

al., 2019). Secondly, in regards to medications traceability, BT plays a crucial role when it comes to ensuring the traceability and authenticity of medications. The pharmaceutical industry has been dealing with a significant challenge of counterfeit medication. It is estimated that approximately 10% to 30% of drugs that are being sold in the developing world are deliberately or fraudulently produced to mimic genuine pharmaceutical products. This poses a serious risk to patients that consume counterfeit drugs, as these fraudulent medications could fail to effectively treat the intended disease or condition. The tracking capability that blockchain brings, allows monitoring the movement of medications from production facilities to distribution centers, pharmacies, and ultimately to patients, (Alladi et al., 2019).

One of the biggest challenges that needs to be taken into consideration is that when implementing a healthcare blockchain, it is necessary to have compliance with the legal requirements mandated by the General Data Protection Regulation (GDPR) of the European Union. According to this regulation, patients will soon have the right to request the deletion of their healthcare-related data if they would like to, which directly conflicts with the foundational principles of BT that once a transaction or data entry is recorded on the blockchain and validated by network participants, it becomes a permanent part of the ledger and cannot be altered or removed. Moreover, storage of data is also considered challenge that needs to be addressed, because medical data, especially over a person's lifetime, can accumulate to vast amounts of information, including medical history, treatments, test results, prescriptions, and even the inclusion of medical images and scans, which consume significant storage space, (Alladi et al., 2019). While BT offers potential advantages such as enhanced data security, interoperability of information, transparency, and decentralized control, there are also challenges and limitations to be addressed, including scalability, regulatory compliance, and privacy concerns. A crucial aspect to consider is the fact that blockchain has the potential to save lives by enabling seamless access to comprehensive and up-to-date patient data across healthcare facilities. Which would be useful particularly in emergency situations, where quick access to critical medical information is important. BT can enable healthcare providers to access the necessary data, such as allergies, medical conditions, and recent treatments, regardless of where the patient was previously treated.

2.2.3 Blockchain technology potential use in the manufacturing industry

The manufacturing industry is undergoing significant changes as it transitions towards smart manufacturing. Those changes are driven by technological advancements, shifting consumer demands, and evolving global trends. According to Jamwal et al., (2021), the development of smart manufacturing involves the adoption of digital innovations such as AI, the IoT, big data analytics, and

automation to enhance efficiency, productivity, and flexibility in manufacturing operations. The core of smart manufacturing lies the principle of fostering connectivity among diverse manufacturing units, facilities, suppliers and machinery. Currently the interconnectivity of various IoT systems faces a challenge due to the fact that those systems operate separately, but are also expected to interact seamlessly with other systems without compromising sensitive data. BT offers a potential solution to this dilemma by enabling secure communication between IoT systems while preserving data privacy, (Lohmer and Lasch, 2020). It is important to consider that, with increased digitization, cybersecurity threats have become a growing concern, (Leng et al., 2021).

BT provides new solutions for addressing sustainability concerns, security issues, operational efficiency, and system resilience. By offering transparent and decentralized transaction systems, blockchain enhances traceability and transparency within manufacturing networks, thus contributing to their overall sustainability. By creating an immutable ledger of shared transactions among all network participants, BT can provide real-time transparency in manufacturing. This transparency enables better visibility into the entire manufacturing process, allowing for quicker identification of issues, improved collaboration, and more efficient decision-making, (Jamwal et al., 2021). According to Leng et al. (2021) the effectiveness of utilizing BT in the manufacturing can be evaluated from the following four criteria:

- **Cybersecurity**: blockchain offers a resilient and robust method for managing distributed records on the Internet. The sequential connection of data blocks in a chain structure safeguards this shared ledger, preventing tampering through cryptographic means. This ensures manufacturers secure product designs, confirm and verify the authenticity of different components, and make decentralized decisions.

- **Decision architecture**: implementing BT brings better data coordination and flexibility, which is necessary for reducing the complexities in controlling dynamic manufacturing processes. Furthermore, the integration of smart contracts promotes collaborative interactions among machines used in manufacturing.

- **System performance**: blockchain's transparency enhances the security of transactions while lowering the expenses associated with transmitting data or information securely between different entities.

- **Trust enhancement**: by include immutable record-keeping, decentralized sharing of data and blockchain's traceability features that enable the tracking of products and components.

Manufacturers dealing with multiple suppliers and numerous production facilities confront the challenge of interoperability, further complicated by stakeholders participating in various blockchain networks. Ensuring seamless integration across these diverse blockchains necessitates standardization and interoperability among various blockchain implementations, which presents a serious challenge that need to be addressed in order to facilitate seamless communication, data exchange, and collaboration between diverse blockchain networks, ultimately unlocking the full potential of BT in this industry, (Alladi et al., 2019).

2.2.4 Blockchain technology potential use in the agriculture industry

The 4IR has triggered significant transformations in the agricultural sector, responding to the increasing demand for food production. The traditional agricultural system has become incapable of meeting this demand without the assistance of innovative technological advancements to enhance productivity. This revolution encompasses the integration of digital technologies, automation, robotics, and data-driven approaches into agricultural practices, fundamentally changing traditional farming methods. Incorporating special sensors in farm lands further enhances these transformations, offering unprecedented opportunities for optimizing productivity, sustainability, and efficiency in agriculture, (Ane and Yasmin, 2019). Within the realm of agriculture, farmers have the capability to apply sensors across their fields, overseeing the growth, harvesting, and transportation of crops. These sensors have the ability to gather important data, seamlessly recording it onto a blockchain network through wireless connectivity. In instances of product recalls, farmers would possess the ability to quickly establish a connection to the contaminated goods with comprehensive SC records. This enhanced traceability would enable them to precisely track the path of their produce and evaluate the scope and cost implications of any necessary recall measures, (Nash, 2016).

Implementing BT could significantly enhance transparency across these complex and interconnected SCs. By leveraging blockchain, the entire journey of produce from the farm to the supermarket becomes accessible to all stakeholders, instilling a sense of security and trust among consumers, (Alladi et al., 2019). A research conducted with regards to utilizing BT in agriculture, emphasizing its widely recognized effectiveness in improving traceability within the agri-food sector. Additionally, it discusses ongoing commercial implementations of blockchain solutions. An example of that is AgriBlockIoT, which is a decentralized system that is aimed for improving food traceability, as it combines digital information gathered from IoT sensors with BT, (Alladi et al., 2019). In regards to commercial implementation, another platform that utilizes BT has been tested within this industry and it is called iGrow. It is a platform that brings together stakeholders including landowners, farmers, investors, and buyers. It helps farmers in the allocation of resources that they may need, and it enables

the establishment of a robust SC network for organic food, (Alladi et al., 2019). Moreover, one of the most significant challenges in this industry is enhancing product safety. As customers increasingly prioritize quality and safety, meeting their selective choices becomes imperative. To address the growing calls for sustainability and transparency, businesses are gradually adopting BT in the agriculture sector. Even though BT brings a number of benefits to the agriculture industry, it is still not commonly used for a number of reasons:

- Costs related to high initial investments.

- The complexities associated with BT could be discouraging to the introduction of these technologies into the agricultural industry unless compensated by a high return on investment.

- Convincing some farmers to adopt BT may be challenging due to its requirement for open and transparent data.

3 Blockchain in Supply Chain Management

In today's rapidly changing business landscape, SCM plays a pivotal role in the success and competitiveness of companies across various industries. However, traditional SC systems often face challenges related to transparency, traceability, and efficiency. In response to these challenges, emerging technologies including blockchain have gained significant attention for their potential to transform SC operations. This chapter explores the intersection of BT and SCM, examining blockchain's applications, benefits, and challenges.

3.1 Supply chain definition

The origins of SCM date back thousands of years, to the times when civilizations conducted trade and exchanged goods. In its earliest phases, the SC revolved around individuals acquiring resources vital for their survival and prosperity, encompassing basic necessities, shelter, and ensuring the continuation of human race. Over time, SCs have undergone significant transformations driven by the development of new transportation modes. Throughout history, the evolution of transporting goods has undergone remarkable transformations, spanning various modes such as land, water, and air transportation, which resulted in a much faster movement of goods. Currently, the transformation of SC is influenced by different technological advancements, globalization, economic changes, and shifts in consumer behavior.

SCM is a gigantic sector and serves as the backbone of every industry, (Dutta et al., 2020). SC can currently be defined as a complex network consisting of organizations, individuals, operations, data, and assets that are engaged in the seamless flow of a product or service from its original source to the end consumer. Its objective is to efficiently and effectively manage the flow of goods or services, while preserving the quality of sensitive goods throughout the entire shipment process, (Azzi et al., 2019). Additionally, ensuring that the right product is delivered to the right place, at the right time, and in the right condition, while minimizing the costs and maximizing the satisfactions of consumers. SCs have become more complex as the number of intermediaries between the producer and the final consumer has risen, according to Azzi et al., (2019), which makes planning, coordination, and execution across the SC networks a complicated process. Furthermore, sharing information is currently considered one of the most crucial parts of SC, as it is very important for creating a transparent, agile, and responsive SC that can adapt to changing market conditions, minimize disruptions, and deliver value to customers, (Vyas et al., 2022, p. 6–10).

3.2 Current supply chain challenges

In today's globalized and interconnected world, SCs play a crucial role in the success of businesses across various industries. However, modern SCs face numerous challenges that impact their efficiency, resilience, and competitiveness. In this chapter key challenges will be explored; these include addressing data accuracy and reliability concerns, tackling visibility and traceability deficiencies, navigating the complexities of centralized data control, and overcoming obstacles in administrative procedures. By comprehensively understanding and effectively addressing these challenges, organizations can improve their operations, and gain competitive advantage in the market.

3.2.1 Data accuracy and reliability concerns

Over the past few years, numerous incidents have occurred, that resulted in questioning the reliability and dependability of SCs along with the accuracy of data that they include. For instance, in March of 2018, an E. coli outbreak affected more than 200 people in the US. Several investigations where conducted by the public health and regulatory authorities. After three months of researching and investigating, the source and origin of the contamination was finally found; all individuals who were infected, were found to have consumed cos lettuce that had been contaminated through water pollution, (Azzi et al., 2019). Another example that showed the deficiencies in SC occurred in year 2008, when a Healthcare Corporation issued a recall for multiple batches of heparin, which is a blood-thinning drug, due to its connection with negative and undesirable outcomes. Three months later, the Food and Drug Administration (FDA) of the US identified a connection between a harmful substance in heparin, and the serious health problems patients had after taking the medication. The origin of the contaminant was traced to 12 separate companies located in China. Additionally, the investigation also discovered that batches of the contaminated medication had already been distributed to 11 countries, (Azzi et al., 2019). Both of the above described cases can be seen as a result of a very poorly managed SC. In the case of the E. coli infection linked to cos lettuce, the contamination of the lettuce through water pollution indicates a breakdown in the safety and integrity of the SC. Failure to adequately monitor and regulate the quality of water used in agriculture, as well as insufficient oversight of farming practices, contributed to the contamination of the lettuce and subsequent public health crisis. Similarly, in the case of recall of heparin medication, the presence of a contaminant, in the medication suggests a big failure in the SCM process. The contamination likely occurred due to insufficient quality control measures and oversight at various stages of the manufacturing and distribution process, which resulted in allowing tainted batches of the drugs to reach patients in 11 different countries. Most importantly, the prolonged duration of more than three months to trace back the destination of all contaminated batches highlights a significant deficiency in SC traceability.

3.2.2　Visibility and traceability deficiencies

Although SCs have expanded globally and become highly intricate, there remains a critical need for transparency and traceability within them. Billions of products are being produced every day, and despite this massive production, there's a lack of comprehensive understanding regarding the origin, manufacturing process, and usage of these products throughout their lifecycle. Before the final products reach consumers, they journey through a very complex network that involves retailers, distributors, transporters, storage facilities, and suppliers. All of whom play a role in various stages like manufacturing, distribution, and sales. However, despite their significant involvement, these intricate journeys often remain hidden from consumers, representing an unseen aspect of the products they own. For example, the manufacturing industry faces numerous negative outcomes such as environmental harm, waste generation, and unethical labor practices. Notable examples of this matter include the Nike child labor controversy in 1996, revealing underage workers in Asian factories, and the Foxconn suicide scandal in 2010, which was linked to harsh working conditions. Consumers and end-users often lack awareness of the various challenges associated with the production of goods. Incidents, such as those mentioned earlier, have heightened the focus on SC transparency. This demand is evolving into a broader call for improved information accessibility to renew consumers' confidence in products, (Abeyratne and Monfared, 2016).

Real-time data visibility is crucial for achieving efficient traceability in SCs. Without access to accurate and up-to-date information at every stage of the SC, it becomes challenging to track the movement of products effectively. Real-time data allows stakeholders to monitor the flow of goods, identify potential issues, and respond promptly to any disruptions. Furthermore, traceability is closely linked to transparency in SCs. By having the ability to trace the origin, production, and distribution of products, organizations can provide clear and accurate information to consumers about the source and manufacturing processes of their products. According to Subashini and Hemavathi (2022), as SCs have been evolving rapidly, they have become more complex, posing challenges for achieving clear traceability of goods. Conventional methods of tracing products through the SC encounter difficulties. These challenges include having a central authority managing the traceability process, limited scalability, a lack of openness regarding information, lack of interoperability, databases may include data that cannot be trusted, or data that has been changed, additionally there is the risk of certain parts of the SC becoming disconnected from the overall information flow as many stakeholders are being involved.

3.2.3 Challenges of centralized data control

Centralized control of data in SCs poses barriers and complications related to data ownership, security, and accessibility. When data is concentrated in a single entity or system, it can lead to dependencies, vulnerabilities, and limitations especially when it comes to sharing data across the SC network. Relying on a single entity to manage sensitive and valuable information in a SC necessitates a considerable amount of trust from all involved parties. This entity or organization results in holding significant influence due to its control over this valuable data, posing the risk of misuse for data manipulation or harm if biased. Even if this centralized entity is deemed trustworthy, and all involved parties of the SC have complete faith in it, it must possess high technical expertise for the purpose of securely storing and managing this data. Centralizing valuable information introduces a critical vulnerability, making the entire system prone to failure; it be through digital breaches, cyber intrusions, corruption, or other means. Despite investments in robust security measures, it has been demonstrated that absolute data security cannot be guaranteed, leaving networked organizations potentially exposed to risks, (Subashini and Hemavathi, 2022).

3.2.4 Obstacles in administrative procedures

Current SC commonly face inefficiencies caused by timing mismatches that significantly contribute to the excessively long product lead times, ranging from weeks to months, commonly seen in such industries. Despite relatively short physical distances between sourcing, manufacturing facilities, and the end consumption points. Sometimes just thousands of miles that could be covered in days by air or a couple of weeks by sea. The majority of delays, wastages, and disruptions, totaling as much as 45 up to 50 percent of total SC costs, result from issues encountered in administrative tasks, disorganized financial transactions, and challenges arising from manual interventions. These issues include the involvement of a number of intermediaries, human errors, inconsistency, and sometimes neglecting important tasks, which lead to delays and inefficiencies of operations. In the UK, according to a 2017 report conducted by Tungsten Network, the average business reported an annual loss of over $113,000 due to inefficient payment practices creating inefficiencies in SCs. This translates to nearly 6,500 work hours spent chasing product order numbers, processing paper invoices, and responding to suppliers' different inquiries. Surveyed businesses estimated that they spent an average of 55 hours each week on manual paper-based processes and checks, 39 hours resolving invoice exceptions, inconsistencies, and errors, and 23 hours responding to supplier inquiries. Furthermore, they dedicated five hours each week to addressing regulatory obstacles such as managing international taxes, and three hours were allocated to dealing with invoice fraud, (Vyas et al., 2022, p. 27–28).

Rick Hurwitz who is the CEO of Tungsten Network states "Numerous processes in the financial world remain cumbersome and time consuming when they needn't to be. Technology means we can do away with the tiresome and menial tasks that clog business work streams and instead boost productivity and efficiency. It is surprising that in this tech-enabled day and age businesses are still spending so many hours per week managing a process that could be automated", (Vyas et al., 2022, p. 28).

The primary five factors contributing to challenges associated with administrative procedure can be summarized as follows according to Vyas et al., (2022, p. 28–29).

- High volume of paper invoices that organizations need to deal with regularly.

- Excessive number of non-purchases order-based invoices.

- A significant number of supplier inquiries regarding payment status.

- Absence of automated handling for exceptions that deviates from the standard or typical process.

- Not having automated authorizations.

In addressing the mentioned challenges, companies and SC managers must explore innovative technologies and strategies that help in enhancing traceability, tracking capabilities, and real-time data visibility. Additionally, embracing decentralization techniques and adopting measures to improve data security can further fortify the resilience of the SC against potential threats. Overcoming obstacles in administrative procedures by implementing automated approval processes can also streamline operations and enhance efficiency within the SC.

3.3 How blockchain can improve supply chain

This chapter examines the crucial significance of blockchain applications in SC operations, investigating their varied advantages, significant influence on essential functions, and crucial uses.

3.3.1 Benefits that blockchain brings to supply chain

According to Abeyratne and Monfared (2019), until recently, a centralized system was the most practical solution to ensure data security and controlled transparency in SCs and services. However, the discovery of BT has changed this model. By implementing innovative technologies, strategies, and by leveraging advanced solutions such as blockchain, and IoT, SCs can overcome obstacles that they currently face and achieve greater transparency, efficiency, and robustness. Moreover, prioritizing the security of data within the SC ecosystem can further bolster its overall strength and adaptability. Both

authors further stated that the technological benefits afforded by BT include the four following key points:

- **Resilience**: due to the fact that decentralized networks remove the vulnerability of having single points of system failure, unlike centralized systems. This vulnerability is solved by distributing the risk across multiple nodes and blockchains.

- **Transparency**: due to the fact that each node on the network maintains an identical copy of the blockchain.

- **Immutability**: refers to the near impossibility of altering data stored on a distributed public blockchain, primarily because validation by other nodes and traceability of changes are required.

- **Operational reliability and consistency:** due to the fact that distributed open-source protocols operate precisely as defined in the code. These protocols operate according to their predetermined rules and specifications, leading to a consistent and reliable performance.

Table 1 illustrates several advantages of integrating BT into SCs showcasing its transformative potential in this sector.

TABLE 1 BENEFITS OF BLOCKCHAIN IN SUPPLY CHAINS, (DUTTA ET AL., 2020).

Benefits of blockchain in SCs	Specifics
Data handling	Blockchain enhances data management in SCs through its decentralized and immutable ledger, which ensures that information is securely stored and transparently shared among all participants.
Enhancing transparency	Blockchain brings the ability to track products' status throughout different SC steps, and provides transparency based on the permission level.
Accelerated responsiveness	BT enables the creation of a SC system that is continuously being updated in real-time, allowing for efficient use of its resources.

Smart contracts management	BT allows for the creation of customized contracts tailored to specific functions within a SC. Also, the use of smart contracts enhances visibility and removes unnecessary intermediaries.
Operational effectiveness	BT enhances the overall speed of SC processes, and helps identifying and resolving problems or errors at an early stage of the process.
Removal of intermediaries	The removal of intermediaries leads to having a seamless and uninterrupted flow of transactions, and fostering trust among all stakeholders involved in the process.
Immutability	Consensus mechanism for validating changes or modifications made within the blockchain system ensures that all transactions are securely verified and approved by the network participants, maintaining the integrity and security of the blockchain ledger.
Management of intellectual property	BT can significantly aid in intellectual property protection and registration through several mechanisms such as immutable record keeping or digital ownership verification.

The upcoming table provides a comprehensive overview of the impact of BT on key functions within the SC. By examining each major SC function through the lens of blockchain, great insights into how this transformative technology revolutionizes traditional processes will be unraveled. As per to Dutta et al., (2020) the primary six functional aspects under examination include the following:

TABLE 2: BENEFITS BLOCKCHAIN BRINGS TO SC FUNCTIONS, (DUTTA ET AL., 2020).

Functional aspects of SC	Specifics
SC provenance	Blockchain enables detailed tracking of the origin of physical products, especially those manufactured and moved through complex, cross-organizational, or globally dispersed SCs. It also ensures a specific certification, traceability, verification, and trackability of all the information related to each product.

SC reengineering	Blockchain boosts transparency and visibility within the SC, while enabling automation of different processes. It also cuts out middlemen and allows immediate tracking through the implementation of traceability, and data management techniques.
Security enhancement	By integrating with IoT and Radio-Frequency Identification (RFID), blockchain enhances security, establishes consensus mechanisms for dynamic data storage, especially crucial in systems where data undergoes frequent updates by various participants. RFID technology has the ability to provide unique identifiers for physical objects, which can be securely recorded on the blockchain. This ensures the accuracy of stored information, fosters transparency and data protection, and enhances reliability and financial management.
Business process management	Blockchain facilitates efficient business process management by leveraging smart contracts, which integrate control flow and business logic across cross-organizational processes. Additionally, it empowers streamlined asset management and customer order process management, thereby enhancing the efficiency, and visibility of orders.
Product management	Blockchain enables detailed products' price tracking throughout the end-to-end SC distribution process. It also improves the speed and efficiency of completing particular processes, and therefore it speeding up the entire life cycle of products.
SC adaptability and robustness	Blockchain offers multilayer protection for the SC network. Also, the architectural framework of blockchain facilitates the identification and mitigation of both organizational and network related risks.

3.3.2   Key blockchain applications

This section will discuss three critical areas in SC where the application BT plays a crucial role. The first application area is food traceability, which plays a crucial role in protecting public health, guaranteeing food safety, upholding SC integrity, and fostering consumer confidence in the food sector. From 2013 to 2016 an outbreak of listeria spread across several US states causing significant harm. The source of the infections was found during first few months of 2016 by the FDA and the Center for Disease Control and Prevention, which resulted in more than 300 different products being recalled. By harnessing blockchain's product tracking capabilities, it becomes feasible to conduct

statistical surveys to analyze various aspects. These include identifying the number of consumers affected, the specific food products they bought, and the retailer that distributed these products. Such data aids in tracing the contamination source, identifying specifics such as the nature and severity of contamination, along with its broader consequences, (Alladi et al., 2019).

Addressing inefficiencies in SC logistics management is the second crucial area requiring improvement. Every day, professionals in various logistics roles, such as transporters, and shippers, face a multitude of decisions and hypothetical situations that they might face, as they oversee the transportation of goods across the country. They thoroughly document each step of the journey with extensive paperwork, despite the available technological advancements. BT offers a solution by recording transactions and tracking assets in a transparent and efficient manner. It establishes a framework that manages all documents involved in the logistics process, making it more seamless, more transparent, and reliable, (Alladi et al., 2019).

The third critical application of BT in SCs revolves around enhancing productivity and refining product management. Blockchain brings numerous benefits to product management, including enhanced traceability, transparency, and security. Furthermore, blockchain facilitates the creation of unique digital identities for products, thereby making it difficult for counterfeiters to attempt to replicate or tamper with them. By verifying product authenticity at every stage of the SC, blockchain serves as a powerful tool in combating the distribution of counterfeit goods, (Alladi et al., 2019). Also, smart contracts play a crucial role in SCM; by automating and enforcing agreements between parties, businesses will be able to identify and eliminate unnecessary steps, which will result in reducing obstacles, optimizing workflows to achieve better productivity, reducing costs, and enhancing efficiency of the SC processes overall. By enabling the use of smart contracts, machine-to-machine (M2M) transactions significantly diminish the need for human intervention and communication within the SC. These transactions operate seamlessly, without the limitations of human factors such as downtime, holidays, or sickness. Once programmed correctly and effectively, machines execute tasks with remarkable precision and consistency, minimizing the occurrence of errors. Moreover, their ability to operate around the clock ensures uninterrupted workflow, enhancing efficiency and productivity within SC processes. As a result, smart contracts facilitate a paradigm shift towards automation and reliability, introducing in a new era of optimized and resilient SC operations, (Vyas et al., 2022, p. 35–36).

3.4 Key factors for consideration

In conclusion, when used effectively, BT can provide organizations with a strategic advantage over their competitors. BT is revolutionizing the SC of organizations from various industries by

addressing a number of longstanding challenges and introducing unprecedented opportunities for innovation. Through its decentralized architecture, blockchain enhances security, transparency, and trust in SC operations, mitigating risks and reducing inefficiencies associated with traditional centralized systems. By providing immutable and transparent records of transactions, blockchain brings greater accountability and traceability throughout the SC, enabling more efficient tracking of goods, streamlined processes, and improved collaboration among stakeholders. Moreover, smart contracts automate and enforce agreements, reducing the need for intermediaries and accelerating transaction speeds. As per Dutta et al., (2020), despite the numerous benefits, various barriers slow down the widespread adoption of BT in organizations. These barriers include factors such as organizational preparedness, available technical expertise, digital infrastructure, scalability issues, financial resources, as well as legal compliance. Additionally, implementation of BT can be delayed or slowed down by regulations at the local and national levels. These regulations may impose restrictions or requirements that make it challenging for organizations to innovate with BT. As a result, it becomes important for organizations to work closely with government agencies to ensure that their blockchain initiatives comply with relevant laws and regulations. Addressing organizational readiness and regulatory challenges is very important to expanding the reach and impact of BT.

4 Methodology

Research design and approach

The methodology section of this research outlines the systematic approach employed to address the research objectives, utilizing an exploratory design coupled with an inductive approach. Qualitative research is frequently associated with inductive thinking or reasoning, as it progresses from specific observations of individual occurrences to formulate broader generalizations and theories, (Mayer, 2015). The aim of this study is to investigate the implementation of BT within SCs, an area that presents both complexity and novelty in its application. By integrating qualitative exploratory methods with inductive approach, this research seeks to uncover insights, patterns, and challenges associated with the adoption of BT. The methodology is structured around the following three key data sources. Literature review, case studies and expert interviews. Each of these components plays a crucial role in providing a comprehensive understanding of the research topic and facilitating the synthesis of diverse perspectives and findings.

The literature review serves as the foundational component of the methodology, providing a comprehensive review of existing scholarly literature on BT, current SC challenges, and BT application within SCs. This review enables the identification of key concepts, theories, as well as trends and it also serves as a foundation for additional investigation. The methodology also incorporates the analysis of three distinct case studies to illustrate real-world implementations of BT within SC contexts. These case studies offer concrete examples of three different companies that have already implemented BT within their SC process, exploring the challenges, and successes, encountered by each company allowing for a deeper understanding of the practical implications and complexities involved. Furthermore, in-depth expert interviews represent another crucial component of the methodology, offering valuable insights from six different industry professionals. Through semi-structured interviews, a diverse range of perspectives is gathered, encompassing experiences, challenges, and future outlooks related to blockchain adoption in SCs. These interviews provide rich qualitative data to complement and expand upon the insights obtained from the literature review and the examined case studies.

Interview methodology

The interview methodology employs a semi-structured approach carefully designed with a predefined set of open-ended questions tailored to extract comprehensive insights from each interviewee individually. These thoughtfully crafted questions span a broad spectrum of topics, delving into the fundamental principles of blockchain and its practical applications across various sectors

including SCM. Although each interview includes predetermined core questions, it also facilitates open discussion with the respondents. The interviewees are from different backgrounds, all actively involved in BT and its use in business, each of them having several years of experiences in this field. The interview questions are categorized into five categories: warm-up questions, questions regarding BT, exploration of BT's application in SCM, questions regarding real use cases that they have been involved with, and considerations regarding the future of BT. Even though the practical part of this research includes a summary of each interview, the entire interviews, including the interview questions can be found in Appendix 1.

Qualitative data analysis and synthesis

While guidelines exist for analyzing quantitative data, qualitative data lacks explicit rules or standardized procedures for analysis, (Mayer, 2015). The data analysis phase employs a range of analytical techniques, based on the gathered information and findings from the literature review, case studies, and expert interviews. These techniques include decision tree analysis, PESTEL analysis, qualitative cost-benefit analysis, and SWOT analysis. Notably, SWOT analysis provides a structured framework for evaluating research findings, facilitating a systematic assessment of the feasibility, advantages, and challenges of implementing BT in a firm's SC. Conducting a SWOT analysis enriches the synthesis of insights and offers a comprehensive perspective on the research findings. Synthesis involves the meaningful integration and evaluation of information and research findings. Qualitative research synthesis is a systematic process designed to review and formally integrate findings from qualitative studies. This process facilitates the identification of connections, patterns, and insights across multiple studies within a specific research area or topic, (Sandelovski and Barroso, 2007, p. 17). In this thesis, synthesis entails combining findings from theoretical segment, case studies, and expert interviews to develop a comprehensive understanding of BT in SC. It also involves recognizing patterns and identifying common themes within the collected data, which are summarized in the discussion of interim results section.

PRACTICAL PART

5 Case studies of blockchain implementation

This chapter will feature three case studies showcasing companies that have successfully integrated BT into their SC. The initial case study will focus on a retailer's experience, the second one will be analyzed from the perspective of a manufacturer, and the final one will provide insights from a multinational apparel brand. Each study will analyze the company's motive for adopting this innovative technology what benefits and challenges it brings to their business. Presenting three distinct case studies, each from a different perspective, offers diverse insights that appeals to a wide range of readers, and fosters a comprehensive understanding of blockchain's impact on SCs.

5.1 Case study 1: Walmart and IBM collaboration

This study case involves a collaboration of IBM, which stands for International Business Machines Corporation and Walmart that involves using BT in SC. This section will provide an introduction to both companies, and will explore aspects such as scope, technology, benefits, challenges, as well as future directions

5.1.1 Introduction to both companies

IBM is a multinational information technology company that was founded in 1911 in the US. IBM operates in number of different technology segments and it offers, consulting services, cloud services, hardware as well as software products, and it is additionally actively involved in the development of blockchain solutions for organizations. IBM explains what is does as the following "We bring together all the necessary technology and services to help our clients solve their business problems", (IBM, 2023).

Walmart is an American multinational retailer that was founded in 1962, and currently operates about 10.500 stores, and employs more than 2 million people. Walmart sells a wide variety of products from different segments including groceries, apparel, electronics, health and beauty products, jewelry, book and so on, (Walmart, 2023). It is stated that about 140 million customers visit Walmart stores weekly and most of them purchase food. Not only regulators, but also Walmart's customer have been demanding for better transparency in the company's grocery business for safety and ethical concerns, (Hoffman, 2021).

5.1.2 Partnerships insights

The Walmart and IBM cooperation started in 2016. Karl Bedwell who is a senior director at Walmart stated "Creating a (traceability) system for the entire food supply ecosystem has been a challenge for years, and no one had figured it out. We thought that BT might be a good fit for this problem, because of its focus on trust, immutability, and transparency", (Hyperledger Foundation, 2024). After a careful consideration, Walmart decided to go for the Hyperledger Fabric, which was introduced to them by IBM. Bedwell declared, "We felt that it best met our needs. It is an enterprise-grade blockchain technology, and it is permissioned", (Hyperledger Foundation, 2024).

5.1.2.1 Demand for innovation and proof of concept

The main goal of Walmart when implementing BT within SC was to enhance traceability of products in order to reduce the risk of food-borne outbreaks and boost food safety. Contaminated food is a very big issue in the food industry, and in an event of food-borne disease outbreak, identifying the source is very important, however, it may take companies days or weeks to do that, (Hoffman, 2021). In the food industry, it is common that contaminated products are found and they need to be recalled immediately, for example a listeria outbreak in the US was linked to several products such as cheese, meat, and salad. This food contamination incident was spread across six different states and several people were infected, (De Avila, 2022). Improved traceability of contaminated products will not only reduce the time it takes to find the source of unsafe food, save retailers a lot of costs, and may eventually end up in saving people's lives, (Hoffman, 2021).

Walmart started testing the proof of concept by using the IBM blockchain for two different projects, and further collaboration would be based on the success and outcome of those two projects. The first project was for tracing mangos that were being sold in Walmart stores because they were very prone to being contaminated with salmonella and listeria, and the second one aimed to trace animal protein and pork, which was imported from China for trustworthiness problems, because Walmart was criticized in the past for mislabeling some imported products from China (labeling them as organic while they were not). Both companies finalized the test of these two pilot projects by the end of 2017 and were impressed especially with the outcome of the mango experiment. This experiment was initiated by Walmart's vice president of food safety, as he bought a pack of sliced mangos from one of Walmart's stores and assigned his team with a task to trace the history and exact origin of this specific product. This task of tracing the origin of sliced mango was finally accomplished after 7 days of research. Nevertheless, by using BT for trackability purposes of the same experiment, the tracing time has been reduced to 2.2 seconds, (Hoffman, 2021). After a successful trial for BT in Walmart's SC for the two mentioned projects, IBM, and Walmart including Unilever and Nestlé started

to work together at the end of 2017 in order to launch the IBM Food Trust. By the end of 2018, Walmart was able to trace more than 25 products by utilizing BT in its SC, (Hyperledger Foundation, 2024).

5.1.2.2   IBM Food Trust

The IBM Food Trust is a cooperative network that includes a variety of stakeholders such as manufacturers, retailers, or distributors with the aim to improve transparency and responsibility across food SCs. This network operates on the IBM blockchain, which makes the data available on it secure, unchangeable, and accessible to all network participants. IBM offers several plans that can be customized depending on the customers' needs and the size of their organization. Each of the offered plans includes products' traceability feature, which is essential for ensuring safety, accountability, and mitigating the risk of food contamination throughout the SC, (IBM, 2023). The IBM food trust blockchain system in built on the Hyperledger Fabric platform that is provided by the Linux Foundation. The Hyperledger Fabric is designed to be used as a permissioned blockchain platform, that is often used in private blockchain networks, which means that all network participants need to have permission in order to be able to join the network and have access to the data available on the shared ledger, (IBM, 2023).

Moreover, according to IBM, the IBM food trust addresses a number of challenges within the food industry by offering the following key features:

- **Trace**: for guaranteeing the origin of the food.

- **Immediate insights**: for better optimization of inventory.

- **Certifications**: in order to ensure the safety of products, licenses and inspections results of farms or factories are stated in special certificated that can be verified by buyers.

- **Data entry**: each organization has the ownership of its data including having full control over who can access it.

5.1.2.3   Implementation challenges

Walmart has been implementing BT in its SC but the entire procedure has been going slower than expected due to the complexity of the utilization of this technology within a complex SC. One of the challenges that the company is facing is the long duration that is needed to operationalize the whole process, other challenges are associated with the enrollment of participants, and with the costs involved. The cost of implementing this technology is much higher than the already existing databases that most retailers and supplier already use, so the return on investment should be very clear, and the

objective of this transition should be very carefully demonstrated and how it is related to the strategic vision of these organizations, so participants have the motivation to agree and invest their money into this innovation. Moreover, Walmart stated that a numerous number of its suppliers such as farmers, lacked digital record-keeping systems and therefore had to make a substantial initial investment before being able to adopt blockchain. In certain instances, Walmart had to invest time and money in order to educate its suppliers about the necessity and benefits arising from adopting BT, (Bousquette, 2022).

5.1.3   Impact on business

Walmart has been using BT in its SC for the past few years, and there a number of benefits that this technology has brought the company including the following according to (Hoffman, 2021):

- **Speed**: in case of food-borne outbreak, speed is crucial, and BT use for tractability can dramatically reduce the costs associated with recalling contaminated products. As a result, Walmart can save millions of dollars.

- **Trust**: by including verification records to products, Walmart can strengthen the credibility of the products it sells and can establish a sense of trust in customers' mind.

- **Reputation**: in the US, Walmart has been known for its low prices, as for now, if the utilization proves to be successful, in the future, it will be known for its openness as the first retailer using BT not only to trace the origin of goods, but also to upload certificates of authenticity on its products.

According to IBM (2024), and their conducted surveys, there are several compelling reasons for retailers in the food industry to consider investing in the innovation of their SC and initiating the integration of BT. Following are a few of the surveys' results:

- 94% of survey respondents indicated that their brand loyalty would increase when provided with complete transparency.

- 63% of American surveyed expressed their willingness to pay an additional one-third for products that are responsibly manufactured and have transparent sourcing.

- 20% of consumers tend to switch retailers after an incident of a product recall.

- Approximately 17% of world's food production goes to waste each year according to the United Nations food waste index (2021).

Currently, Walmart uses BT to track products in the US and in Canada. There are over 1500 different types of food products that are being traced, which come from 70 different suppliers.

Walmart is also considering implementing blockchain in its invoice processes, (Castillo et al., 2023). While initial efforts of Walmart are praiseworthy, scaling is essential to fully realize the transformative potential of blockchain traceability. This could pose several challenges, primarily due to the vast number of products the company sells, and such challenges include high costs considerations, required cooperation from a large number of suppliers, and complexity of implementation.

5.2 Case study 2: Blockchain integration at Nestlé

This study case covers the transformative journey undertaken by Nestlé, which includes a collaboration with several partners such as IBM, Carrefour Group and OpenSC. This case study focuses on the integration of BT in Nestlé's SC. It begins by introducing the companies involved in this collaborative effort, and the role of each contributor. Following this, the study explores insights into the adoption of BT, highlighting key strategies, and challenges encountered throughout the whole process.

5.2.1 Introduction to companies involved

According to Nestlé "We are Nestlé. The Good food, Good life company. We believe in the power of food to enhance lives", (Nestle.com, 2024). Nestlé is multinational Swiss organization that operates in more than 180 countries and its roots go back to 1866. Nestlé is not only one of the world's largest food, beverage companies, but it is also involved in various other segments such as, nutrition, healthcare, skin care and wellness. The company's goals involve providing good food and high-quality healthcare products while honoring planet earth and taking into account the protections natural resources for the wellbeing of future generations. The company sells a diverse range of products across various categories such as cereals, chocolate, coffee, baby foods, dairy and pet care, (Nestle.com, 2024).

Carrefour Group is a French multinational retailer that was founded in 1959. The company expanded internationally in 1993, it launched its own online supermarket in year 2000, currently has a chain of more than 12,000 supermarkets, and sells a wide range of products including home care, groceries, electronics, and apparel. The core mission of the company is articulated as the following, "Our mission is to provide our customers with quality services, products, and food that is accessible to all across all distribution channels. Through the expertise of our employees, a responsible and multicultural approach, our broad territorial presence, and our ability to adapt to production and consumption modes, our ambition is to be the leader of the food transition for everyone", (Carrefour Group, 2024).

OpenSC stands for Open Supply Chain. It is an Australian company that was founded in 2019. The company was established in response to the necessity for ensuring the well-being of individuals as well as the environment in the food industry. "Transforming global food systems is key to tackling the climate crisis and protecting people and planet", (OpenSC, 2024). According to OpenSC (2024), by using technology their aim is to create transparency and tractability in SC and revolutionize how people buy products and how producer make them. Markus Mutz who is the CEO of OpenSC stated, that the main primary components that add value to SC are the following three: verification, tracing, and sharing. Mutz (2019) furthermore explains those three essential steps as listed below:

- **Verify**: ethical production and source assertions.

- **Trace**: individual physical goods and products through the whole SC.

- **Share**: all the gathered information with consumers, so they can make more knowledgeable decisions in accordance with their principals.

Following is an example of how OpenSC tracks products using BT. Each product gets a specific RFID chip, which could be understood as a product's passport. For instance, when a fish is caught from the sea, immediately on the boat it gets an identification chip with a particular serial number, so it can be tracked through the whole SC from the moment it was caught up to the point when it is packaged or separated into portions. The RFID chip includes GPS (Global Positioning System) of participating boats, so anyone can see the exact location where a boat was catching fish, whether this location was a government protected one, furthermore when and how the fish were transported. In order for consumers to be able to verify the origin of the fish themselves, when a fish is being packaged, the chip is removed from the flesh and it is substituted with a QR code accessible to anyone. The QR code includes the same data that the RFID chip included, (Mutz, 2019).

5.2.2   Adoption of blockchain within Nestlé

In 2017, Nestlé started testing out BT with cooperation with IBM Food Trust. According to the Nestlé, what motivates them the most to adopt BT and implement it within their processes, is their customer's need and demand for transparency. One year later, Carrefour Group also join the IBM Food Trust and together with Nestlé, both companies have been involved in utilizing BT project that is focused on Mousline Purée in order to enhance transparency by offering precise a reliable information about the products, (Nestlé, 2019). Services provided by IBM contribute to an extraordinary visibility into the whole food SC. This unique network links farmer, processors, distributors, as well as retailers using a private, and shared record for food data, which leads to reducing food loss, and increase in organization's efficiency, (IBM, 2020).

In 2019, Nestlé has partnered with OpenSC for a new collaboration in order to create a new system of distributed ledgers that brings even more transparency. This new system is different from the one that it has been testing for the past few years and, and it will work on it separately with OpenSC without the involvement of IBM, (Kuhn, 2019). The main difference is the use of a public blockchain and not a permissioned private one which IBM offers. The executive vice president of Nestlé, Magdi Batato, stated in regards to Nestlé piloting the BT "We want our consumers to make an informed decision on their choice of products – to choose products produced responsibly. Open BT might allow us to share reliable information with consumers in an accessible way", (Nestlé, 2019). This programs' initial phase involves tracking the origin of milk, tracing it from farms in New Zealand to Nestlé facilities that are located in the Middle East. The next phase will include tracking and monitoring of palm oil production, (Kuhn, 2019). In 2020, Nestlé started to further test the BT on additional products such as Zoégas beans to allow all coffee enthusiast to trace the origin of their coffee beans. Each pack of coffee includes a QR code that can be scanned by consumers, so they can trace coffee's route, starting from its cultivation sites up to the Zoégas factories in Sweden where beans get grinded, roasted and packaged. Customers also get the ability to look into data such as, exact harvest time, exact duration of the roasting process, and certificates that are related to every specific shipment, (Nestlé, 2020).

5.2.3   Motives behind choosing a public and a private blockchain

The primary goal behind the company's adoption of BT in its SC was to meet consumer demands while enhancing overall operational efficiency and effectiveness. Today's consumers are increasingly seeking detailed information about their food, including the precise origins of the products they purchase, insights into the manufacturing processes, and confirmation of responsible sourcing practices. Benjamin Ware, global head of responsible sourcing for Nestlé, expressed that by using BT, any person, from any part of the world will be able to access Nestlé's responsible sourcing data and information, (Kuhn, 2019). The main motivation for Nestlé to transition to the use of public blockchain along with the private one is centered around the desire for an even more increased transparency and openness in its SC. Nestlé blockchain lead and SC digital transformation manager Benjamin Dubois explains, the reasons behind the testing our the public blockchain as follows, "Something that allows full disclosure, without any Nestlé control, where the data is uploaded by every actor along the value chain and is available for anyone and anywhere to take on this data", (Pirus, 2019). Using a public blockchain makes more information widely accessible to the public. Dubois further clarified that the cooperation with OpenSC is not meant to replace the existing partnership with IBM Food Trust as Nestlé will keep on using both public and private blockchains, because they are meant to complement each other. The IBM Food Trust solution is primarily designed for business-to-business cooperation,

providing a powerful and appropriate solution for a company such as Nestlé with its large number of supplies, and distributors. On the other hand, by using a public blockchain, it becomes simpler for individuals to engage with the company. In order to fulfill Nestlé's commitment to complete transparency, Dubois stated, that choosing a public blockchain is the only effective approach for reaching this goal, (Pirus, 2019).

5.2.4 Benefits of using a public blockchain

Utilizing a public blockchain in SC offers numerous advantages to businesses and individuals. In essence, it revolutionizes how people make buying choices, because of the access that they have to information. The high level of traceability gives people the ability to verify detailed information about the products they buy. For example, before making a purchase, consumers can check where a fish was caught, who caught it, when was it caught, whether it was sustainable to catch it from that exact place, how and when was it transported. Moreover, the previous example is applicable to all products from our surroundings, (Mutz, 2019). Through blockchain traceability, individuals gain access to information that was previously unavailable to them, which empowers consumers to make more informed choices. Until now, individuals made decisions by placing blind trust in producers and sellers, relying on the hope that the information conveyed to them was accurate. The blockchain revolution now empowers people to independently verify and seek evidence supporting ethical claims in production.

As indicated by OpenSC (2024), some of the benefits that these platforms bring to organizations, to the industry as a whole, and to the planet are listed below:

- Efficiency and cost saving.

- Taking transparency to new level.

- Fostering trust among stakeholders.

- Public blockchain bring the ability to share all important information with partners, and customers (Business to business and business to consumer).

- Facilitating an automated, real-time, and continuous verification of responsible and ethical production claims.

- Contributing to prevention of fraud in business.

- Investors can easily verify whether the environmental, social, and governance criteria of the company have been met.

- Businesses become obligated to prioritize accountability and ethical practices.
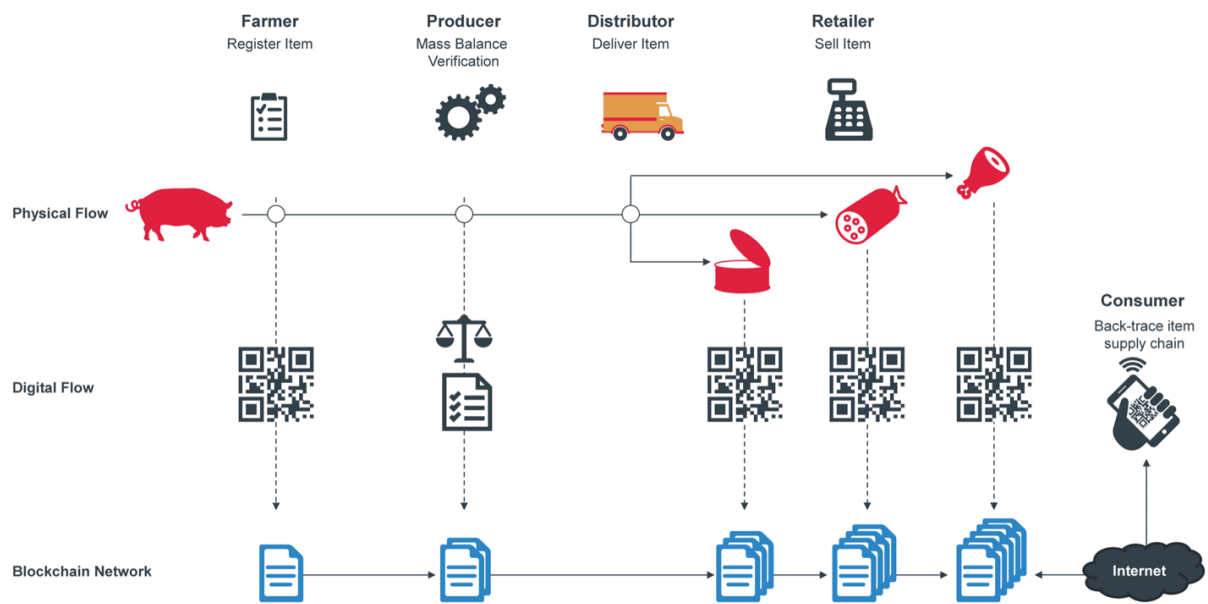
FIGURE 5: PUBLIC BLOCKCHAIN USE FOR TRACEABILITY, (SWISS IPG, 2023).

5.2.5   Implementation challenges

Understanding the challenges of blockchain implementation for every manufacturer and food producer is crucial in order to effectively plan the process of implementation, mitigate risks, and to effectively communicate realistic expectation with company's stakeholders. When tracing food in a SC, it's crucial to consider the ultimate destination of the final product. Depending on this destination, the technology employed should be tailored accordingly. Mutz (2019) explains that a fish that are bought from a freezer at a retailer have QR codes with the product's history. However, a challenge arises when consumers at restaurants would like to know the origin of a fish that they ordered. Therefore, a distinct technological engagement strategy would need to be created and specifically crafted for tracing and verifying food at restaurants. This example is not limited to fish; it extends to all products destined for restaurants rather than supermarkets. In Nestlé's case, this would for instance be applicable to coffee beans and milk among other products.

Many consumers do not understand how blockchain works, what value does it bring, and that it is tamper-proof. Therefore, they need to be educated in order to appreciate this added value that this innovation brings, so they be willing to pay more for products that are reliable, have a verified history and come from ethical and sustainable sources. Ultimately, an informed consumer base plays a pivotal role in driving positive change that the blockchain revolution brings. Large manufacturers may also face scalability challenges as the number of participants in the network increases as well as the number of transactions. Growing transaction volume may end up in slowing down the whole transaction network as each transaction would take more time to be finalized which impacts the

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overall efficiency. Additionally, managing and storing large volumes of data can become a challenge, impacting the scalability of the system, (Leng et al., 2020).

5.3 Case study 3: Hennes & Mauritz AB and Textile Genesis

This case study showcases the important role that BT plays in the fashion industry, how can it reshape the future of fashion, and how it addresses various challenges faced by the industry. This case study explores the operations of Hennes & Mauritz AB, commonly known as H&M Group, with a particular emphasis on the integration of BT in its SC.

5.3.1 Introduction to both companies

H&M Group is a Swedish multinational fashion and design enterprise that was established in 1947. Over the years it has expanded dramatically, became a key player in the fashion industry and it currently operates in Europe, North America, and Asia. H&M Group include several brands such as H&M, COS, Monti and Weekday and it currently operates more than 4300 stores worldwide, and it has about 150,000 employees. H&M Group sells apparel, accessories, footwear, cosmetics, and home textiles. The company's vision is "to make great fashion available to everyone and to do it in the right way", (H&M Group, 2024). The company's SC is very complex, as each product undergoes a lengthy journey, passing through various suppliers from raw material sourcing to the point of being a finished product available for sale, either on store shelves or online. The company operates without owning any factories; instead, it collaborates with independent manufacturers. As stated on the company's website, "We are committed to building strong, long-term relations with our suppliers that are based on mutual trust and transparency", (H&M Group, 2024). This commitment emphasizes the importance of developing strong and transparent partnerships within its SC. Figure 6 illustrates the multitude of steps encompassed by H&M's complex SC, attributed to its vertically integrated business model.
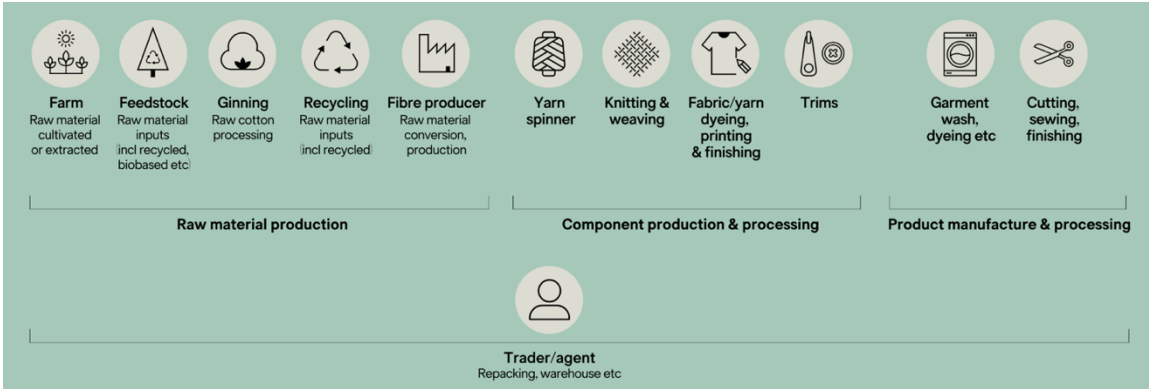

FIGURE 6: H&M GROUP'S SUPPLY CHAIN, (H&M GROUP, 2023)

Textile Genesis is a company based in Hongkong and India that was established in 2018. It aims to enhance transparency in the fashion industry by utilizing BT. Through the digitization of the SC, the company enables different brands to track their entire production process of clothing, starting from raw materials to a finished product, (Gerretsen, 2021). The company articulates its vision as the following, "Our vision is two-fold: creating radical transparency from fiber-to-retail, and ensuring authenticity & provenance of sustainable textiles against generics", (Textile Genesis, 2023). The fundamental innovation that Textile Genesis have brought to the fashion industry are called Fiber coins, which are digital tokens that have the ability to "provide a time-stamped record of the flow of physical products" through the whole SC, (Gerretsen, 2021). Each 1 kg of fiber is equivalent to 1 fiber coin, and according to Amit Gautam who is the founder and CEO of Textile Genesis, the company's main objective for using fiber coins and to digitize physical volume, is driven by two primary motivations. The initial reason is the elimination of paper-based clothing certificates through fiber coins. Textile Genesis aims to reduce dependence on conventional paper-based or PDF transaction certificates, which currently serve as a fundamental element in the industry's traceability practices. The second reason for using fiber coins is the establishment of a closed loop system. By digitizing physical volume, the company intends to create a zero-sum game, which means that resources or transactions will be monitored and managed very precisely, ensuring that any input or output is accurately accounted for without the risk of having duplications in the system or overcounting, (Textile Genesis, 2023). Textile Genesis has achieved significant milestones, including winning a Global Change Award for innovations, as a result of promoting eco-friendly practices in the fashion industry, (Gerretsen, 2021).

5.3.2   Motives behind using blockchain technology

The transformative landscape that the fashion industry is going through is one where innovation meets sustainability, giving rise to a new era of responsible and conscious practices as more people become aware of the environmental and social impacts of their consumption choices. This awareness drives a growing demand for ethically sourced goods, environmentally friendly products, encouraging fashion brands to adapt and embrace sustainable innovations. As innovation and sustainability unite, they not only redefine industry standards, but also inspire a collective commitment to a more sustainable future. The collaboration of H&M Group and Textile Genesis began in 2020, and according to Merel Krebbers who is a Business Expert at H&M Group Business Tech, "H&M Group believes that SC traceability and transparency should go hand-in-hand to create greater accountability for where materials and products come from, and to drive positive change in the fashion industry", (H&M Group, 2022). H&M Group places a significant importance on traceability; the impact

of adopting specific tools and systems that enhance traceability not only benefit the company, and its customers, but also it changes the entire industry. The company strives to provide customers with a complete product history, detailing the entire journey of each garment from the origin of its fibers, to the various stages of production, and ending with the customer's purchase, (H&M Group, 2022). According to (Kapfunde, 2022), the integration of BT in the fashion industry brings a number of benefits such as:

- Establishing a real-time data stream throughout the complex apparel SC.

- Providing an easy way to trace the origin of sustainable materials.

- Building stronger relationships of the companies and their suppliers.

- Using smart contracts results in having a smoother and more well-managed SC.

- Achieving real environmental sustainability by providing an immutable record of carbon footprints at each phase of the SC.

- Offering reliable product information that serves the company's internal needs and benefits the end user.

In the year 2020, Fashion Revolution undertook a survey across 5 major European markets, in order to determine the importance and influence of SC transparency and sustainability on people's purchasing decisions, (Fashion Revolution, 2020). The survey results revealed compelling insights that highlight the crucial role these factors play in shaping consumer behavior. The following data indicates a growing awareness and consideration among individuals regarding the ethical and sustainable practices within the fashion industry.

- 19% of individuals surveyed have the desire to purchase clothing manufactured in an environmentally responsible manner.

- 37% of respondents highlighted how significant it is for them to buy clothing that are produced without the use of harmful chemicals.

- 69% of surveyed participants expressed a desire to understand the manufacturing process, and to know the origin behind their clothing.

- 72% of people surveyed emphasizing the importance of buying apparel that include ethical certifications.

As the preferences of consumers in the fashion industry evolve, and they demand more transparency when making purchasing decisions, BT emerges as a great solution as it plays a crucial

role in enhancing transparency in the SC, allowing consumers to verify the environmental and social responsibility claims associated with their clothing purchases.

5.3.3 Collaboration insights

H&M started implementing a traceability platform from with collaboration with Textile Genesis, that focuses on tracking recycled polyester, wool and synthetic cellulosic fibers like viscose, which can be linked to environmental concerns. By utilizing BT, the incorporation of sustainable fibers into clothing can be easily verified and monitored. H&M Group collaborates with over 600 different suppliers, producing items across more than 1500 factories, (Holger, 2023). Products may go through several stages and of manufacturing as well as transportation until they end up with a customer, and until now, clothing has typically been accompanied by a label indicating its country of origin. However, the integration of BT is positioned to revolutionize this norm, as it offers stakeholders an extensive amount of information about the entire journey of their garments.

One of the primary ambitions of H&M Group (2024) is "At H&M Group, we consider the needs of present and future generations, and conduct our business in a way that is economically, socially and environmentally sustainable. This is why we set clear ambitions and bold goals." The first goal that was set by the H&M Group and Textile Genesis was that by 2021 H&M would be able to track up to 1.5 million pieces, and that by 2022 number of traceable goods would increase to more than 200 million throughout the whole SC. Additional H&M Group goals include the following: by the year 2025, the company aims that 30% of the materials used in our retail products to be certified as recycled, and by the year 2030, ensuring that all materials used in the production of commercial products to be either responsibly and ethically obtained or recycled, (H&M Group, 2022). Pierre Börjesson, who is the head of transparency and traceability at H&M Group stated that, "The closer we get to our 2030 goal for all our materials to be either recycled or sourced in a more sustainable way, the more traceability we gain" (Holger, 2023). For fashion brands to truly achieve effectiveness, efficiency, and sustainability, it's essential that they extend their focus beyond profitability. A comprehensive approach involves considering and prioritizing societal and environmental impacts. By incorporating a commitment to social and environmental responsibility, fashion brands can contribute to a more comprehensive and sustainable industry.

5.3.4 Implementation challenges

Achieving a smooth and efficient technological transition within a complex SC requires the successful implementation of the new technology, which consequently demands active cooperation from all suppliers involved in the process. One of the primary challenges in implementing blockchain

is the onboarding of suppliers, often obstructed by hesitancy due to being unfamiliar with the technology or concerns related to costs. It is crucial that every supplier is well-informed about the ongoing transition, and its importance. The comprehensive training required for such a significant shift poses a considerable challenge, particularly for a company like H&M Group, which collaborates with a large number of suppliers across different continents. However, according to Textile Genesis (2023), they have created a special and intensive supplier training program, which enables suppliers to gain a comprehensive understanding and operate the blockchain independently after just one hour of coaching. Effective communication, collaboration, and systematic training procedures are pivotal for the success of such a complex process. In order for a company's customers to benefit from use BT in its SC, they first need to establish an internal solid foundation of information that is credible, and provides highly reliable data on a large scale. The CEO of Textile Genesis stated in an interview that it is not enough for a company to disclose the traceability of 5% of its products, because customers would not be satisfied, it fails to disclose the story behind the remaining 95% of their products. Therefore, it is crucial to solve the issue of scalability prior to sharing the narrative with consumers, (Lenzing Group, 2020).

5.4 Expert interviews

This section includes interviews with blockchain experts who offer valuable insights into this emerging technology. It's noteworthy that the pool of experts in this field is quite limited, largely due to the novelty of the technology, which means that relatively few individuals possess a comprehensive understanding of it. All interviewees shared their experiences with various use cases, and their thoughts on future trends in the field. The interviews, each lasting approximately an hour and a half, have been summarized below individually, and the full transcripts can be found in Appendix 1. Moreover, the interviewees represent diverse industries and backgrounds, with participants originating from different locations including the Czech Republic, Switzerland, Italy, Germany and the US. It's worth noting that a considerable number of individuals as well as companies involved in blockchain, including current users and providers of blockchain solutions, declined the interview, citing concerns about sharing confidential information on this topic.

5.4.1 Interview with Jakub Tesař

The following paragraphs are a summary of an in-person interview with Jakub Tesař on January 26th of 2024. Tesař is the head of innovation, digital solutions, and new technologies department at Ernst & Young Ltd. (EY) Prague. Tesař stated that "the holy trinity of all blockchains are decentralization, scalability and security", which all together form a foundation for a revolutionary

impact on various industries and society in general. At EY blockchain plays a significant role particularly for advancing transactions and cooperation of companies with their external stakeholders rather than extensively focusing on the internal improvements that this technology brings. It is also believed that the future of blockchain's use in business resides in companies using a public blockchain and not a private one as the benefits arising from the private blockchain are very limited. The essential factor that must be included in all public blockchains so companies can use them freely is privacy. This is very important because businesses may engage in transactions that are confidential by default and additionally, they need to protect the sensitive information related to their customers, suppliers, partners and other essential processes. In order for a business to have a competitive advantage, such data needs to be protected and kept in private in order not to be misused for example by the company's competitors. Tesař considers the public, enterprise blockchain the only long-term viable option, as the private, incl. the consortium, ones are permissioned, lack decentralization and transparency. Not only that the public blockchain brings organizations a number of advantages, but also, in some cases the implementation and use of a public blockchain may even be cheaper than using other types of infrastructure.

When choosing the best blockchain for a business, several important factors need to be taken into consideration for example, since 2014 the Ethereum public blockchain has been up and running without a break and gradually being decentralized ever since, it is sustainable as it runs the PoS consensus mechanism, a large number of developers is working on this blockchain and numerous use cases have already been implemented utilizing Ethereum as settlement layers. So, the longer a blockchain has been operational without encountering significant security and performance issues the more it is encouraging for businesses to trust it and use it.

Blockchains' networks are inherently immutable and transparent. However, EY and Polygon organizations have been developing techniques that allow public blockchains to have enterprise-grade privacy features, and this privacy-based protocol is called Nightfall. This protocol could be understood as a privacy layer on top of a public blockchain, which permits users to have completely private and confidential transactions. Tesař further points out that the Nightfall protocol is for instance incorporated into the EY OpsChain platform, which brings innovative solutions to SC as well as inventory management. The EY OpsChain SC manager can for instance be used to trace the land or farm where its sub-components are from, to its customers and further all the way to its decomposed state back in the recycling point, eventually back to production again. The EY OpsChain is currently being successfully used by Birra Peroni, which is an Italian beer brand. This cooperation started already a several years ago and Birra Peroni's main goal was to increase transparency and be closer to its customers. The company's goal has been achieved by using a non-fungible token (NFT) as a digital

certificate, which is listed on the blockchain, and it contains detailed information about the whole journey of each bottle from the moment a seed was put into the ground by a farmer, up to the point of a customer buying the final product. By implementing BT to the SC, Birra Peroni is being very transparent about source of production for its products, and it can also ensure the quality of the ingredients that are used in the production process. Birra Peroni is known for its Italian heritage, and by using BT this company is able to prove the origin of every ingredient that its products are made of, and this way it can guarantee the products' quality, while presenting the customers with a unique and customized experience as they are able to verify all the provided information regarding the products that they buy. This cooperation was summarized in the following quote by Federico Sannella who is a corporate affairs director at Birra Peroni "For Birra Peroni, the bond with the agricultural SC and the quality of our 100% made-in-Italy malt are fundamental strategic assets. We believe that sustainability is deeply related to the respect for the raw material, and we wanted to bring this value alive to our consumers, allowing them to follow the journey of the malt from the field to the bottle. With EY OpsChain Traceability, we have found the ideal platform to carry out this important project. This is a major step forward in our commitment to bring visibility and transparency to our SC for both consumers and SC partners", (Ernst & Young Global Ltd., 2021).

Another successful example of blockchain's implementation is collaboration between EY and Microsoft in the gaming industry. BT and smart contracts are being used for the gaming platform Xbox in order to manage royalty processing. By using this automated solution, operational costs have been reduced, the processing time of royalties is much faster and more transparency has been accessible to all participants. The application of smart contracts and BT in this case improved the overall user experience of game developers, enhanced the effectiveness of Microsoft royalty processing system, and eliminated the occurrence of errors in the entire process. Luke Fewel who is the General Manager, Global Finance Operations at Microsoft stated that "By implementing a blockchain-based network and streamlined royalty processing, game publishers and Xbox benefit from a more trusted, transparent and connected system from contract creation through to royalty settlements", (Ernst & Young Global Ltd., 2024).

The future of BT is seen in two major aspects, the first one is the tokenization of assets. Tokenization will not only be used in SC for transparency and tractability purposes, but it can also be used in the financial sector, in brand promotion for incentivizing customers' engagement with the brand, and also in specific loyalty programs that some companies are starting to offer, such as Starbucks, Adidas and Nike. All these three companies have already adopted the concept of transforming their loyalty program strategies into tokens. The second aspect is the use of smart contracts, which is very crucial for businesses as it brings them many benefits such as improved process

efficiency, business logic composability, manual error removal, higher speed of automated transaction settlement as they are executed without the need of any manual verification, and this all results in cost saving, which also includes a reduction of administrative costs that are related to traditional record keeping, and the elimination of intermediaries such as third-party payments processors like banks. Last but not least, Tesař stated that "anonymity is not the same as privacy". As organizations move to public blockchain and aim to become more transparent, earn the trust of their customers, partners, and regulators, it is necessary for transactions to be transparent and not anonymous while allowing organizations to have some level of privacy in order to protect their businesses.

5.4.2   Interview with Travin Keith

This interview was conducted via Zoom due to the interviewee's location in Switzerland. Keith is an entrepreneur, and a technology consultant; he is the co-founder and currently an Advisor of Immunefi, which is a platform that specializes in bug bounties, particularly in the areas of web3 (the third era of the internet) and smart contract security. He was also involved in a project called Blockchain 4 EU by the European Commission, where he served as the lead technical designer for blood and organ donation platform, which regrettably never saw eventual launch. He also is the co-founder and currently an Advisor for STOKR, which is a digital investment platform for alternative assets utilizing BT. Keith has been involved in the BT space since 2016, he worked on numerous projects revolving around this technology, and he presently also serves as an advisor for BT companies, for cryptocurrency related projects, and for some government organizations as well. One of Keith's noteworthy engagements was his involvement with Hyperledger, which was a project of the Linux Foundation and is now its own foundation, the Hyperledger Foundation. He played a key role in co-authoring the white paper for Hyperledger titled "An Introduction to Hyperledger" as well as its updated version.

According to Keith, blockchain has a profound impact on various industries, with the financial sector experiencing significant transformations, especially due to cryptocurrencies. The ideal selection of a blockchain solution should align with the specific needs and goals of a given project or company. While speed and efficiency are important considerations, they are not the sole factors determining viability. There will consistently be alternatives that outpace blockchain in terms of speed, as traditional databases frequently exhibit faster performance, while distributed databases introduce the same level of data storage redundancy while compromising minimally on speed, unlike blockchain. This difference in speed is primarily attributed to the fundamental differences in how these technologies are designed and their intended purposes, where a blockchain is centered around the need for decentralized processing. When it comes to choosing between the public and private blockchain, the main difference is in regards to the access rights. On a public blockchain, general

information is accessible to anyone, in contrast to a private blockchain where access is restricted to a specific group of individuals. It is important to highlight that a public blockchain does not necessarily have to be permissionless in terms of transaction entries to the blockchain. A permissionless blockchain implies unrestricted access and freedom to engage in any activity. In theory, a blockchain can be both public and permissioned, allowing certain elements to be publicly accessible, while maintaining control over who actively participates in the given network. In most cases it is very hard to justify the use of private blockchain networks, because if organizations focus on only one benefit that this technology brings, then there is probably some other technology that is better for solving that concrete problem. What makes blockchain innovative is all the grouped benefits and solutions that it brings altogether. For example, if a company's primary goal is to address versioning for the clear tracking of versions and history of changes, and this is the sole problem they aim to solve, leveraging cryptography can be a more practical and efficient approach than blockchain implementation, and the problem would be solved without the necessity of setting up an entirely new and costly network. This would also prevent improper modification, one of the key benefits that is highlighted by blockchain technology, without the use of it.

The decentralization, specifically with regards to the processing of addition of new blocks containing new data or modification to existing data, offered by BT is a key advantage; however, this aspect is constrained in the context of private blockchains, which means that this technology is not used to its fullest potential. In a private blockchain setup, the company that initiates and manages the blockchain network typically has a significant level of control over the data being entered. For instance, Walmart's utilization of a private blockchain likely enhances traceability within their SC, addressing issues arising from outdated technology. Nevertheless, from the consumers' perspective regarding the transparency emphasized by Walmart, the value diminishes since all data is managed exclusively by Walmart and its suppliers within the limits of the private blockchain. Moreover, just because blockchain made the internal traceability of goods for Walmart better, it does not mean that it was the best technology to use. It would be more practical to consider utilizing a public or semi-public network with varying privacy levels if Walmart desires to truly deliver on the value that it is presenting. In the majority of instances, employing private blockchain networks to enhance internal company processes is inefficient and lacks rationale in 99% of cases.

There is a big difference between if a retailer joins a network versus a retailer starting a network. So, based on the publicly available information in the example of H&M, it is a fashion brand that is joining the Textile Genesis network including production companies and other apparel brands, which creates an alliance of different relationships with Textile Genesis or a consortium. This represents a good use case and a great implementation of BT. The key important factor is that the leader of the association (in this case Textile Genesis) is a neutral member that is not competing with

other apparel brands, or textile producers. This could be an example of a permissioned semi-public network. As soon as consumers have the ability to view some data available on the network, this means that it has some level of publicness. The level or private/public could be understood as a scale, which goes up and down, because H&M would be sharing only a certain amount of data and not necessarily need to share information like how much inventory it has and so on.

Several aspects defy precise calculation of costs and benefits that such innovations bring. The integration of blockchain demands a substantial number of developers and solution architects. Given the relatively short duration of this technology, the scarcity of proficient blockchain solution architects is notable. Consequently, companies might find themselves compensating and paying for developers who are still in the learning curve during the development phase. This situation may dramatically affect the estimation of costs for blockchain implementation. Keith further states that when a company delves into unexplored areas, extensive investments in research are imperative, and predicting these costs becomes very difficult. Moreover, various implementations come with distinct costs, and each one must be tailored to meet the specific requirements of individual users. Blockchain implementation is fairly expensive and most companies (like startups) cannot afford it. However, the precise expenses incurred by companies that have adopted this technology remain undisclosed to the public.

5.4.3   Interview with Giuseppe Perrone

The interview was held over Zoom on March 26th, 2024 since the interviewee resides in Italy. Giuseppe Perrone is a very experienced blockchain expert with a background in financial services, government and public sector, consumer products, as well as retail, healthcare, transportation, and automotive industries. He is dedicated to driving innovation, and currently he is the leader of EY's blockchain sales and the innovation consulting practice in Italy for Europe, Middle East, India, and Africa. Perrone worked on a number of cases for the integration of BT into various businesses which will be explored in this interview.

Perrone states that it's crucial to begin by exploring several core elements associated with BT and its role in this transformative era. Following this exploration, examining real-world examples becomes imperative to comprehensively assess the multitude of benefits this innovative technology offers to companies and its potential impact across various sectors. When beginning to work on blockchain projects, it's important to consider the decentralized environment of the shared data, especially within complex ecosystems like SCs. This environment facilitates benefits such as the ability to modify data while still linking it to specific owners, thereby enabling provenance verification for interconnected elements stored on the blockchain. In simpler terms, one unique method to attain transparency, traceability, and automation and tokenization is by leveraging a decentralized

blockchain. Specifically, permissionless public blockchains like Ethereum offer opportunities to achieve these objectives.

Firstly, blockchain serves as a foundational tool for classical notarization. For instance, it can be associated with data stamping for specific time and location parameters, ensuring the integrity and authenticity of data. This application extends to various digital properties, including digital art. The second facet involves tokenization; this capability enables the transformation of tokens into unique values containing multiple attributes. A prime example is seen in the traceability of SCs, where tokens gather diverse metadata and stamps. This process ultimately gives rise to tokenomics, which can be understood as an environment merging public fungible tokens such as Bitcoin and NFTs. Lastly, the third step centers on automation, harnessing the power of smart contracts to streamline processes. These processes are designed to be self-auditable, as verification can be conducted at each step of the automation process without reliance on third parties or intermediaries. Automation assumes a critical role in various domains, including procurement and the equitable distribution of royalties. Organizations implementing BT can benefit from three distinct advantages. Firstly, it reduces the time spent on quality control by approximately 25%. Secondly, it promotes better engagement from consumers who prioritize purchasing products that are LATTE: local, authentic, traceable, transparent and ethical, because with the use of blockchain organizations can ensure food safety, and the authenticity of goods. Thirdly, this allows companies to sell their product for a higher price, potentially increasing it by up to 15% or 20%. This price premium is connected with providing consumers valuable information regarding their purchase.

Perrone has participated in several projects focused on incorporating BT into SC operations, particularly focusing on multiple agri-food elements with the goal of establishing digital ecosystems. For instance, in the Birra Peroni project, the initiative began with the participation of 100 farmers, 2 breweries, 3 production plants, and the establishment of a virtual environment to connect information. BT was utilized to trace tokens with associated metadata linked to the owner of each phase of the SC. This approach allowed for comprehensive visualization and digitalization of the entire SC process. To engage the end consumers, beer bottles were equipped with QR codes that, when scanned, redirected customers to a webpage where they could access certificates for each step of the process. The integration of physical and digital product information relies on tokenization, which plays a crucial role in establishing the authenticity of products. This model of a successful blockchain implementation can then be replicated for similar SC uses.

The traceability aspect that blockchain offers is utilized in various other fields as well. For instance, in the automotive industry, a use case has been realized with Automobile Club d'Italia when a digital car folder has been introduced by EY. This car folder contains essential information about the car, such as kilometers driven, current status, maintenance activities and the entire service

history of the car. All this information that the car folder includes are placed on the blockchain. By leveraging blockchain for this purpose, a system effective system is created that combats the significant issue of counterfeiting linked to tachometer frauds, providing consumers with trustworthy and transparent data about their vehicles. So, in a secondary market the value of the car can be ensured because of the availability of all the information linked to the entire lifecycle.

Another unique example of the use of blockchain is a platform called ANSAcheck, which was created by EY for National Associated Press Agency (ANSA), which is the number one news agency in Italy. Using ANSAcheck brings the ability for readers to check and trace the origin of the news from creation to publishing distribution. The news is traced on the blockchain in each step of its distribution. This proves particularly valuable, especially in scenarios involving cyberattacks targeting news provider websites, such as the incident that occurred approximately two years ago when ANSA experienced a cyberattack that led to the publication of Russian propaganda on their official website. Since using ANSAcheck, ANSA can guarantee their readers the quality of information they provide. Also, the readers are provided with the ability to check the authenticity of a particular story or article by themselves. This can be done by clicking on an ANSAcheck icon at the end of the story, where reader can check the information of the writer and publisher, along with other publication details and certificates of legitimacy, that are all securely recorded on a blockchain. This use of ANSAcheck was seen to be very useful during the initial months of the pandemic, when numerous fake news stories regarding COVID-19 vaccines as well as treatments circulated. Many readers inquired verification about the origin of certain published stories. This serves as an excellent example of how blockchain can aid in not only safeguarding a brand, but also by protecting customers from encountering fake news. BT is revolutionizing the way data is shared in the world it offers numerous promising applications across various industries, including healthcare. In the healthcare sector, blockchain provides a secure solution for storing and sharing patient data. Individuals retain ownership of their data, empowering them to selectively share information with authorized parties of their choosing. This ensures data security, privacy, and enables seamless control over personal health information.

When organizations consider whether to implement a private or public blockchain, the advantages of a private blockchain are often limited, making a distributed database a more appealing option. The critical issue arises when control of data remains confined to a private circle, such as the owners of the SC, without external oversight. This arrangement contrasts with the transparency and accountability offered by public blockchains. In private SC systems, control typically resides with a restricted group of stakeholders, potentially compromising transparency and external validation. In contrast, the decentralized nature of public blockchains ensures that data is not under the control of any single entity, thereby minimizing the risk of manipulation and ensuring information integrity. It

is important to note that in the case of a private blockchain, organizations must bear substantial infrastructure costs. Moreover, if data is exclusively controlled by a single user, assurance of third-party oversight is uncertain. As a result, the blockchain ledger may not fully realize the advantages of transparency and security. Due to the limitations associated with private blockchains, there has been a noticeable decline in their usage in recent years. Taking these factors into account, the trajectory of blockchain seems to favor public blockchains. These platforms provide enhanced transparency, accountability, and security, all while reducing the risks linked with centralized control.

Transaction costs on the blockchain are not a significant concern, because in the example of Birra Peroni the implementation of tokenization typically occurs in batches, which include a significant number of beer bottles. It's crucial to prioritize understanding the complexity of the entire process and the implementation of a final blockchain solution that is customized for a specific SC, rather than fixating solely on operational expenses. Overall, the benefits brought by this technology far outweigh the associated costs.

5.4.4   Interview with Filipe Martins

The interview was conducted via telephone on March 26th, 2024, as the interviewee is based in Germany. Martins has over 15 years of credit risk experience in the international equipment leasing industry, and he currently is a general representative at Süddeutsche Leasing AG (S.D.L). S.D.L is a leasing company based in Germany that offers financial services for the purchase of machines and systems as well as complete production lines. What differentiates S.D.L from other financial services providers, is that they also offer leasing arrangements where the lessee pays periodic lease payments for the use of the asset over a specified period. S.D.L works closely two startups, the first is called Climate Grid, which is an Environmental, Social, and Governance (ESG) provider, and the second startup is called Cap-on, which is a machine data provider, and its main focus is the integration of machine data with banking systems, enabling flexible installment plans. This innovative approach allows for payments to be adjusted based on machine productivity, ensuring a fair and dynamic payment structure; this concept is called pay-per-use (PPU). So, the first use case of blockchain in this field revolves around tokenization of assets. Machines are being rented by numerous production companies even by large players in the market such as Porsche, and Mercedes. These machines used for production are being connected through the IoT and BT. This connection involves tokenizing the machines as assets, allowing for enhanced monitoring, control, and optimization of their performance and usage. Due to the fact that the entire history of the machine is recorded on the blockchain, when the owner decides to re-lease it to another organization or sell it after it has been used for several years, the blockchain data guarantees the machine's technological condition, maintenance records, and the origin and quality of spare parts. The comprehensive digital logbook of each machine ensures

transparency and immutability of data, inherent to the BT. Even though the leasing company takes on some risk with the PPU concept, as it lacks guaranteed monthly income, the benefits derived from integrating machines with BT are numerous. One key advantage is transparency, as the leasing company can monitor each machine's activity in real-time, including production output, maintenance status, and any reported issues from the producer. This real-time monitoring enables the leasing company to react promptly to any issues, thereby enhancing customer satisfaction. Moreover, having the entire history of the machinery recorded on a blockchain increases its value by at least 10% when sold, as buyers gain greater transparency and confidence in the machine's condition. This increased transparency is a substantial advantage for the leasing company, as it enhances the perceived value of its leased machinery. Not only is the input and output of each machine tracked and saved on the blockchain, but also its energy consumption. This enables the determination of whether the machine is environmentally friendly, leading to data-driven ESG practices. With all this data tracked on the blockchain, information related to energy consumption and the use of certain chemicals is recorded, resulting in a comprehensive footprint. As a result, the environmental impact of every machine's production can be quantified. The verification of environmental data is made possible by Climate Grid, which helps assists organizations in minimizing their carbon dioxide footprint, by recording data related to energy consumption, chemical usage, and other related factors on a blockchain ledger. Thereby organizations get the ability to create a transparent and tamper-proof record of their carbon dioxide emissions and environmental impact.

According to Martins, blockchain offers the following three primary advantages:

- **Intelligent payment systems**: automating payments using smart contracts allows for payments to be arranged based on the output of machines.
- **P2P payments in real time:** allowing individuals and entities to transfer funds directly.
- **Cost-effective transactions**: especially when compared to traditional international money transfers.

It's crucial to consider that the performance of a blockchain slows down as more information is added to it. Therefore, especially in complex SCs with a large number of daily transactions, it's important to store most of the collected information on centralized machines. Periodically, select important data to be recorded on the blockchain using a hash code. This approach involves hashing only the selected data, rather than the entirety of the information, helping to maintain the efficiency of the blockchain. In such cases, the blockchain ledger would not fully replace a centralized database; instead, it would complement it. Martins identifies several reasons why BT is not currently used extensively. The primary reason is the widespread lack of understanding among people regarding this technology and the benefits it offers. It's a common reaction for people to panic and withdraw when they hear the term "blockchain" mentioned in the context of its potential implementation within their

business or operations. Additionally, when considering the adoption of BT within the SC, it's important to note that some companies may not be fully prepared to embrace complete transparency.

Martins further suggests that the future of blockchain will be influenced by several key factors. Firstly, payments will evolve to become interoperable, facilitating P2P transactions. In the context of SCM, suppliers can receive payments directly from buyers, streamlining financial transactions and reducing delays. Secondly, within his area of expertise, which lies predominantly in the industry sector, transformation will manifest through the token economy and the rise of M2M transactions. This paradigm shift will introduce heightened efficiency, as the integration of IoT and blockchain will enable machines to autonomously procure necessary materials, conduct production processes, and even schedule maintenance and parts replacement beforehand. In the context of SCM, blockchain facilitates the creation and exchange of digital tokens representing assets, goods, or services. These tokens can be used to automate and optimize various SC processes, such as inventory management, asset tracking, as well as payment settlements. Thirdly, the use of smart contracts is essential for efficiently facilitating payments of machines that operate on the PPU concept, where customized payment mechanism ensures precise compensation based on the production output. Payments can then be generated in real-time, enabling the creation of invoices within a few seconds at a minimal cost. In contrast, instant payments through traditional institutions in Germany are considerably more expensive.

Having machines connected through IoT and BT, do not only offer organizations enhanced predictive maintenance, better automation, increase traceability and strengthened security, but also through retrofitting machines, it contributes to the circular economy through two key factors as explained below:

- **Efficient resource management**: continuous maintenance facilitated by this connectivity ensures machines receive timely care, thereby extending their lifespan.
- **Protecting the environment**: by preventing the accumulation of scrap and broken machines, organizations mitigate environmental impact.

 In terms of costs, according to Martins, most companies can afford the application of BT, because it is not as complicated as it may seem, and it operates on an open-source basis. This means that the software code and protocols that make up BT are freely available for anyone to view, utilize, use and modify. So, companies only need to modify it to fit their specific purposes. Martins envisions a future where blockchain serves as the singular, authoritative source of truth in operational processes. This is crucial because it ensures that there is one unalterable record of transactions and data, thus leading enhancement of transparency, accuracy, and trustworthiness within the operations of an organization. It reduces the risk of disputes, fraud, or errors, and all parties involved can with all certainty rely on the integrity of the information stored on the blockchain.

5.4.5 Interview with Věra Šmídová

This interview took place via a Zoom call on March 28th, 2024. Šmídová is a business development manager at ELA Blockchain services a.s. (EBS). Her main tasks involve ensuring the trustworthiness of data for companies using BT and guiding organizations through the entire process of integrating blockchain into their processes. EBS was founded in 2019 by the Electrotechnical Association of the Czech Republic, and their main goal is to provide customized blockchain that is tailored specifically for the needs of a particular organization or group of organizations. EBS has developed a blockchain on the Hyperledger Fabric consortium platform. Node ownership is diverse, with various independent institutions and companies, both small and large. The network includes 36 nodes, each owned independently. Examples of node owners include IBM, the Czech Technical University in Prague, and the Ministry of Industry and Trade of the Czech Republic. Šmídová believes that there are significant opportunities, particularly in leveraging BT for SCM, and also large companies, such as automotive manufacturers, can utilize this blockchain to track and trace their products effectively throughout the production and distribution processes. EBS builds three types of networks:

- **Private networks**: these networks are restricted to a single organization or entity.
- **Hybrid blockchains**: the core of the network is private. However, they can permit some individuals or entities outside of the given organization to interact with certain aspects of the blockchain.
- **Consortia blockchains**: these blockchains are of a collaborative nature, and they can be formed by multiple organizations or institutions.

The private blockchain is mainly used by manufacturers that utilize this technology to efficiently monitor and trace their products throughout the entire production process. A use case that EBS has participated in within the realm of SCM is in cooperation with ETD Transformers Inc. (ETD), that has a long history dating back to 1923 in manufacturing and supplying power transformers and other related products. Those transformers are shipped to customers packed in large boxes or containers, and customers assemble them upon delivery. Recently, the company has encountered an issue where some international customers have complained about missing components from the delivered containers and requested the delivery of the missing part. However, ETD insists that they have sent the complete package containing all necessary components and believes the customer's complaints are unfounded. A single source of truth blockchain system was found to be the perfect solution that helps in such cases by providing an immutable and transparent record of the entire SC process. In order to enhance the exit control process of ETD, it was necessary to incorporate cameras for the purpose of recording this exiting protocol. When all necessary components of a transformer are being packed, a camera records a video of the process, ensuring careful documentation of each

step of the packaging procedure. Once packed, the box is securely sealed with specific numbered seals. Subsequently, a video recording of the packaging operation is saved, and the hash of this video is stored on the national blockchain registry. Upon receipt of the box by the carrier, confirmation is obtained in the form of a picture of the sealed container. In the event of any accusations from the customer's side, ETD maintains immutable proof detailing precisely which components were packaged into a given container. This ensures precise knowledge of the contents received, with a comprehensive record maintained throughout the process. This is a great example of how BT can enhance trust between business partners through improved traceability. By serving as a single source of truth, blockchain can help prevent misunderstandings and disputes by providing an immutable record of transactions and events.

Šmídová further states that conservative organizations are usually hesitant to adopt technologies like blockchain for several reasons such as, lack familiarity with emerging technologies like blockchain and lack of understanding how they work or their potential benefits. Some traditional institutions are resistant to change due to the companies' culture, as they may struggle to overcome the resistance to change and embrace new ways of operating. Moreover, the perceived complexity of BT can also pose a challenge, so conservative organizations may perceive blockchain as overly complicated and may be hesitant to invest time and resources in understanding it. BT has the potential to effectively reduce risk exposure and it serves as a preventive measure against various forms of fraud, data breaches, and security vulnerabilities by leveraging its inherent features to ensure trust. A lot of companies may not prioritize implementing this technology until they experience specific challenges or issues, such as data attacks or security breaches. This reactive approach to technology adoption is often driven by a desire to address immediate concerns rather than proactively investing in preventive measures. The implementation complexity varies depending on the nature of the blockchain network. For a straightforward network where documents are stored and basic metadata is added, with up to 10 nodes, the implementation timeline typically spans up to 1 month. An experienced programmer can effectively build this network within that timeframe. However, for a more intricate blockchain system requiring tracing functionality, involving independent institutions or companies as corporate node owners, and incorporating smart contracts, the implementation timeline extends significantly. In such cases, the process usually takes between 6 to 12 months to complete. This longer timeline accounts for the additional complexities involved, including the development of sophisticated tracing mechanisms, integration of diverse corporate entities, and accurate deployment of secure and efficient smart contracts.

The costs of implementation are not easily specified because they vary depending on the size and complexity of the project. Additionally, during the operational phase, the cost of storing records in a national blockchain registry typically fluctuates around 100 CZK per record. Node owners have the

ability to store records for even less, often around tens of crowns each. For large companies, such as those in the automotive industry collecting production data, fees are determined based on ledger size. The pricing structure can also vary based on the amount of data being stored. Following is an estimated list of costs for the integration of private blockchains:

- **Simple application:** around 100,000 CZK.

- **Average and medium size projects**: approximately 500,000 CZK.

- **Large projects**: such as those from industrial automation spanning over two years, may incur costs totaling around 10,000,000 CZK.

Regarding return on investment (ROI), in some instances, monitoring of returns is not conducted at all, because some company's objectives are not monetary, and the benefits of the project may be measured in terms of non-financial outcomes rather than monetary gains.

5.4.6   Interview with Paul Brody

The interview took place via a Zoom call on April 2nd, 2024, as the interviewee is based in the US. Since 2016, Brody has been a global blockchain leader at EY. According to Brody, BT will be very useful in SCM. The benefits arising from BT can be categorized into two main areas. Firstly, tokenization of assets facilitates reconciliation across the network. In this system, a token must leave its original location before it can be transferred elsewhere. Such a mechanism is currently absent in traditional SC processes. However, with blockchain and tokenization, the implementation of such a system becomes feasible, leading to a substantially more accurate and transparent SC. This end-to-end SC will greatly enhance visibility and accuracy in tracing the origins of items, thanks to the historical records associated with each token. The second area is automating business transactions using smart contracts, and the result would be having a much more efficient SC. Incorporating BT effectively necessitates addressing specific privacy considerations. This is because companies cannot include certain sensitive information, such as inventory levels and other proprietary data, in the blockchain to prevent competitors from accessing it.

The solutions to a successful and effective utilization of public blockchains within the SCs is the establishment of a scalable privacy infrastructure. This is being achieved through the creation of the following two tools; the first tool is a layer two blockchain network built on top of Ethereum, known as Nightfall. Nightfall operates as a Zero-knowledge Roll-Up solution, which is a method facilitating private transactions on the public Ethereum blockchain. By leveraging Nightfall, organizations can seamlessly conduct private transactions, and moving tokens around, while ensuring efficiency without compromising the transparency, data immutability, and security. The second tool, is called Starlight, which has the ability to turn smart contracts into a set of mathematical proofs, which are called a zero-

knowledge circuit. Starlight enables one party to demonstrate awareness of specific information to another party without disclosing the information itself. This was created for the necessity to make the business agreements private, in order to protect sensitive information and maintain confidentiality. Both tools are currently being tested and utilized by a few companies, yet they are still in the early stages of implementation.

There are several challenges arising from organizations utilizations of private blockchains. Firstly, there has been significant confusion in the market regarding this technology until recently. There is a common misconception that private blockchains provide complete privacy. However, the privacy they offer is quite limited, as all members of the private blockchain can view all transactions. This becomes problematic when a company works with two competing suppliers on the same network, and each supplier can see the other's transactions. This exposes sensitive information that neither party would want to disclose. So, numerous companies that have invested in private blockchains have realized that not only are these systems costly, but they also fail to deliver the expected level of privacy. Another significant issue, especially with private networks, is their proprietary nature. For example, if Company A has its own private blockchain network (Blockchain A) and Company B has its own (Blockchain B), and they share the same supplier, that supplier would need to join both Blockchain A and Blockchain B. This process is not only a complex procedure, costly and time-consuming but also inefficient. In regards to immutability, most private blockchain have only one node. Essentially, if there's only one node in a private blockchain, the owner of that node has complete control over the data and transactions recorded on the blockchain. While it's true that a centralized system can replicate many functionalities offered by blockchain, it's crucial for companies to grasp the strategic value proposition that blockchain presents.

Ultimately, despite the initial costs and challenges, the benefits derived from BT far outweigh the investment for enterprises. A compelling illustration of this principle is evident in EY's collaboration with Microsoft. By leveraging smart contracts, they transformed their Xbox video game procurement system. This transition led to a remarkable reduction in contract data processing time, which was cut by 99% from 45 days to a just 4 minutes. Moreover, the overall costs associated with managing the contract infrastructure dropped by 40%. This example clearly demonstrates how BT can revolutionize processes, significantly enhancing efficiency and cost-effectiveness for enterprises.

5.4.7 Notable findings from expert interviews

TABLE 3: KEY INSIGHTS OBTAINED FROM EXPERT INTERVIEWS; SOURCE: AUTHOR

Insights obtained from expert interviews	Specifics
Public blockchains	5 out of 6 interviewees agreed that public blockchains bring way more benefits for enterprises than the private ones, because they are cost efficient, immutable, and fully decentralized.
Asset tokenization	All interviewees agree that asset tokenization hold the potential to revolutionize traditional SCs by enhancing traceability, efficiency, transparency, and accountability.
Benefits exceed the costs	All interviewed experts believe that the short-term as well as long-term benefits of BT outweigh the costs, making it a worthwhile investment for enterprises seeking to innovate, improve efficiency, and to remain competitive in the digital era.
Privacy and scalability concerns	For unlocking the full potential of BT, privacy technologies, and scalability solutions are necessary for having seamless and effective processes of public blockchains.
Blockchain within SC	All interviewees agree that BT introduces a transformative approach to SC by offering transparency, traceability of goods, real-time visibility, as well as enhanced security.
Positive impact on the environmental and life in general	Most interviewees agree that BT holds significant promise for improving environmental sustainability by reducing the occurrence of counterfeit products, ensuring authenticity of goods, and minimizing the environmental impact of fraudulent manufacturing. Moreover, it encourages responsible sourcing and production methods, leading to better carbon dioxide emissions. Additionally, it enables faster recalls in case of food contamination.

6 Analysis and insights

Building upon the data collected through literature review, case studies, and expert interviews, comprehensive analysis of this chapter cover decision tree analysis, PESTEL analysis, qualitative cost-benefit analysis, and SWOT analysis, providing valuable insights for organizations that would be interested in implementing BT within their SC.

6.1 Decision tree analysis

Prior to diving into the BT implementation, it's crucial for each company to carefully assess whether this technology truly represents the optimal solution for their existing challenges. Moreover, in the event that blockchain implementation is deemed viable, the decision tree assists in determining whether the organization should select a private or public blockchain solution.
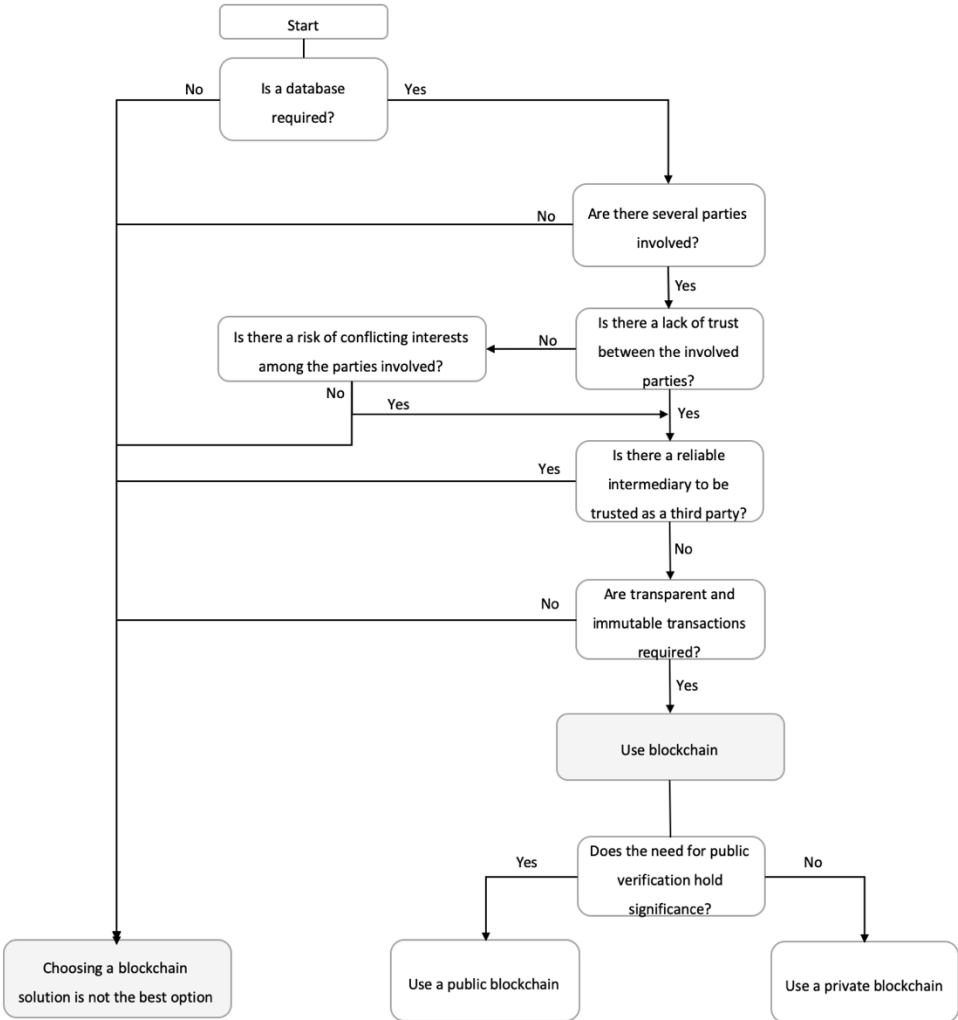

FIGURE 7: DECISION TREE FOR ASSESSING BLOCKCHAIN UTILIZATION; SOURCE: AUTHOR

6.2 PESTEL analysis

Conducting political, economic, social, technological, environmental, and legal analysis provides organizations with valuable insights into the external factors that could potentially have an impact on the success of implementation of BT.
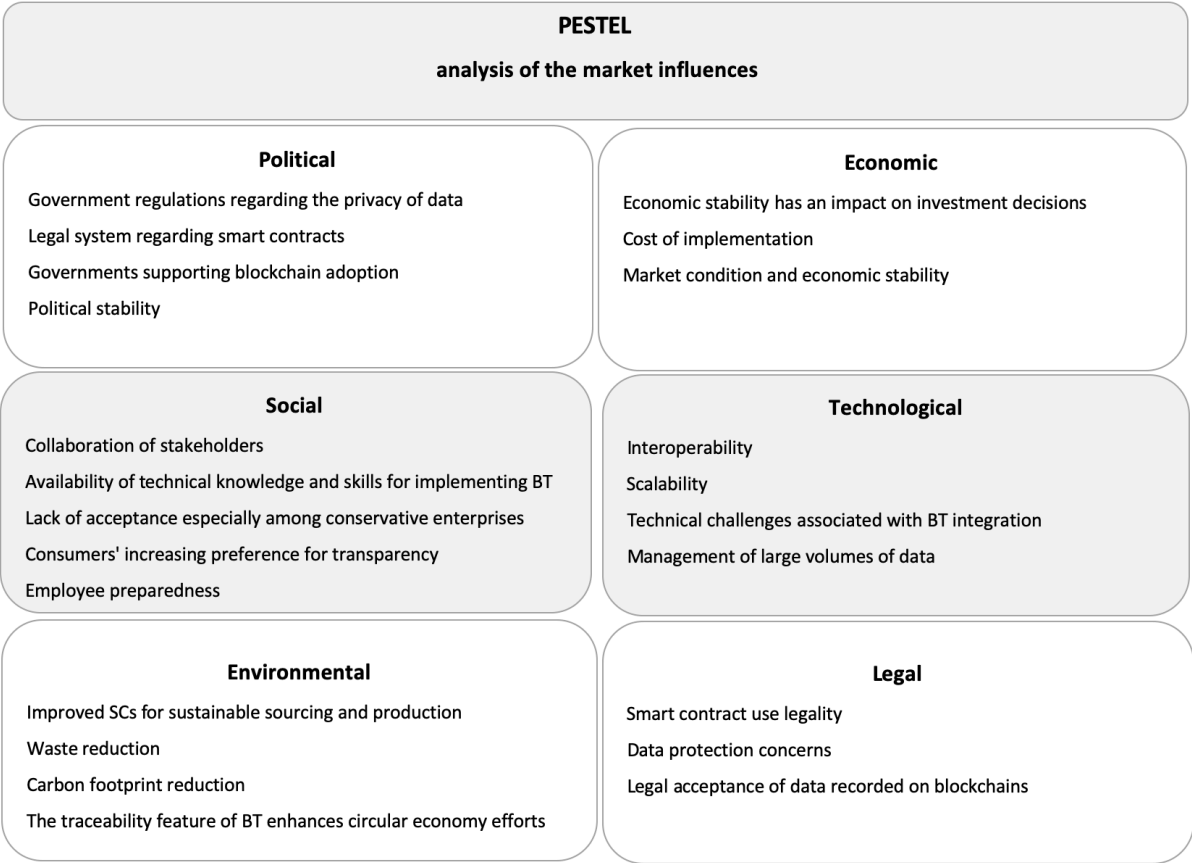
PESTEL

analysis of the market influences

Political

Government regulations regarding the privacy of data

Legal system regarding smart contracts

Governments supporting blockchain adoption

Political stability

Economic

Economic stability has an impact on investment decisions

Cost of implementation

Market condition and economic stability

Social

Collaboration of stakeholders

Availability of technical knowledge and skills for implementing BT

Lack of acceptance especially among conservative enterprises

Consumers' increasing preference for transparency

Employee preparedness

Technological

Interoperability

Scalability

Technical challenges associated with BT integration

Management of large volumes of data

Environmental

Improved SCs for sustainable sourcing and production

Waste reduction

Carbon footprint reduction

The traceability feature of BT enhances circular economy efforts

Legal

Smart contract use legality

Data protection concerns

Legal acceptance of data recorded on blockchains

FIGURE 8: PESTEL ANALYSIS FOR BLOCKCHAIN IMPLEMENTATION; SOURCE: AUTHOR

6.3 Qualitative cost-benefit analysis

Even though quantitative analysis is often favored for making important business decisions due to its precision and numerical clarity, a qualitative analysis is chosen in this case for several reasons:

- Challenges in quantifying certain aspects.
- The impact of BT on organizations can vary widely depending on subjective factors such as organizational culture, and readiness for innovation.
- As companies that adopted this technology several years ago have not yet revealed their outcomes and quantifiable benefits.

- In terms of costs, very few rough estimates are publicly accessible due to the novelty of this technology.
- The number of participants using the blockchain can also have an impact on the costs.

TABLE 4: COSTS ASSOCIATED WITH BLOCKCHAIN IMPLEMENTATION; SOURCE: AUTHOR

Costs
Costs related to development and testing of a customized blockchain solution
Costs associated with integrating BT with existing SCM systems
Training costs for employees and business partners
Transaction fees
Maintenance and support fees

TABLE 5: BENEFITS ASSOCIATED WITH BLOCKCHAIN IMPLEMENTATION; SOURCE: AUTHOR

Potential benefits and challenges		
Factors	**Potential benefits**	**Potential challenges**
Transparency	Enhanced transparency	Resistance to transparency from certain partners
Traceability	Improved traceability of products through the entire SC	Initial investment costs of tracking systems
Real-time visibility	Enhanced visibility into product movement	Related technological challenges
Efficiency	By automating manual processes	Training and skill development requirements
Immutability	Immutability and enhanced security	Data accuracy concerns
P2P transactions	Removing certain intermediaries results in reduction of associated costs	Possible regulatory challenges
Improved collaboration	Facilitated collaboration among SC partners	Compatibility concerns
Customer satisfaction	Enhancing customer experience through transparency Increased customer loyalty	Customers need to be educated
Process automation	Minimize human involvement leading to fewer errors Increase in productivity Reduced labor costs	
Faster response to outbreaks	Prompt detection and rapid response to outbreaks Minimized impact of product recalls Enhanced customer satisfaction	Data in the network needs to be accurate and reliable

	Reductions of waste due to accurate tracking and monitoring	
Environmental impact	Reduced paper consumption due to digitizing certificates, invoices, etc.	
	Carbon footprint reduction	
Brand reputation	Brand reputation enhancement	

The costs associated with implementing BT in a company's SC vary based on factors like SC size, technological infrastructure, and customization needs. Thorough assessments are necessary to understand individual requirements before undertaking BT initiatives. Despite potential costs, implementing BT offers numerous benefits such as efficiency improvement, enhanced collaboration, environmental impact, customer satisfaction, and brand reputation enhancement. Successful BT adoption can yield significant financial advantages, though actual impacts depend on factors like implementation scale and industry conditions. Uncertainties in ROI calculations stem from uncertain timelines, delayed benefits realization, and external dependencies. According to Vyas et al., organizations need to undergo a fundamental transformation, change in perspective, mindset, or approach when it comes to investments into innovations. Most organizations have primarily focused on ROI as a key performance indicator when evaluating investments. Organizations often prioritize projects or investments that promise quick and tangible financial gains. This shift involves recognizing the strategic value of an investment and the long-term benefits of investing in innovation. Instead of solely focusing on ROI, organizations should broaden their perspective beyond short-term financial returns and embrace a more comprehensive approach to investment decision-making. This approach can be referred to as Return on Investment into Innovation (ROI^2). This term specifically refers to the return generated from investments made in innovation initiatives, such investments include research and development, new product development, or technology adoption. While similar to traditional ROI, ROI^2 focuses on the outcomes and benefits resulting from investments in innovation and technological advancements. These benefits may include increased revenue, market share, competitive advantage, cost savings, improved efficiency, or enhanced customer satisfaction. ROI^2 considers not only financial returns, but also strategic benefits and intangible outcomes associated with innovation efforts, (Vyas et al., 2022, p. 253–254).

6.4 SWOT analysis

In this segment, a SWOT analysis is performed to methodically assess the strengths, weaknesses, opportunities, and threats linked to integrating BT into the company's SC. The qualitative

data utilized for the SWOT analysis were derived from theoretical research, practical applications of BT, insights gathered from expert interviews, and PESTEL analysis. Firstly, factors are identified that organizations may face when implementing BT. Secondly, factors are assigned importance weights based on their perceived significance. Thirdly, each factor is numerically evaluated based on its current status or impact. The numerical scale used is, 1 to 5, with 1 representing the lowest and 5 representing the highest.

STRENGHTS	Importance	Evaluation	Weighted values
Enhanced data security and accessibility	0.1	5	0.5
Improved traceability of data	0.1	4	0.4
Enhanced transparency in data management	0.1	4	0.4
Seamless transition of data between stakeholders	0.1	4	0.4
Enhanced compatibility and integration of data	0.05	3	0.15
Immutablity ensuring tamper-proof transaction records	0.1	5	0.5
Ability to bypass intermediaries, facilitating direct transactions	0.1	4	0.4
Ensuring authenticity of products, certificates, and information	0.15	5	0.75
Optimized payment processes by using smart contracts	0.1	4	0.4
Validating the authenticity of products	0.1	4	0.4
Total	**1**		**4.3**

FIGURE 9: STRENGTHS ANALYSIS FOR BT IMPLEMENTATION; SOURCE: AUTHOR

WEAKNESSES	Importance	Evaluation	Weighted values
Insufficient familiarity with this technology	0.1	-3	-0.3
Limited availability of skilled personnel	0.1	-4	-0.4
Limited number of use cases to learn from	0.1	-3	-0.3
Lack of industry standards for blockchain	0.1	-3	-0.3
Lack of incentives for small entities and partners to join the network	0.1	-2	-0.2
Scalability concerns	0.1	-4	-0.4
Implementing BT can involve significant upfront costs	0.15	-5	-0.75
Essential restructuring and adjustment of current systems	0.25	-5	-1.25
Total	**1**		**-3.9**

FIGURE 10: WEAKNESSES ANALYSIS FOR BT IMPLEMENTATION; SOURCE: AUTHOR

OPPOURTUNITIES	Importance	Evaluation	Weighted values
Enhanced transparency	0.15	4	0.6
SC optimization by utilizing smart contracts	0.15	5	0.75
Better collaboration with industry partners	0.1	4	0.4
Faster response to outbreaks	0.1	4	0.4
Consumers tracking product journey/story	0.15	5	0.75
Strengthened consumer trust and loyalty	0.15	5	0.75
Gaining a competitive leading to increased market share	0.1	4	0.4
Brand reputation enhancement	0.1	4	0.4
Total	**1**		**4.45**

FIGURE 11: OPPORTUNITIES ANALYSIS FOR BT IMPLEMENTATION; SOURCE: AUTHOR

THREATS	Importance	Evaluation	Weighted values
Restricted understanding of the technology beyond its association with cryptocurrencies	0.15	-4	-0.6
Lack of clarity on the appropriate applications	0.15	-4	-0.6
Selecting an inappropriate blockchain platform	0.1	-3	-0.3
Vulnerability to low-quality information heightens the risk to information resilience	0.15	-4	-0.6
Emphasis on traditional practices and a lack of innovation	0.1	-3	-0.3
SCs' preparedness for genuine information transparency	0.15	-4	-0.6
Unknown costs associated with innovations in BT	0.1	-3	-0.3
Scalability concerns	0.1	-4	-0.4
Total	**1**		**-1.5**

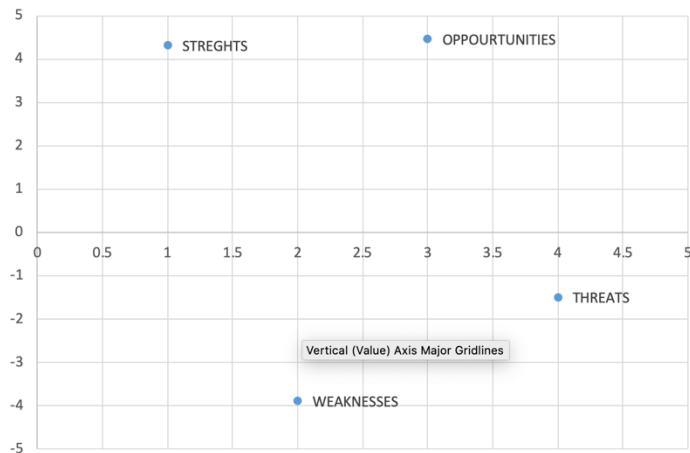FIGURE 12: THREATS ANALYSIS FOR BT IMPLEMENTATION; SOURCE: AUTHOR

FIGURE 13: SWOT ANALYSIS RESULTS PRESENTED IN A DOT CHART; SOURCE: AUTHOR

The results of the SWOT analysis indicate that the integration of BT into a company's SC offers significant internal advantages or strengths, as well as s external opportunities that could be gained by companies after a successful application of this technology. Strengths highlighted, with an average score of 4.3, significantly enhance organizational competitiveness and performance by ensuring enhanced data integrity, streamlined processes, increased transparency, and secure transactions. Bypassing intermediaries reduces fees and grants more control over negotiations, while smart contracts automate payment processes, minimizing errors and delays. Validating product authenticity improves quality control and efficiency, positioning blockchain adopters as industry leaders in innovation and excellence. However, weaknesses an average score of -3.9 such as lack of familiarity with the technology, shortage of skilled personnel, and limited use cases for learning, coupled with the absence of industry standards and incentives for small entities to join the network, pose significant challenges. Successful implementation requires cooperation from all stakeholders, including small entities, which may be discouraging by high costs and the need for system restructuring. Nevertheless, opportunities indicated by a weighted average score of 4.45 offer opportunities for increased efficiency through smart contracts, innovation positioning, fraud reduction, and improved collaboration. Faster response to outbreaks builds customer trust and compliance with regulations, while product tracking enhances consumer satisfaction. Early adoption grants competitive advantage and brand reputation enhancement, driving organizational success and strategic positioning in the market. Threats of an average score -1.5 are relatively low. These include limited understanding of BT necessitating customer education on its benefits for product authentication. Educating business partners is also crucial, while cost concerns, scarcity of industry professionals, and vulnerability to low-quality information pose additional threats, highlighting the importance of proactive mitigation strategies. Based on the results from the SWOT analysis, the strengths and opportunities outweigh the weaknesses and threats for implementing BT. So, companies equipped with sufficient resources should strongly consider adopting BT.

6.5 Discussion of interim results

Despite limited disclosure of results by companies who implemented BT within their SCs, BT shows great promise in addressing SC challenges and revolutionizing various industries. Its decentralized and secure nature enhances data sharing and collaboration among business partners, particularly in sectors requiring trust. BT's transparency and traceability reshape product monitoring and provide customers unprecedented access to product information. Industry experts believe BT yields substantial returns, but its full benefits require maximum utilization. Moreover, BT promotes sustainability, reduces waste, and enhances food safety by enabling swift outbreak responses.

Scalability is crucial for large companies with numerous partners, ensuring effective management of data and transactions within blockchain networks. Companies like H&M must integrate a significant portion of their product range into the blockchain ecosystem to maintain transparency and customer trust. Selective inclusion of products may raise concerns about system integrity and completeness of information. Investing in scalable blockchain solutions is essential for most companies to track their extensive product portfolios, while ensuring efficiency and reliability. Additionally, it's vital to choose the right type of blockchain based on organizational objectives. For companies prioritizing transparency and customer involvement, a public ledger is ideal, but privacy layers are necessary to protect sensitive information. This ensures transparency while safeguarding competitive advantage. Alternatively, for companies like ETD needing immutable proof of components sent to customers, a private blockchain offers great control and privacy. Restricted access to approved participants ensures confidentiality and security, while maintaining transparency and traceability for internal processes.

6.5.1   What the future holds?

Blockchain holds significant promise when used correctly and utilized effectively. From numerous use cases of BT, it is apparent that, the use of private blockchains have dominated the market, (Lohmer and Lasch, 2020). However, according to professionals with expertise in the blockchain field such as Perrone (2024), while achieving full transparency is anticipated to be complex and time-consuming, a significant market shift is underway. More companies are transitioning to using public blockchains to embrace transparency fully. Professionals in the blockchain field are noting this movement towards increased acceptance and usage of public blockchain networks, indicating a growing trend across various applications and signaling a notable evolution in the industry. Other industry experts such as Martins (2024), see considerable potential for the integration of IoT, BT, and AI. In today's fast-moving consumer environment, manually verifying the origin of every product in a supermarket can be impractical for consumers. However, AI offers innovative solutions, particularly in online shopping, as it can filter products based on criteria aligned with a shopper's values, such as environmentally-friendly production methods, ethical manufacturing standards, or traceable origins. This automated decision-making process customizes product selections to individual preferences, (Mutz, 2019). Moreover, integrating BT into the SC further enhances transparency and trust. By securely recording and verifying the origin and journey of products, blockchain ensures the authenticity and sustainability of purchases. When combined with AI-driven solutions, consumers receive customized selections of filtered and verified choices, building confidence in purchases without the need for manual inspection. This streamlined approach not only saves time for consumers, but also strengthens SC integrity, fostering greater consumer trust in the products they buy. As a result,

organizations that utilize public BT to adopt full transparency gain a competitive advantage over others in the market.

6.5.2   Research limitation

A notable limitation of this research stems from the difficulty in acquiring firsthand insights from individuals within companies involved in the case studies that have integrated blockchain solutions into their SCs. For instance, many of these individuals express hesitance in sharing their experiences and the obstacles they encountered, citing privacy concerns and contractual obligations. Consequently, several interview requests extended by the researcher were regretfully declined. Furthermore, the data collection method used in the research was exploratory and qualitative due to the novelty of this technology and its limited implementation in SCs. Despite analyzing three use cases and conducting expert interviews, a notable research gap exists in the absence of comprehensive empirical studies examining the long-term impacts and adoption challenges of BT implementation in SCs. While numerous studies discuss the technology's benefits, empirical evidence validating these claims remains limited. Therefore, future research efforts should prioritize conducting robust empirical investigations to bridge this gap and provide valuable insights for decision-makers in the field.

Conclusion

This comprehensive document analyzes the current state and potential opportunities associated with the utilization of BT within the realm of SCM. The research methodology takes an exploratory qualitative approach. In addition to the theoretical exploration, this analysis gains depth through the examination of three distinct use cases. The first case study delves into the experience of a retailer in integrating BT into its SC processes, providing valuable insights into real-world implementation challenges and benefits. The second case study offers perspectives from a manufacturer's journey in adopting blockchain solutions, shedding light on practical considerations and outcomes. Lastly, insights from a multinational apparel brand's experience with BT are included. Moreover, this study also incorporates insights obtained from expert interviews, adding rich perspectives and practical wisdom to the analysis. Additionally, the findings from all stages are thoroughly analyzed using a variety of techniques, including decision tree analysis, PESTEL analysis, qualitative cost-benefit analysis, and SWOT analysis. As a result, it was found that BT stands as a transformative innovation in modern business practices, offering solutions to numerous challenges faced by contemporary SC. In the realm of SCM, blockchain presents significant potential for enhancing transparency, optimizing processes, and maintaining competitive advantages in a globalized environment. The decentralized structure of this technology, transparency, and resistance to manipulation can revolutionize the management and control of SC. The effectiveness of blockchain implementations depends on various factors, including the involvement of business partners in the implementation process, scalability, and interoperability. Collaborating with partners ensures that the blockchain solution aligns with the needs and objectives of all stakeholders, while scalability and interoperability ensure seamless integration and adaptability to evolving business environments. Although detailed financial information regarding costs may be lacking, industry experts agree that the implementation of blockchain solutions within SCs offers benefits that far exceed the associated costs. It is imperative for each company initiating on this integration to carefully assess the potential costs, tailored to its specific operations and needs. Looking ahead, continued advancements in the implementation of blockchain solutions are anticipated, with a growing emphasis on the utilization of public blockchain networks, due to their full decentralization. This trend is expected to drive widespread adoption, and companies that fail to invest in this innovation risk falling behind their competitors and may miss out on opportunities for enhanced competitiveness and unique positioning in the evolving SCM landscape.

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Appendix 1: expert interviews

Interview 1 with Jakub Tesař

1. **What are the fundamental elements of BT?**

   Tesař believes that decentralization, scalability, and security are the key factors forming the foundation of all blockchains. These three could be understood as "the holy trinity of all blockchains"

2. **Which blockchain is most commonly used in the enterprise, public, private, or consortium?**

   Public blockchains emerge as the preferred choice for companies looking to leverage BT. Other blockchains are also used, but they do not offer as many advantages as the public ones. Tesař emphasizes the pivotal role of public blockchains in revolutionizing transactions and external stakeholder cooperation within businesses. He highlights the inherent benefits of decentralization, scalability, and security as the core pillars of public blockchains, which form the foundation for their transformative impact across various industries.

3. **What are the limitations of private blockchains?**

   Tesař underscores the limited benefits of private blockchains compared to public ones, noting their permissioned nature and lack of decentralization and transparency. He argues that public blockchains offer greater transparency and inclusivity, making them more suitable for businesses seeking to enhance trust and transparency in their operations. Moreover, Tesař suggests that in some cases, the implementation and use of public blockchains may even be more cost-effective than other types of infrastructure, further reinforcing their appeal to businesses.

4. **What is EY OpsChain that is used by the Italian company Birra Peroni? What did they mainly want to achieve when implementing BT within their SC?**

   EY OpsChain platform brings innovative solutions to SC as well as inventory management. The EY OpsChain SC manager can instance be used to trace the land or farm where its sub-components are from, to its customers and further all the way to its decomposed state back in the recycling point, eventually back to production again. The EY OpsChain is currently being successfully used by Birra Peroni. The main goal of Birra Peroni was to increase transparency throughout its SC. They achieved this by utilizing EY OpsChain, which enabled them to track the entire journey of their products, from the origin of raw

materials to the final product delivered to customers. By leveraging blockchain technology, specifically through the use of NFTs as digital certificates, Birra Peroni ensured transparency and traceability, allowing customers to verify the origin and quality of their products. Through this implementation, Birra Peroni successfully addressed their objective of enhancing transparency in their SC operations.

5. **Does Birra Peroni already have any results regarding the success of the implementation? How satisfied are they with the use of BT?**

   Tesař did not provide specific details on the outcomes or satisfaction levels of the company, as the project has been under the control of the Italian EY team. However, based on the information that he has, the project has been successful. Products are still being tracked through BT and beers that are currently being sold include the special QR codes, so customer can track the journey of each bottle/can.

6. **How would you define the role of BT in the context of SCM?**

   Tesař defines the role of BT in SCM as transformative and foundational. He emphasizes blockchain's ability to enhance transparency, traceability, and trust throughout the SC ecosystem. By leveraging blockchain, companies can securely record and track every stage of the SC, from the sourcing of raw materials to the delivery of finished products to consumers. This ensures greater visibility into product provenance, quality control, and compliance with regulations. Additionally, blockchain facilitates real-time sharing of data among SC partners, enabling seamless collaboration and efficient decision-making. Overall, BT serves as a catalyst for driving operational efficiency, reducing costs, mitigating risks, and ultimately improving the overall resilience and sustainability of SC networks.

7. **How important is the role of asset tokenization?**

   The role of asset tokenization is crucial in the evolution of BT. He emphasized that asset tokenization is seen as a major aspect of the future of BT, particularly in two significant aspects. Firstly, asset tokenization is vital for enhancing transparency and traceability in SCs. Secondly, it has broader applications beyond SCs, such as in the financial sector and brand promotion strategies. Tesař highlighted examples of companies like Starbucks, Adidas, and Nike, which have already adopted tokenization in their loyalty programs. Overall, he underscored that asset tokenization plays a pivotal role in leveraging BT to create more efficient and transparent systems across various industries. Additionally, Tesař mentioned a collaboration between EY and Microsoft in the gaming industry, where BT was utilized for royalty processing on the Xbox platform. This implementation improved operational efficiency, reduced processing time, and enhanced transparency for all participants involved.

8. **How can companies assure the privacy of their information provided on a public ledger?**

   Companies can ensure the privacy of their information on the ledger through various means. One effective approach is to utilize techniques like zero-knowledge proofs or privacy protocols such as Nightfall, which provide enterprise-grade privacy features on public blockchains. These protocols add a layer of privacy on top of the blockchain, allowing users to conduct completely private and confidential transactions while still leveraging the benefits of BT. Additionally, companies can implement robust access controls and encryption mechanisms to safeguard sensitive data stored on the ledger, ensuring that only authorized parties have access to the information they need. It's also essential for companies to stay updated on the latest advancements in blockchain privacy technology and continually reassess their privacy strategies to mitigate emerging threats and vulnerabilities. Tesař also stated that "anonymity is not the same as privacy". As organizations move to public blockchain and aim to become more transparent, earn the trust of their customers, partners, and regulators, it is necessary for transactions to be transparent and not anonymous, in order to allow organizations to have some level of privacy so they can be able to protect their businesses.

9. **Are there differences in implementation costs by blockchain type?**

   Tesař emphasized that there are indeed differences in implementation costs depending on the type of blockchain being used. While the specific costs can vary based on factors such as the complexity of the implementation, the type of industry, and the scale of the project, certain trends can be observed. In many cases, implementing the public blockchain is cheaper than implementing a private one. Public blockchains, such as Ethereum, often have lower upfront costs because they rely on decentralized networks of nodes and do not require extensive infrastructure investments by individual organizations.

10. **Do you think Smart contracts play a key role in process automation?**

    Yes, absolutely, Tesař stated. Smart contracts are instrumental in process automation. They offer several benefits to businesses, including improved process efficiency, the ability to compose business logic seamlessly, reduction of manual errors, and faster settlement times for transactions without the need for manual verification. Overall, smart contracts significantly contribute to streamlining operations and driving automation in various business processes.

11. **What future trends and developments do you foresee in the use of BT?**

    Tesař highlights two major future trends in BT. Firstly, he emphasizes the increasing tokenization of assets, which is not only applicable in SCM for transparency and traceability but also extends to other sectors such as finance and brand promotion.

Secondly, he underscores the importance of smart contracts, which offer numerous benefits to businesses including improved process efficiency, composability of business logic, error reduction, and faster transaction settlements without manual verification. These trends are poised to drive further adoption and innovation in the blockchain space.

Interview 2 with Travin Keith

1. **Can you give me a brief overview of your experience with BT?**

   Keith has been deeply involved in BT since 2016, working on numerous projects and serving as an advisor for various blockchain companies and government organizations. Notably, he co-authored the white paper for Hyperledger and has been an advocate for blockchain's potential across industries.

2. **What sectors will BT affect the most?**

   Keith believes that BT holds immense potential to revolutionize a multitude of sectors. While its impact is already observable in finance, particularly with the advent of cryptocurrencies and DeFi, its influence extends far beyond. SCM stands out as a sector ripe for transformation, where blockchain's inherent features of transparency, immutability, and traceability can address longstanding challenges like counterfeit goods, inefficient processes, and lack of trust among stakeholders. Moreover, industries such as healthcare, where secure and transparent sharing of patient data is paramount, and real estate, where tokenization can democratize access to property ownership, are poised to benefit significantly from blockchain integration. Additionally, sectors like logistics, energy, and government services are also likely to experience substantial disruption as BT continues to evolve and find new applications.

3. **What projects have you participated in?**

   Keith has been involved in several projects revolving around BT since 2016. Some of these projects include co-authoring the white paper for Hyperledger, an initiative of the Linux Foundation, and serving as the lead technical designer for a blood and organ donation platform as part of the Blockchain 4 EU project by the European Commission. Additionally, he has co-founded and currently advise companies such as Immunefi, a platform specializing in bug bounties for web3 and smart contract security, and STOKR, a digital investment platform for alternative assets utilizing BT. His involvement also extends to advising various blockchain companies, cryptocurrency-related projects, and government organizations.

4. **Which blockchain is most often used in a company, public, private, or consortium?**

   Keith emphasizes the importance of aligning blockchain solutions with specific project needs and goals. While public blockchains offer transparency, private blockchains restrict access to a defined group. However, he suggests that private blockchains may not fully utilize the decentralization aspect of BT.

5. **How would you define the role of BT in the context of SCM?**

   In the context of SCM, BT serves as a transformative force, fundamentally reshaping how goods and information flow across complex networks. At its core, blockchain offers unparalleled transparency, immutability, and traceability, providing a secure and decentralized ledger for recording transactions and tracking assets at every stage of the SC. By leveraging blockchain, companies can enhance visibility into the provenance and movement of goods, mitigating risks related to counterfeiting, fraud, and inefficiencies. Moreover, smart contracts, a key feature of BT, enable automated execution of predefined agreements and conditions, streamlining processes such as payments, compliance verification, and contract management. This automation not only reduces reliance on intermediaries but also minimizes errors and delays, leading to increased efficiency and cost savings. Additionally, blockchain facilitates greater collaboration and trust among SC participants by establishing a shared, tamper-proof record of transactions and data exchange. This heightened level of trust fosters stronger relationships between stakeholders, paving the way for innovative business models and SC optimization. Overall, the role of blockchain in SCM extends beyond mere digitization; it represents a paradigm shift towards more transparent, resilient, and sustainable SCs that can adapt to the evolving demands of the global marketplace.

6. **How would you define the main difference between the public and private blockchain?**

   The main difference between public and private blockchains lies in their accessibility and control. Public blockchains, such as Bitcoin and Ethereum, are open networks where anyone can participate, transact, and access the data stored on the blockchain. These networks are decentralized and permissionless, meaning there are no restrictions on who can join or interact with the blockchain. On the other hand, private blockchains are permissioned networks where access is restricted to a specific group of participants. These networks are typically controlled by a central entity, such as a corporation or consortium, which governs who can join the network and participate in consensus mechanisms. Keith emphasizes the importance of aligning blockchain solutions with specific project needs and goals, particularly in the context of choosing between public and private blockchains. He suggests that while public blockchains offer transparency, private blockchains restrict access to a defined group. However, Keith points out that private blockchains may not fully utilize the decentralization aspect of BT. He highlights the need for careful consideration of these factors and the importance of selecting a blockchain solution that aligns with the desired level of accessibility, control, and decentralization required for each use case. This nuanced approach reflects Keith's deep understanding of the complexities involved in

implementing BT and underscores the need for tailored solutions that address the unique requirements of each project or organization.

7. **When speaking of increasing transparency, does it make sense to use a private blockchain?**

    Private blockchains restrict access to a defined group of participants, which inherently limits transparency compared to public blockchains where data is accessible to anyone. In 99% of the cases, using a private blockchain does not make sense. Especially when a company promotes transparency and would like to involve the customer in this process. Anytime people or the public are involved, it means that the blockchain has some level of publicness. The level or private/public could be understood as a scale, which goes up and down. In the example of H&M sharing only a certain amount of data and not necessarily need to share information like how much inventory it has and so on. However, to embrace full transparency, it is necessary to use a public network

8. **What challenges does blockchain implementation bring to businesses?**

    Keith highlights the challenges that blockchain implementation presents to businesses, notably the significant investment required in developers and solution architects. Due to the scarcity of proficient blockchain experts and the evolving nature of the technology, estimating costs for implementation can be challenging. Additionally, the integration of blockchain demands extensive investments in research, particularly when entering into unexplored areas. Predicting these costs becomes challenging as various implementations come with distinct costs, tailored to meet the specific requirements of individual users. Furthermore, Keith underscores that blockchain implementation is fairly expensive, posing a barrier for many companies, particularly startups, which may struggle to afford it. The precise expenses incurred by companies adopting this technology often remain undisclosed to the public, indicating the complexity and variability of costs associated with blockchain implementation. He states that one of the biggest challenges that companies face when implementing BT, is lack of technology experts, lack of developers, and people who know how to work with BT.

9. **Is there a general solution for all companies looking to improve their SC, or does blockchain need to be tailored to each business differently?**

    Keith suggests that there isn't a one-size-fits-all solution for companies seeking to enhance their SC using BT. Instead, he emphasizes the importance of tailoring blockchain solutions to meet the specific needs and goals of each business. While blockchain offers various benefits such as transparency and traceability, its implementation should align with the concrete problems and objectives of a given project or company. Keith highlights that

simply focusing on a single benefit that blockchain brings might not justify its use, as there might be more efficient technologies for solving specific problems. He stresses the innovative nature of blockchain lies in the combined benefits it offers rather than any singular advantage. Therefore, businesses should carefully assess their requirements and objectives to determine whether BT is the most suitable solution for their SC challenges.

10. **Is it hard for companies to convince their suppliers to join the network and implement blockchain solutions?**

    Sometimes it may not be very easy. However, for a giant such as Walmart, it is fairly easy because such a large corporation has significant influence and control over its suppliers due to its market dominance.

11. **Can a ROI be estimated? How about the costs of implementation?**

    Keith acknowledges that estimating ROI for blockchain implementations can be very challenging due to various factors. The integration of blockchain demands a substantial number of developers and solution architects, and the scarcity of proficient blockchain experts can significantly impact costs during the development phase. Additionally, when a company delves into unexplored areas, extensive investments in research are imperative, making it difficult to predict these costs accurately. Furthermore, the costs associated with blockchain implementation vary depending on the specific requirements of each project, making it challenging to provide a general estimate. Keith also notes that while blockchain implementation is fairly expensive, precise expenses incurred by companies adopting this technology often remain undisclosed to the public. Therefore, estimating ROI and implementation costs for blockchain projects requires careful consideration of factors such as development expenses, research investments, and the unique needs of each business. Companies that offer blockchain solution do not disclose the costs of implementation, for privacy reasons, and they may also have different costs for different customers.

12. **What future trends and developments do you foresee in the use of BT?**

    Keith anticipates several future trends and developments in the use of BT. He believes that blockchain will continue to evolve and people will not talk about it that often due to the fact that it will be used everywhere and it will be just as the internet is used everywhere now and people do not talk about it and take is as a matter of course. This case is probable, unless humanity develops even a better technology that will replace BT.

13. Do the benefits outweigh the costs when it comes to implementing BT?

If utilized correctly, then definitely yes. When employed effectively, BT undoubtedly offers significant benefits that outweigh its costs. The key lies in leveraging its advantages to their fullest extent.

Interview 3 with Giuseppe Perrone

1. **Can you give me a brief overview of your experience with BT?**

    Perrone is a blockchain expert with a background in financial services, government and public sector, consumer products, as well as retail, healthcare, transportation, and automotive industries. He is dedicated to driving innovation, and currently he is the leader of EY's blockchain sales and the innovation consulting practice in Italy for Europe, Middle East, India, and Africa. Perrone worked on a number of cases for the integration of BT into various businesses, which will be explored in this interview.

2. **How would you define BT?**

    BT can be defined as a decentralized, distributed ledger system that records transactions across multiple computers in a way that is immutable and transparent. It enables secure and transparent peer-to-peer transactions without the need for intermediaries, utilizing cryptographic techniques to ensure data integrity and authenticity. This technology serves as the foundation for various applications, providing a means to create transparent, traceable, and tamper-proof records of transactions or data exchanges. In essence, blockchain facilitates trust in digital interactions by creating a shared, immutable record of events. BT plays a crucial role across various industries, as highlighted by Giuseppe Perrone. In SCM, BT facilitates traceability, transparency, and authenticity, streamlining processes and combating counterfeiting.

3. **What projects regarding blockchain implementation have you participated in?**

    Perrone has participated in several projects focused on implementing BT various industries. One notable project involved integrating blockchain into SC operations, particularly in agri-food elements, aiming to establish digital ecosystems. An example is the Birra Peroni project, which connected farmers, breweries, and production plants through a virtual environment, utilizing blockchain to trace tokens with associated metadata linked to each phase of the SC. This approach enabled comprehensive visualization and digitalization of the entire SC process, enhancing transparency and authenticity. Perrone has also been involved in projects within the automotive industry, such as introducing a digital car folder containing essential vehicle information on the blockchain, addressing issues like tachometer fraud and providing consumers with trustworthy data about their vehicles. Additionally, Perrone contributed to the development of ANSAcheck, a blockchain-based platform created for the Agenzia Nazionale Stampa Associata (ANSA), ensuring the traceability and authenticity of news content from creation to distribution, thereby combating fake news and safeguarding journalistic integrity.

4. **How can reader check the authenticity of a news posted on the ANSA website?**

ANSAcheck, was created by EY for ANSA, which is the number one news agency in Italy. Using ANSAcheck brings the ability for readers to check and trace the origin of the news from creation to publishing distribution. The news is traced on the blockchain in each step of its distribution. This proves particularly valuable, especially in scenarios involving cyberattacks targeting news provider websites, such as the incident that occurred approximately two years ago when ANSA experienced a cyberattack that led to the publication of Russian propaganda on their official website. Since using ANSAcheck, ANSA can guarantee their readers the quality of information they provide. Also, the readers are provided with the ability to check the authenticity of a particular story or article by themselves. This can be done by clicking on an ANSAcheck icon at the end of the story, where reader can check the information of the writer and publisher, along with other publication details and certificates of legitimacy, that are all securely recorded on a blockchain. This use of ANSAcheck was seen to be very useful during the initial months of the pandemic, when numerous fake news stories regarding COVID-19 vaccines as well as treatments circulated. Many readers inquired verification about the origin of certain published stories. This serves as an excellent example of how blockchain can aid in not only safeguarding a brand, but also by protecting customers from encountering fake news. ANSAcheck is utilized selectively for important articles containing valuable information that should be verifiable, rather than for every article posted. It ensures that readers can trace the origin and verify the authenticity of such critical information, enhancing transparency and trust in the content provided by ANSA.

5. **How is BT used in the automobile industry?**

The traceability aspect that blockchain offers is utilized in various other fields as well. For instance, in the automotive industry, a use case has been realized with Automobile Club d'Italia when a digital car folder has been introduced by EY. This car folder contains essential information about the car, such as kilometers driven, current status, maintenance activities and the entire service history of the car. All this information that the car folder includes are placed on the blockchain. By leveraging blockchain for this purpose, a system effective system is created that combats the significant issue of counterfeiting linked to tachometer frauds, providing consumers with trustworthy and transparent data about their vehicles. So, in a secondary market the value of the car can be ensured because of the availability of all the information linked to the entire lifecycle.

6. **Is Birra Peroni company satisfied with blockchain use?**

   Birra Peroni is satisfied with the use of BT in their SC operations. The project involved the participation of 100 farmers, 2 breweries, and 3 production plants, establishing a virtual environment to connect information and utilizing blockchain to trace tokens with associated metadata throughout the SC process. By equipping beer bottles with QR codes linked to blockchain-based certificates, Birra Peroni enhanced transparency and authenticity for consumers, allowing them to access detailed information about each step of the production process. This level of traceability and transparency indicates that Birra Peroni values the benefits brought by BT in ensuring the integrity of their SC and meeting consumer demands for authenticity and transparency. They have achieved their goal to enhance transparency and to offer their customers' the whole story of their beer origin that is verifiable.

7. **What advantages BT brings to organizations?**

   Perrone emphasizes that implementing BT offers organizations a multitude of advantages, notably enhancing transparency and traceability throughout operations, particularly in SCM. By utilizing blockchain, organizations can automate processes through smart contracts, improving efficiency and reducing costs. Moreover, BT fosters consumer trust and engagement by providing verifiable information about product origins, attributes, and authenticity, leading to increased consumer loyalty and potential revenue generation. Additionally, blockchain mitigates risks associated with security breaches and fraud, ensuring data integrity and confidentiality. Overall, Perrone underscores that BT empowers organizations to drive innovation, streamline operations, and gain a competitive edge in their respective industries. Organizations implementing BT can benefit from three distinct advantages. Firstly, it reduces the time spent on quality control by approximately 25%. Secondly, it promotes better engagement from consumers who prioritize purchasing products that are LATTE: local, authentic, traceable, transparent and ethical, because with the use of blockchain organizations can ensure food safety, and the authenticity of goods. Thirdly, this allows companies to sell their product for a higher price, potentially increasing it by up to 15% or 20%. This price premium is connected with providing consumers valuable information regarding their purchase.

8. **Which blockchain should business implement private or public and why?**

   Perrone highlights that private blockchains may have limited advantages, particularly when control of data remains confined to a restricted group of stakeholders without external oversight. In contrast, public blockchains offer enhanced transparency, accountability, and security by decentralizing control and minimizing the risk of

manipulation. Therefore, Perrone's perspective suggests that the trajectory of blockchain implementation favors public blockchains due to their ability to provide transparency and security while reducing the risks associated with centralized control. He also states that implementing a private blockchain that is not fully decentralized has not value for organizations.

9. **What trends do you see in the future of BT use?**

   Perrone believes in the continued growth and evolution of BT. He emphasizes its transformative potential across various industries and its ability to address challenges such as transparency, traceability, and efficiency. Perrone sees a promising future for BT as organizations continue to explore and adopt its innovative solutions. There is a major shift that is already being seen that more and more companies and switching from using the private blockchain to the public one and that is where is sees the future. Organizations are understanding the limitation that private blockchain offer and therefor there it a notable shift that is occurring in the market which is to be seen in the future as well.

10. **Do the benefits outweigh the costs when it comes to implementing BT?**

    They definitely do.

Interview 4 with Filipe Martins

1. **Can you give me a brief overview of your experience with BT?**

   Martins' experience with BT stems from its application within the equipment leasing industry, particularly in the context of integrating leasing arrangements with innovative payment systems and machine data tracking. Over the years, he has witnessed firsthand the transformative potential of blockchain in enhancing transparency, efficiency, and trust in financial transactions and SCM.

2. **How would you define the crucial role of BT?**

   BT is a decentralized and distributed ledger system that ensures transparency and immutability of data. It records transactions across multiple computers in a tamper-proof manner, providing a secure platform for P2P transactions without the need for intermediaries. Each transaction is cryptographically linked to the previous one, forming a chain of blocks, which serves as a transparent and immutable record of data. It is crucial because it enhances trust, transparency, and security in financial transactions and SCM processes. By eliminating the need for intermediaries and providing a single source of truth, BT enables efficient and secure peer-to-peer transactions, reduces the risk of fraud, and fosters trust among participants. Additionally, its decentralized nature ensures that data cannot be altered or manipulated, making it an ideal solution for industries where transparency and security are paramount. According to Martins, blockchain offers the following three primary advantages: an intelligent payment system that is automates payments using smart contracts, which allows for payments to be arranged based on the output of machines, P2P payments in real time allowing individuals and entities to transfer funds directly, and cost-effective transactions, especially when compared to traditional international money transfers.

3. **What specific projects regarding blockchain implementation have you participated in?**

   In terms of specific projects involving blockchain implementation, Martins' involvement has primarily centered around revolutionizing equipment leasing arrangements within Süddeutsche Leasing AG. They've embarked on initiatives aimed at integrating BT into their leasing operations to enhance transparency, efficiency, and trust. One notable project involves the implementation of PPU leasing models, which leverage BT to offer dynamic payment structures based on machine productivity. Through partnerships with innovative startups Climate Grid and Cap-on, they've been at the forefront of integrating machine data with blockchain to facilitate real-time monitoring and optimization of asset usage. Furthermore, the collaboration with these startups has enabled the company to tokenize leased assets, thereby enhancing asset management and transparency. By

recording the entire history of leased machinery on the blockchain, including maintenance records and usage data, they ensure transparency and immutability of data, thereby increasing the value of leased assets and enhancing customer satisfaction. Additionally, they've explored the application of BT in SCM, particularly in tracking and tracing assets across the SC. By utilizing blockchain, they've been able to streamline SC processes, mitigate risks, and enhance transparency and trust among stakeholders. Overall, these projects have not only demonstrated the transformative potential of BT in the leasing industry but have also positioned Süddeutsche Leasing AG as a leader in leveraging blockchain to drive innovation and efficiency in financial services. Machines are being rented by a lot of companies including some giants in the market such as Porsche, and Mercedes. These machines used for production are being connected through the IoT and BT. This connection involves tokenizing the machines as assets, allowing for enhanced monitoring, control, and optimization of their performance and usage. Due to the fact that the entire history of the machine is recorded on the blockchain, when the owner decides to re-lease it to another organization or sell it after it has been used for several years, the blockchain data guarantees the machine's technological condition, maintenance records, and the origin and quality of spare parts. The comprehensive digital logbook of each machine ensures transparency and immutability of data, inherent to the BT.

4. **What benefits does the blockchain bring to machines leased?**

Martin highlights the importance of connecting machines to both the IoT and BT, emphasizing the benefits of enhanced predictive maintenance, improved automation and efficiency, increased traceability and transparency, strengthened security, and contribution to the circular economy. Through IoT sensors and blockchain integration, organizations can optimize machine usage, automate payment structures, and securely record transactions, maintenance records, and machine history on a tamper-proof ledger. This not only enables real-time monitoring and proactive maintenance but also ensures the integrity and security of data, ultimately driving efficiency and innovation in the leasing industry while contributing to sustainable practices. . One key advantage is transparency, as the leasing company can monitor each machine's activity in real-time, including production output, maintenance status, and any reported issues from the producer. This real-time monitoring enables the leasing company to react promptly to any issues, thereby enhancing customer satisfaction. Moreover, having the entire history of the machinery recorded on a blockchain increases its value by at least 10% when sold, as buyers gain greater transparency and confidence in the machine's condition.

5. **Can most companies afford utilizing BT?**

Martins mentions states that most companies can afford the application of BT because it operates on an open-source basis, meaning the software code and protocols are freely available for anyone to view, utilize, and modify. This accessibility lowers the barrier to entry for companies looking to adopt blockchain solutions. Additionally, Martins envisions a future where blockchain serves as the singular, authoritative source of truth in operational processes, reducing the risk of disputes, fraud, or errors. While there may be initial investment costs associated with implementing BT, the potential benefits in terms of transparency, accuracy, and trustworthiness within operations outweigh the costs in the long run.

6. **Does scalability pose a challenge?**

Yes. As more data is added to the blockchain, the performance of the network can slow down, potentially impacting transaction processing speed and overall efficiency. This issue is particularly relevant in complex smart contracts with a large number of daily transactions, where the volume of data can strain the network's capacity. To mitigate scalability challenges, Martins suggests storing most of the collected information on centralized machines periodically and selecting important data to be recorded on the blockchain using a hash code. By hashing only selected data rather than the entirety of the information, the efficiency of the blockchain can be maintained. Additionally, he highlights that blockchain ledgers would complement centralized databases rather than fully replacing them in scenarios where scalability is a concern.

7. **What does the future hold?**

Martins envisions a future where BT will continue to evolve and play a transformative role across various industries. He believes that payments will become more interoperable, enabling seamless P2P transactions and streamlining financial transactions within SCs. In particular, within his expertise in the equipment leasing industry, Martins anticipates a paradigm shift towards the token economy and the rise of M2M transactions. This transformation will lead to heightened efficiency, with machines autonomously procuring materials, conducting production processes, and scheduling maintenance. Additionally, smart contracts will facilitate precise compensation based on machine productivity, enabling real-time payments and reducing costs compared to traditional financial institutions. Martins anticipates a fundamental transformation in Europe in the coming years, with the potential introduction of a digital Euro. He envisions a shift that will necessitate government involvement and the implementation of new legislation to accommodate emerging technologies such as blockchain. This transformation represents

a significant evolution in financial systems, with digital currencies likely to reshape how transactions are conducted and regulated. As governments adapt to these changes, there will be a need for proactive regulation and policy frameworks to ensure the stability and integrity of financial markets in the digital age. Overall, Martins sees BT driving innovation, efficiency, and transparency, particularly in industries with complex SCs and transactional processes.

8. **Why there is lack of use of BT in organizations despite all the benefits that it brings?**

Martins identifies several reasons for the lack of widespread adoption of BT in organizations, despite its numerous benefits. Firstly, he highlights the pervasive lack of understanding among stakeholders regarding the technology and its potential advantages. This lack of awareness often leads to apprehension and resistance to adopting blockchain solutions within businesses. Additionally, some companies may not be fully prepared to embrace complete transparency, which is inherent in blockchain systems. Moreover, Martins underscores that scalability issues can pose challenges, particularly in complex smart contracts with a high volume of transactions. Overall, Martins suggests that overcoming these barriers will require concerted efforts to educate stakeholders, and address scalability issues, to realize the full potential of BT in organizational settings.

9. **What benefits does the connections of machines to IoT and blockchain bring?**

Having machines connected through IoT and BT, does not only offer organizations enhanced predictive maintenance, better automation, increase traceability and strengthened security, but also through retrofitting machines, it contributes to the circular economy through two key factors. Firstly, Efficient resource management: continuous maintenance facilitated by this connectivity ensures machines receive timely care, thereby extending their lifespan. Secondly, Protecting the environment: by preventing the accumulation of scrap and broken machines, organizations mitigate environmental impact.

10. **Do the benefits outweigh the costs when it comes to implementing BT?**

The benefits of implementing BT often outweigh the associated costs. While there may be initial investment costs involved in adopting BT, such as development, integration, and training expenses, the potential benefits can far exceed these upfront expenditures. BT offers advantages such as enhanced transparency, efficiency, security, and trust in financial transactions and SCM processes. These benefits contribute to improved operational processes, reduced risks of fraud or errors, and increased trust among stakeholders. Additionally, the open-source nature of BT and its potential to serve as a singular, authoritative source of truth in operational processes further enhance its value

proposition. Therefore, despite the initial costs, the long-term benefits of implementing BT in organizations can result in significant value creation and competitive advantages. Moreover, having the entire history of the machinery recorded on a blockchain increases its value by at least 10% when sold, as buyers gain greater transparency and confidence in the machine's condition. This increased transparency is a substantial advantage for the leasing company, as it enhances the perceived value of its leased machinery. Not only is the input and output of each machine tracked and saved on the blockchain, but also its energy consumption. This enables the determination of whether the machine is environmentally friendly, leading to data-driven ESG practices. With all this data tracked on the blockchain, information related to energy consumption and the use of certain chemicals is recorded, resulting in a comprehensive footprint. As a result, the environmental impact of every machine's production can be quantified.

Interview 5 with Věra Šmídová

1. **How would you define EBS and its main objectives?**

   EBS Blockchain services a.s. was founded in 2019 by the Electrotechnical Association of the Czech Republic. Their main goal is to provide customized blockchain solutions tailored specifically to the needs of organizations or groups of organizations. They focus on ensuring the trustworthiness of data for companies using BT and guiding organizations through the process of integrating blockchain into their processes. EBS has developed a blockchain on the Hyperledger Fabric consortium platform. Node ownership is diverse, with various independent institutions and companies, both small and large. The network includes 36 nodes, each owned independently. Examples of node owners include IBM, the Czech Technical University in Prague, and the Ministry of Industry and Trade of the Czech Republic.

2. **What types of blockchain networks does EBS build, and how do they differ?**

   EBS builds three types of networks: private networks, hybrid blockchains, and consortia blockchains. Private networks are restricted to a single organization or entity. Hybrid blockchains have a private core but can permit some individuals or entities outside of the given organization to interact with certain aspects. Consortia blockchains are collaborative and can be formed by multiple organizations or institutions. EBS does not offer any public blockchain solutions.

3. **Could you provide an example of how EBS's BT is applied in SCM?**

   One of our notable use cases is with ETD, which is a Czech company that is based in Pilsen. ETD is a company with a history dating back many years in manufacturing and supplying electrical devices and transformer. This company has encountered challenges with missing components in delivered containers. One of the company's main international customers kept reporting on some missing pieces even though ETD was sure they included all the necessary components into the shipped containers. Usually the process included having all the necessary components in huge container to be shipped. The transformers were then assembled upon delivery by the customers. To address this issue, a single source of truth blockchain system was implemented. Cameras were integrated to record the packaging process, and the hash of these videos was securely stored on the national blockchain registry. This provided immutable proof of the packaging process and ensured transparency throughout the SC. Once packed, the box is securely sealed with specific numbered seals. Subsequently, a video recording of the packaging operation is saved, and the hash of this video is stored on the national blockchain registry. Upon receipt of the box by the carrier, confirmation is obtained in the form of a picture of the sealed container. In

the event of any accusations from the customer's side, ETD maintains immutable proof detailing precisely, which components were packaged into a given container. This ensures precise knowledge of the contents received, with a comprehensive record maintained throughout the process. This is a great example of how BT can enhance trust between business partners through improved traceability. By serving as a single source of truth, blockchain can help prevent misunderstandings and disputes by providing an immutable record of transactions and events.

4. **What are some of the challenges that lead to lack of BT adoption in the market?**

   Conservative organizations often lack familiarity with emerging technologies like blockchain and struggle to understand its potential benefits. Additionally, resistance to change within the company culture can hinder adoption. The perceived complexity of BT can also be a barrier, as some organizations may view it as overly complicated and hesitate to invest time and resources in understanding it.

5. **How does the implementation timeline and complexity vary for different types of blockchain projects?**

   The implementation timeline and complexity depend on the nature of the blockchain network. For a straightforward network with basic document storage and metadata, with up to 10 nodes, implementation typically takes up to 1 month. However, more complex systems involving smart contracts and multiple node owners can take between 6 to 12 months to complete due to additional complexities.

6. **Could you provide some insights into the costs associated with BT implementing?**

   The costs of implementation are not easily specified because they vary depending on the size and complexity of the project. For simple applications, it can be around 100,000 CZK, average and medium size projects may cost approximately 500,000 CZK, while larger projects spanning over two years may incur costs totaling around 10,000,000 CZK. Additionally, during the operational phase, the cost of storing records in a national blockchain registry typically fluctuates around 100 CZK per record. Node owners have the ability to store records for even less, often around tens of crowns each. If a company opts for a private channel, it can self-manage without incurring any charges from EBS. However, should it require management services from EBS, then the pricing would range from 2,000 to 5,000 CZK per node. For large companies, such as those in the automotive industry collecting production data, fees could also be determined based on ledger size. The pricing structure can also vary based on the amount of data being stored.

7. **Can you share a use case of hybrid blockchain?**

In regards to the hybrid blockchain, there are two use cases that are yet to be implemented. The first use case involves sending research and scientific works belonging to the university of Tomas Bata to blockchain in order to protect data and research integrity. This process ensures that even if cases are to be patented, which may take several months, the university can maintain ownership and control over the results of the development and research. The second use case is in cooperation with University of Tomas Bata and NEXPRO Communication s.r.o. It focuses on digitalizing specific documents, including university diplomas. This initiative aims to modernize document management practices, while ensuring the security and accessibility of important records. By digitizing these documents, the university enhances efficiency and facilitates easier access for students and stakeholders.

8. **How about the ROI? Are there any details that you can share?**

Regarding ROI, in some instances, monitoring of returns is not conducted at all, because some company's objectives are not monetary, and the benefits of the project may be measured in terms of non-financial outcomes rather than monetary gains. It is also important to consider the non-tangible benefits arising from BT implementations such as enhanced security, and reduced risks. In case of University of Tomas Bata, protecting their valuable research data stands out as a significant advantage, and the associated costs in this case are of minimal concern. Also, when an enterprise operates with just one node, the associated costs are notably diminished. Nevertheless, all users thus far have enjoyed benefits surpassing the costs linked to implementation and utilization of BT.

Interview 6 with Paul Brody

1. **How would you define BT role in SCM?**

   According to Brody, BT will be very useful in SCM. The benefits arising from BT can be categorized into two main areas; tokenization of assets and automating business transactions using smart contracts. In this system, a token must leave its original location before it can be transferred elsewhere. Such a mechanism is currently absent in traditional SC processes. However, with blockchain and tokenization, the implementation of such a system becomes feasible, leading to a substantially more accurate and transparent SC. This end-to-end SC will greatly enhance visibility and accuracy in tracing the origins of items, thanks to the historical records associated with each token. NFT allow having a historical record of where a token has been. This is something not something that has existed before in the world of SCs. This brings, accuracy, visibility and transparency, additionally when adding smart contracts to this, organization would be able to automate transactions between enterprises. Automating business transactions using smart contracts would result in having an accurate and efficient SC network.

2. **Do you agree with the prevailing viewpoint among experts that public blockchains offer greater advantages compared to private ones?**

   Yes, there are several challenges arising from organizations utilizations of private blockchains. Firstly, there has been significant confusion in the market regarding this technology until recently. There is a common misconception that private blockchains provide complete privacy. The privacy that they have is extremely limited. On a public blockchain such as Ethereum everybody can read what anybody is doing. On a private blockchain, all member of the blockchain can read he transactions. As all members of the private blockchain can view all transactions, it becomes problematic when a company works with two or more competing suppliers on the same network. Each supplier can see the other supplier's transactions. This exposes sensitive information that neither party would want to disclose.

3. **Have you noticed a trend in the market where companies are increasingly favoring public blockchains over private ones?**

   Yes, numerous companies that have invested in private blockchains have realized that not only are these systems costly, but they also fail to deliver the expected level of privacy. Another significant issue, especially with private networks, is their proprietary nature. For example, if Company A has its own private blockchain network (Blockchain A) and Company B has its own (Blockchain B), and they share the same supplier, that supplier

would need to join both Blockchain A and Blockchain B. This process is not only a complex procedure, costly and time-consuming but also inefficient.

4. **Immutability is a fundamental characteristic of BT. Would you consider private blockchain immutable?**

If a blockchain only has 10 nodes, and all of them are in one cloud, then this blockchain is not immutable. Immutability is a practical emergent property of a very large public blockchain networks, so if any private blockchains ever reaches the size of potentially have 1000 different nodes operating in many different infrastructures, then it could become immutable. However, most private blockchain have only one node. Essentially, if there's only one node in a private blockchain, the owner of that node has complete control over the data and transactions recorded on the blockchain.

5. **What is the biggest challenge that users of private blockchains face?**

A huge problem is that private networks are proprietary, so when a Walmart set up their own network, Target would definitely not join the same network. So, if for example Target and Walmart have the same supplier, this supplier would need to join the private network of each of them, which is very expensive, it's time consuming, and ineffective.

6. **Are the costs of implementing private blockchains similar to implementing public blockchains?**

No at all. Private blockchains are incredibly expensive, because when using a private blockchain, a company needs to build an entire blockchain infrastructure for itself and for its customers. When considering costs, there's simply no need for comparison.

7. **What is the biggest challenge when it comes to BT implementation, is it the length of the process, the costs, scalability, or something else?**

The first difficulty is that companies struggle with being in a public blockchains, they get nervous, they do not understand how it works, and they tend to have concerns regarding the legality of the whole process. This kind of mirrors the early days of the internet, when people were unsure whether using the internet was even safe. Another issue is that people struggle to understand what is tokenization and how it works. Lastly, people do not understand the strategic value proposition.

8. **What is the main thing that organization need to take into consideration when implementing a public blockchain within their SC?**

Incorporating BT effectively necessitates addressing specific privacy considerations. This is because companies cannot include certain sensitive information, such as inventory levels and other proprietary data, in the blockchain to prevent competitors from accessing it. The solutions to a successful and effective utilization of public blockchains within the SCs

is the establishment of a scalable privacy infrastructure. This is being achieved through the creation of the following two tools; the first tool is a layer two blockchain network built on top of Ethereum, known as Nightfall. Nightfall operates as a Zero-knowledge Roll-Up solution, which is a method facilitating private transactions on the public Ethereum blockchain. By leveraging Nightfall, organizations can seamlessly conduct private transactions, and moving tokens around, while ensuring efficiency without compromising the transparency, data immutability, and security. The second tool, is called Starlight which has the ability to turn smart contracts into a set of mathematical proofs, which are called a zero-knowledge circuit. Starlight enables one party to demonstrate awareness of specific information to another party without disclosing the information itself. This was created for the necessity to make the business agreements private, in order to protect sensitive information and maintain confidentiality. Both tools are currently being tested and utilized by a few companies, yet they are still in the early stages of implementation.

9. **Could the lack of BT adoption in the market be sue to the uncertainty of ROI?**

ROI is definitely not an issue, because improving the accuracy of inventory or automating the contracts is usually not hard to calculate and provide the ROI. Typically, enterprises only replace their IT systems when they are working ineffectively, when they are outdated. Otherwise enterprise IT systems stay the same for years. So, enterprise IT systems definitely move much slower than for example consumer products.

10. **Do the benefits exceed the costs when it comes to implementing BT?**

Brody agrees that the benefits that BT brings to companies hugely exceed the costs associated with its integration. Blockchain pays for itself the same way like any other IT investment. The benefits derived from BT far outweigh the investment for organizations. A compelling illustration of this principle is evident in EY's collaboration with Microsoft. By leveraging smart contracts, they transformed their Xbox video game procurement system. This transition led to a remarkable reduction in contract data processing time, which was cut by 99% from 45 days to a just 4 minutes. Moreover, the overall costs associated with managing the contract infrastructure dropped by 40%. This example clearly demonstrates how BT can revolutionize processes, significantly enhancing efficiency and cost-effectiveness for enterprises.

11. **Can startups also afford implementing blockchain within their services?**

They can, because public blockchains are affordable. When it comes to startups, there aren't any use cases within SC, as startups are mostly focused on the use of BT in the finance industry, but they prove the point that implementing blockchain is hugely accessible to all.

12. **Do you see the future in using public blockchains mainly?**

Brody definitely sees the future lying in the utilization of public networks. 20 or 30 years from now, most of business to business transactions will be done on a public blockchain.