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THE IMPLEMENTATION OF BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN MANAGEMENT

Case SmartlLog Project – Kouvola Innovation Oy

International Business Unit
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ABSTRACT

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Blockchain has evolved as an important technology with far-reaching significance for a variety of sectors. Thus, the combination of blockchain and supply chain management has increasingly accelerated the interest of many companies. Blockchain with its characteristics may, on one hand, provide several benefits, yet on the other hand, remain limitations that hinder companies from adopting it in their supply chain management.

The objective of the thesis is to investigate the potential benefits and obstacles from the adoption of blockchain technology in supply chain management, as well as recommendations for companies in order to successfully apply the technology in the future.

The research was conducted using the qualitative method, in which the data was collected primarily from SmartLog Project – Kouvola Innovation Oy case study and secondarily from the literature review.

The theoretical framework revisited the academic terminologies and concepts that are relevant to the research purpose, which includes Supply Chain, Supply Chain Management, and Blockchain Technology.

The results of this thesis can provide a demonstration of the advantages and disadvantages of blockchain applications for supply chain management. Also, the suggestions for planning and adopting the technology successfully are explained. The thesis can be utilized as an evaluation material for organizations in their decision-making process to deploy this technology in supply chain management.

Keywords	blockchain technology, blockchain implementation, supply chain, supply chain management

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LIST OF ABBREVIATIONS

DDoS	Distributed Denial of Service
EID	Electronic Identification
IoT	Internet of Things
POC	Proof of Concept
RFID	Radio Frequency Identification
SC(s)	Supply Chain(s)
SCM	Supply Chain Management

1 INTRODUCTION

1.1 Research Problem

Market conditions have evolved to be more dynamic and demanding, resulting in a difficult competitive situation for companies. Supply chains have become heavily reliant on collaboration, integration, flexibility, and trust among stakeholders to adapt to this challenging environment. Moreover, in today's competitive business world, supply chain management is commonly viewed as a crucial business strategy for cost reduction and improving economic performance. However, supply chain management techniques must be modernized in response to growing issues such as emerged supply chain complexity, transparency, and flexibility standards if enterprises wish to remain competitive. (Helo & Hao, 2019). For example, in traditional supply chain management, there are major concerns regarding tampering of goods during transportation, delays, and frauds, identify verification, and lack of information management including accuracy and authenticity of the information. (Dwivedi et al., 2020).

As a result, companies have been developing information technologies for the optimization of supply chain processes, which enables the significance of new technical applications in supply chains to expand even more. It is obviously believed that to better control the supply chain flow, a modern specialized technological application must be implemented. Although numerous digital technology tools such as EID, RFID, IoTs are utilized to improve the efficiency of supply chain processes for years, challenges in transparency, visibility, flexibility, and trust in time-manner stay unresolved.

In this circumstance, thanks to its powerful technological features, blockchain appears to solve the challenges mentioned above. By increasing the level of data management and the protection of shared data, the implementation of blockchain may contribute to the improvement of supply chain security, traceability, and efficiency. (Meidute-Kavaliauskiene, Yıldız, Çiğdem and Činčikaitė, 2021) Furthermore, blockchain technology has the potential to improve collaboration and communication among stakeholders, with benefits such as lower costs and increased performance. Also, customers' trust can be increased by blockchain technology because it allows for product traceability at all stages of the supply chain. Additionally, blockchain technology plays a vital role in fraud prevention, real-time product data management, as well as quality control during the entire product lifecycle.

For the reasons stated above, it is crucial for businesses to actively command blockchain technology and ensure that it is integrated into their supply chain operations.

1.2 Thesis topic

The thesis's main objective is to explore the potential benefits and obstacles from the adoption of blockchain technology in international supply chain management, as well as recommendations for companies in order to successfully apply the technology in the future. To accomplish this goal, the author aims to answer investigation questions which are presented below:

1. What are the advantages of blockchain technology itself and the benefits of blockchain adoption in supply chain management?
2. What are the limitations of blockchain technology itself and the challenges of blockchain adoption in supply chain management?
3. What are the recommendations for companies to successfully adopt blockchain technology in supply chain management, if any?

1.3 Thesis structure

First, the thesis starts by introducing research problem, thesis topic, and its structure. (Chapter 1). The second chapter covers the theoretical framework, where the author discusses supply chains, supply chain management and its operational models, and the information complexity in the process. Next, due to the goal of the thesis, it is also important that blockchain technology can be approached fundamentally enough. However, technological features and specific applications of blockchain technology will not be undergone in a specific nature in the theoretical framework, as the main goal of the thesis focuses on the implementation of the technology on the business operation level. Following the second chapter, the selected research methodology and data collection process are explained in the third one. Then, research results will be presented in chapter 4 and finally, the conclusion including summary discussion, reliability, validity, limitation, and future research recommendation will be suggested.

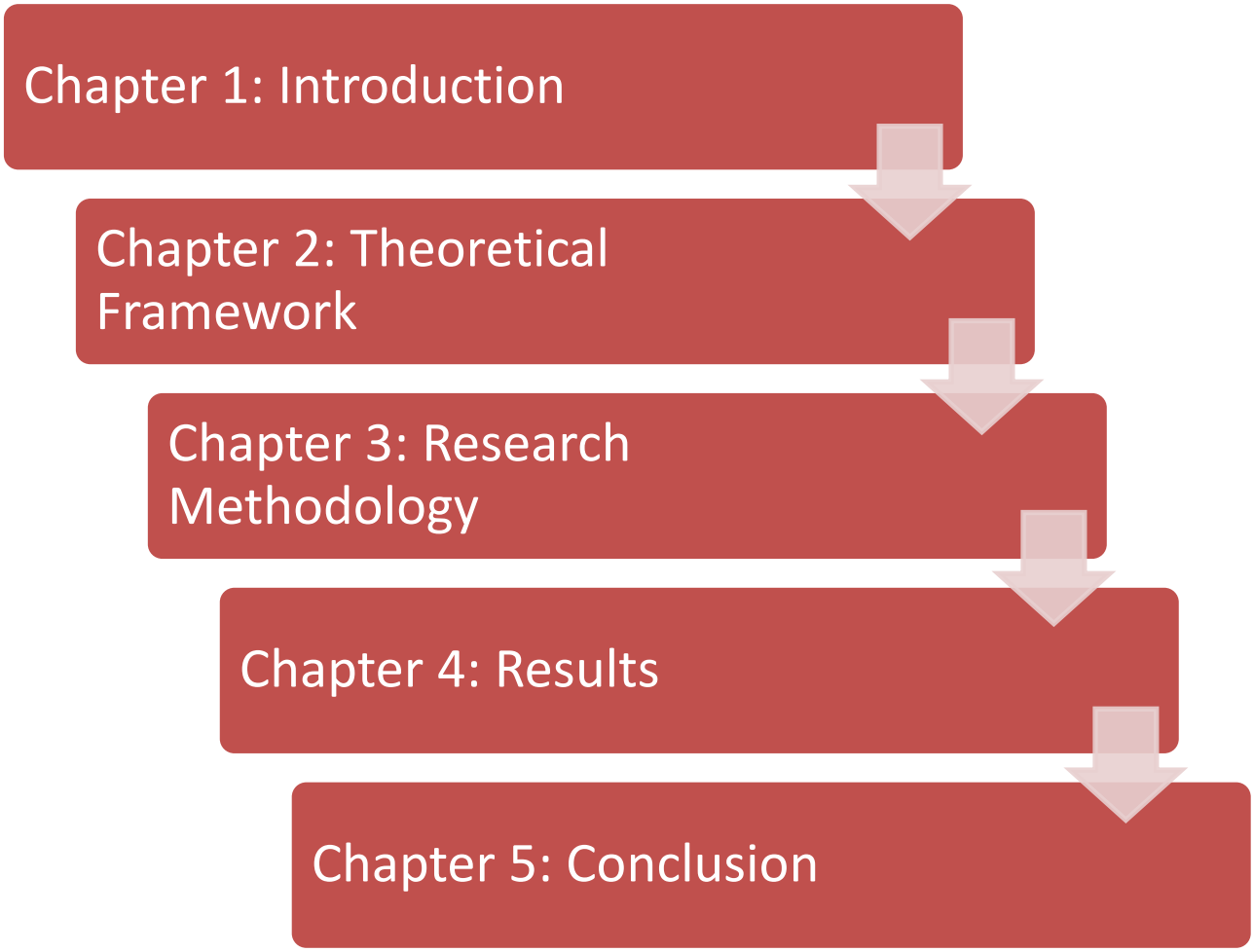


Figure 1 Thesis structure

2 THEORETICAL FRAMEWORK

2.1 Supply Chain Management

Since the 1980s, when businesses recognized the benefits of collaborative relationships both within and outside of their organization, there has been a steady increase in interest in Supply Chain Management. Firms are discovering that they can no longer compete effectively in isolation from their suppliers or other supply chain stakeholders. (Lummus & Vokurka, 1999)

In fact, Supply Chain Management helps to achieve a variety of business objectives, and thus performs an undoubtedly significant part in the operation of businesses. (Fernando, 2021) Several strategic and operational definitions and other key fundamental concepts of Supply Chain Management will be reviewed and discussed.

2.1.1 Supply Chain Definition

As reported by CIPS (2021), the supply chain is "the activities required by the organization to deliver goods or services to the consumer."

Kenton (2021) defines that "a supply chain is a network between a company and its suppliers to produce and distribute a specific product to the final buyer."

Agreeing on the same point, Grimshaw (2020) indicates that:

> The supply chain is defined as the entire process of making and selling commercial goods, including every stage from the supply of materials and the manufacture of the goods through to their distribution and sale. Successfully managing supply chains is essential to any company hoping to compete.

Meanwhile, Chopra and Meindl (2010) expand the definition as follow:

> A supply chain includes all parties (manufacturers, suppliers, transporters, warehouses, retailers, and customers) as well as all functions within each organization that are directly or indirectly involved in fulfilling a customer request.

APICS, The Association for Operations Management, contributes the definition more broadly, by mentioning the method flow of supply chain:

> The supply chain is the global network used to deliver products and services from raw materials to end customers through an engineered flow of information, physical distribution, and cash.

Discovering Supply Chain as a process that boost product life cycle in operation, Ayers (2006) explains in the following way:

> *Supply chain.* Product life cycle processes comprising physical, information, financial, and knowledge flows whose purpose is to satisfy end-user requirements with physical products and services from multiple, linked suppliers.

Those definitions all focus on the most important aspects of a successful supply chain. They highlight the requirement for provenance and a target within which commodities flow, and adopt the concept that overall Supply Chains begin with resources (raw materials), integrate a variety of value-adding activities, and end with the transfer of finished products to customers. Profoundly considering the term, Ayers (2006) introduced the supply chain as a product life cycle, which emphasizes the value of two-way flow in the process. It brings the broader perspective that instead of limiting in terms of one-way flow direction from suppliers to end-customers, the backward flows for products returns, repair, and overhaul, or any other reasons, also should not be underestimated, to ensure the continuous connections of involving supply chain activities.

2.1.2 Supply Chain Management Definition

When it comes to supply chain management, it is likely to be perceived as the management in a centralized way of the supply chain. In a more fundamental opinion, they are grouped into three types: management philosophy, management philosophy implementation, and a system of management processes. (Mentzer et al., 2001)

Fernando (2021) describes that:

> Supply chain management is the management of the flow of goods and services and includes all processes that transform raw materials into final products. It involves the active streamlining of a business's supply-side activities to maximize customer value and gain a competitive advantage in the marketplace.

To emphasize the importance of process integration, The Global Supply Chain Forum defines the term as follow:

> Supply Chain Management is the integration of key business processes from ended user rough original suppliers that provides products, services, and information that add value for customers and other stakeholders

Monczka, Trent, and Handfield (1998) shares the same opinion, yet additionally implied that:

> Supply Chain Management requires traditionally separate materials functions to report to an executive responsible for coordinating the entire materials process, and also requires joint relationships with suppliers across multiple tiers.

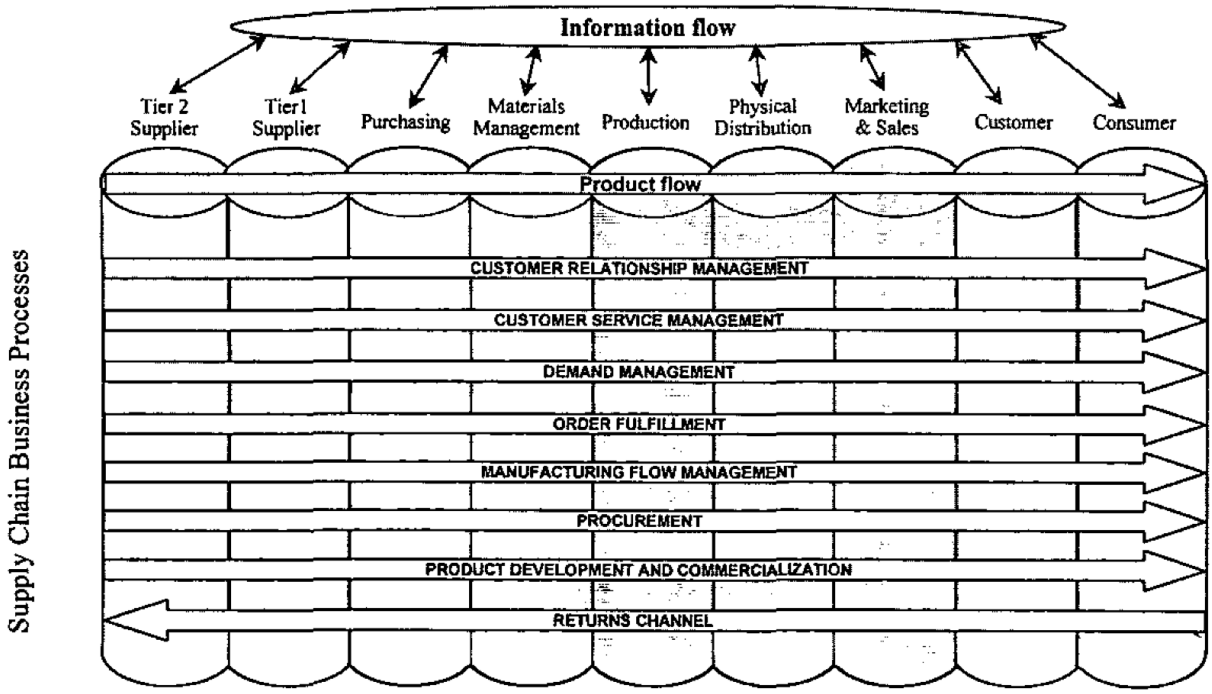
In a concise view, La Londe and Masters (1994) mentioned different aspects which generate the supply chain management concept, including "two or more firms in a supply chain entering into a long-term agreement, the development of trust and commitment to the relationship; the integration of logistics activities involving the sharing of demand and sales data; and lastly the potential for a shift in the locus of control of the logistics process."

As a philosophy, Supply Chain Management is a systems-based approach to viewing the supply chain as entirely itself, rather than as a collection of disparate elements, each fulfilling its role. (Ellram and Cooper 1990; Houlihan 1988; Tyndall et al. 1998). Thus, Supply Chain Management is a set of beliefs that each business in the supply chain has a direct and indirect impact on the performance of all other supply chain members, as well as overall supply chain performance. (Cooper, et al., 1997).

Along these lines, the concept of Supply Chain Management, as employed in numerous studies, is frequently associated with the globalization of manufacturing and the greater propensity of manufacturers to source their inputs worldwide, necessitating the management of global flows of inputs or outputs. Moreover, Supply Chain Management is considered to primarily involve a set of integrating activities among all stakeholders in the supply chain. (Figure 1). To conclude, according to the Supply Chain Management Professionals' Council (2009), Supply Chain Management focuses on the design and management of all sourcing and purchasing, transformation, and logistics management activities. It mostly incorporates coordination and collaboration with network partners, who can be suppliers, mediators, third-party service providers, and customers. Supply Chain Management fundamentally organizes supply and demand management within and across company boundaries. (Figure 2)

1. Integrated Behavior
2. Mutually Sharing Information
3. Mutually Sharing Risks and Rewards
4. Cooperation
5. The Same Goal and the Same Focus on Serving Customers
6. Integration of Processes
7. Partners to Build and Maintain Long-Term Relationships

Figure 2: Supply Chain Management Primary Activities (Mentzer et al., 2001)



Supply Chain Management Components

- Planning and Control
- Work structure
- Organization structure
- Product flow facility structure
- Information flow facility (IT) structure
- Product structure
- Management methods
- Power and leadership structure
- Risk and reward structure
- Culture and attitude

Figure 3: A Framework of Supply Chain Management (Cooper et al., 1997)

2.1.3 Supply Chain Management Processes Model

To begin with, Supply chain management is perceived to be a systematic, tactical coordination of traditional business processes and practices inside a firm and between firms within a supply chain, with the goal of improving the long-term performance of individual enterprises and the whole supply chain (Mentzer et al., 2001). Thus, a successful supply chain, indeed, necessitates a shift from controlling individual functions to integrating them into essential supply chain processes. A supply chain can be visualized as a pipeline, which displays supply chain flows in both directions (products, services, financial resources, the information associated with these flows, and the informational flows of demand and forecasts). (Figure 3). Marketing, sales, research and development, forecasting, production, procurement, logistics, information technology, finance, and customer service are all traditional business functions that manage and complete these flows from the supplier's suppliers to the customer's customers in order to act profitability, competitive advantage and satisfy the customer. (Chopra & Meindl, 2010) Also, the role of trust, commitment, risk, and dependence on the viability of internal functional sharing and coordination is examined in inter-functional coordination. Lastly, the role of various types of third-party suppliers, how connections between corporations should be managed, and the sustainability of alternative supply chain structures are all covered by inter-corporate coordination.

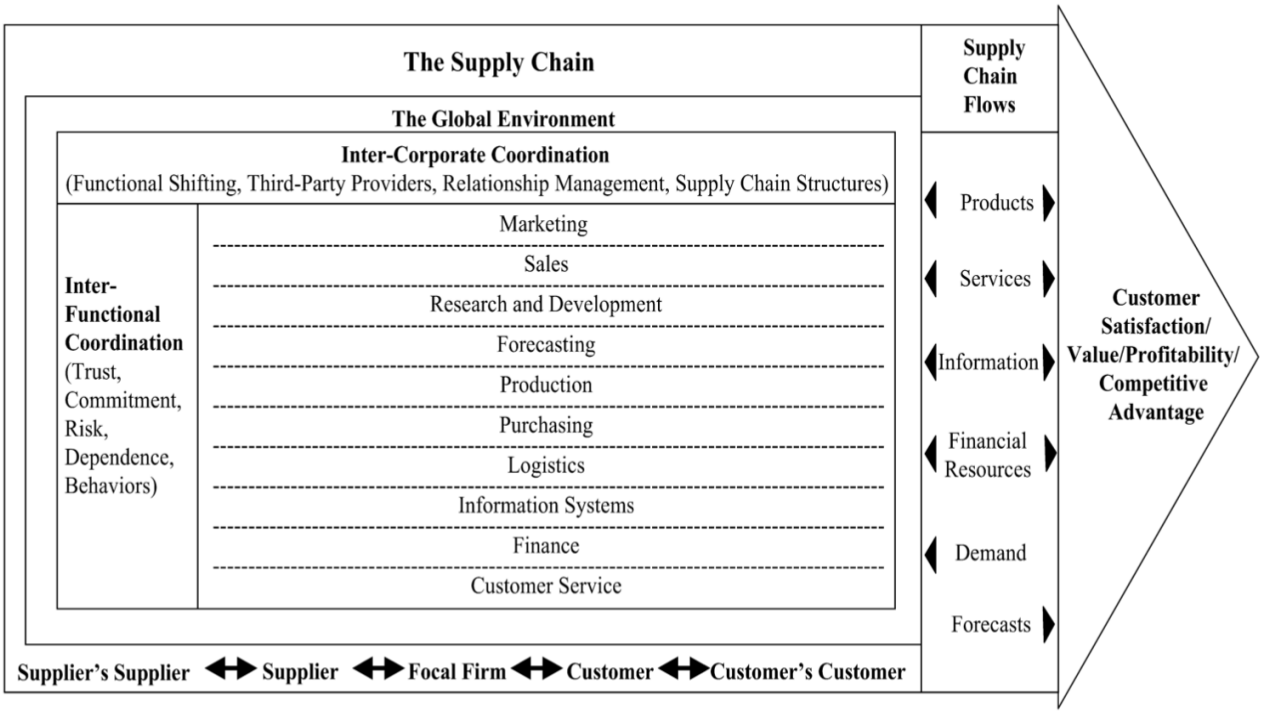


Figure 4 Supply Chain Management Structural Model (Mentzer et al., 2001)

In this matter, the other eight essential supply chain processes are identified by the Global Supply Chain Forum. (Croxton et al., 2001). Although the relevance of each of these processes and how they were performed can be varied between different enterprises, they can provide a general overview of integrated supply chain management.

- Customer relationship management,
- Customer service management,
- Demand management,
- Order fulfillment
- Manufacturing flow management,
- Supplier relationship management (procurement),
- Product development and commercialization,
- Returns management (returns).

Examining into more detail with order fulfillment as an example, Figure 4 will show sub-steps for both a strategic perspective and operational perspective, as well as the potential impact on other seven key processes.

In conclusion, SCM's operational model includes all the activities of functional processes between each member of the network in which the flows of materials and information are the concrete foundation. Concisely, a purchase order (information flow) is frequently seen as a start of a flow of products (material flow), which is then followed by an invoice and payment (information and financial flow), and further steps until the process ends. Despite the fact that numerous functions and network members are involved, the end success of entire supply chain management cannot be obtained within either one function or member.

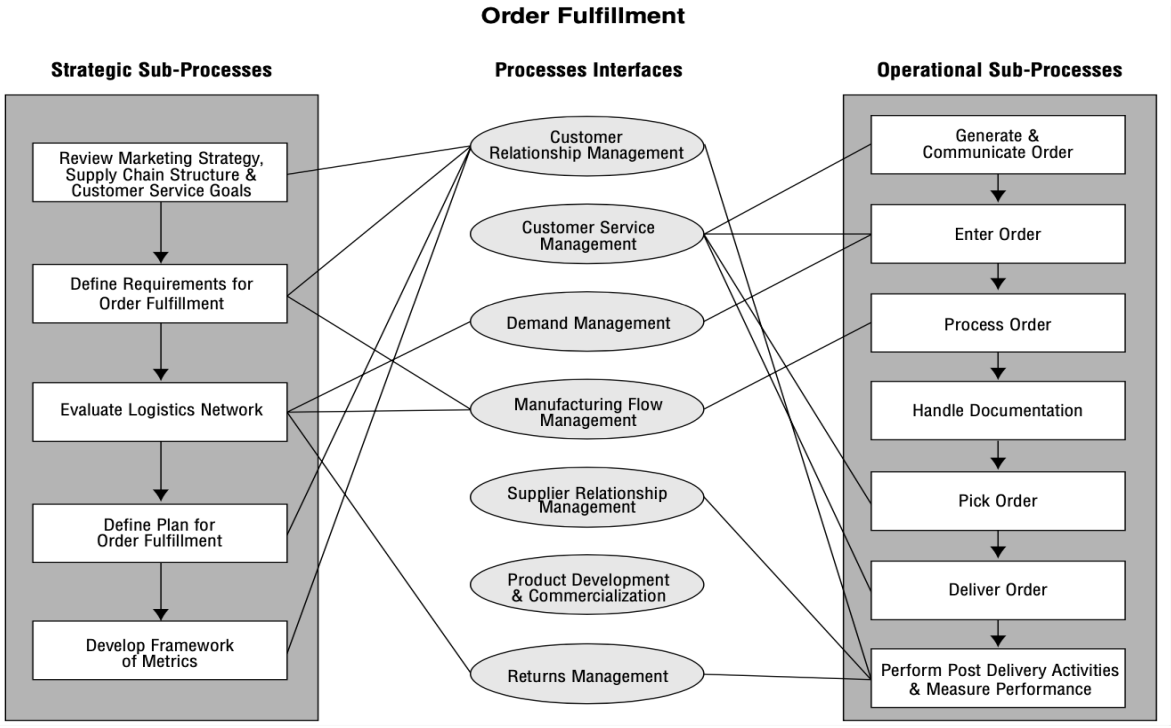


Figure 5 Order Fulfillment process (Croxton et al., 2001, p. 21)

2.1.4 Information complexity and related challenges in Supply Chain Management

Key challenges in the supply chain and logistics industry in 2021 are primarily centered around technology supply chain integration (Iggo, 2021). Interestingly, these challenges seem to arise principally from the information complexity of a complete end-to-end network.

With the four main goals of the process including lower cost, higher quality, more flexibility, and faster response times, the exchange of information among all entities and levels that comprise the whole chain is significantly important. However, in reality, the amount of data that flows in all direc-

tions is enormous, and it is not necessarily precise or reliable, making it vulnerable to misinterpretation. The way information is filtered and modified, currently, as it moves from one entity or level to another might hinder the visibility of true demand and supply situations. The so-called 'Bullwhip' effect is an example of how several phases in the chain can cause demand messages to be significantly distorted. As a result of this distortion, the data utilized as input to planning and forecasting operations may be wrong, leading to lower forecast accuracy and higher expenses. (Christopher, 2016).

In everyday language, the phrase "time is money" may be overplayed, but in supply chain management, it reaches to the heart of the matter. Not only does delay represent a cost to the supply chain manager, but it also implies a penalty in terms of customer service. In terms of cost, there is a direct relationship between the length of the supply chain pipeline and the transportation process, in which the combination of slow flawed information flow in time-manner and lack of responsiveness generates decline, delay, and decay. (Christopher, 2016). Furthermore, in today’s globalization business, the simple network of the supply chain has become a much more complex and integrated ecosystem where various goods and materials pass through several stages governed by multiple parties and geographically different processes. In another way, because of the globalized character of modern trade, trade flows and geopolitics have a greater impact on supply and demand than ever before., which emphasizes the significance of integrating information across the supply chain in order to respond rapidly to changes, ensure the chain of custody is secure, and prevent data silos. (Iggo, 2021)

Regarding the solution for information complexity and related issues mentioned above, increased visibility, transparency, and traceability can be an antidote. A greater level of collaborative working across the supply chain, where information transparency is recognized as a necessary prerequisite for a more efficient and effective value delivery system, is one way to tackle these challenges. Despite the fact that technology and its application in various industries are developing remarkably, in SCM industry, there are still arguments about whether the digital transformation is a key priority or not, given the sector's poor adoption of these advancements. The slow uptake of technological advancement is one of the driving factors for delaying the significant growth of the industry in the future. Explaining for this matter, according to the research of Coyote (2021) even though companies are fully aware of the relevancy between innovation and technology, and success and sustainable development, they are primarily uncertain regarding achieving the most outcome of new transformation. (Figure 5)

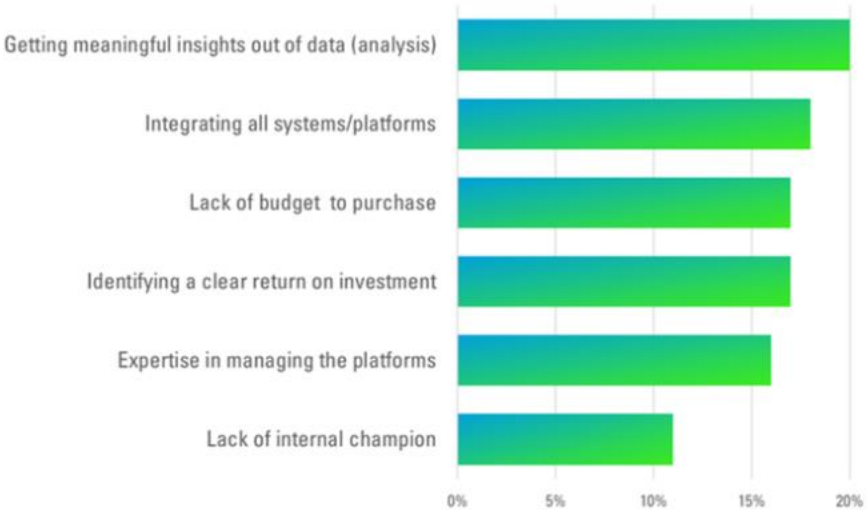


Figure 6 Supply chain companies' biggest challenges with technology (Coyote, 2021)

To summarize, the present supply chain is a highly complicated system due to changing client demands, competition, geographically separate enterprises, and the adoption of new business models. These out-of-date supply chains are battling to enhance demand management, offer data visibility across the entire flow, and monitor goods from raw material to end consumer—all of which are extremely difficult tasks. (Zhang, 2019) In addition, today's supply chain's outmoded technology fails to provide effective risk management, cost reduction, or the ability to address constantly changing market requirements. (Kersten et al, 2017) To some extent, the majority of challenges for SC, nowadays, have related to the information complexity of the whole network itself, in which companies have issues on maintaining data accuracy and updating the information throughout the system and in the real-time nature. Hence, it can be an urging situation for parties in SC process to considerably obtain a comprehensive digitalisation transform and not to let themselves lay far behind in the technology arms race as the cost can be dejectedly tremendous.

2.2 Blockchain Technology

In this chapter, the theory of blockchain and its characteristics will be reviewed.

2.2.1 Blockchain Overview

According to the definition of IBM (2021), "blockchain is a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network" (IBM, 2021).

More technically, Prableen (2016) defines that:

> A blockchain is a digitized, decentralized, public ledger of all cryptocurrency transactions. Constantly growing as ‘completed’ blocks (the most recent transactions) are recorded and added to it in chronological order, it allows market participants to keep track of digital currency transactions without central recordkeeping. Each node (a computer connected to the network) gets a copy of the blockchain, which is downloaded automatically.

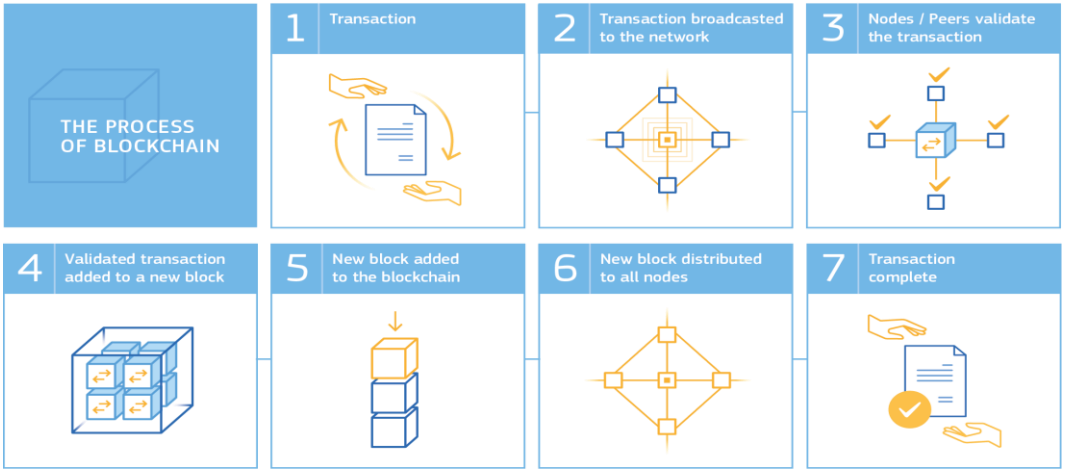


Figure 7: The process of Blockchain (European Union, 2019)

To share another point of view for this technology, according to (Anon., 2018), blockchain can be seen as a distributed ledger technology with extra functionalities. In a blockchain, transaction records are shared through blocks that form a chain. Every block in a blockchain's online ledger has a timestamp and a hash pointer that connects it to the preceding block. Simply said, a hash is a cryptographic signature that closes the blocks. The next block begins with the same "hash," which can be thought of as a form of "wax seal”.

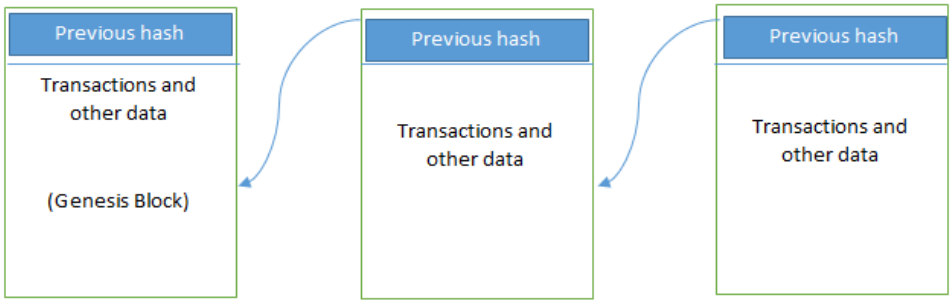


Figure 8: Structure of Blockchain (Bashir, 2017)

In conclusion, blockchain can be claimed as a "secure distributed and decentralized digital ledger" or "database created by a network of computers" which holds "continuous blocks" including information of transaction securely and verifiably. (Kshetri, 2021)

2.2.2 Blockchain Characteristics:

As stated by Nir Kshetri (2018), blockchain's main characteristics— decentralization, immutability, and cryptography-based authentication—are what make it such a powerful cybersecurity tool.

- Decentralization: The value proposition of blockchain is undoubtedly contained in its decentralization feature. Blockchain, by enabling decentralized models, can help make sustainability-related operations more visible, hence fostering trust. Blockchain eliminates the need for a trusted third party in the transfer of value, allowing for faster and less expensive transactions. (Kshetri, 2021)

- Immutability and append-only database: New data can be added to an append-only database, but current data cannot be changed. The data in a blockchain is immutable, which is a very useful advantage in the context of the Supply Chain. The term immutable refers to the fact that once an item has been created and recorded in software code, it cannot be changed. As a result, blockchain-based transactions are indelible and cannot be forged. The immutability feature makes blockchain transactions auditable, which can promote transparency. Controlled access to pertinent data can be granted to a party.

- Cryptography-based authentication: Blockchain systems use cryptography-based digital signatures to verify the identities of participants in order to ensure that only authorized users have access to the information. Users use a private key to sign transactions. When a user creates an

account, a key of this type is generated. Typically, the private key is a very long and random alphanumeric code. Blockchain systems generate public keys from private keys using complex algorithms. Information can be shared using public keys. This tool allows users to assess and track relevant results.

2.2.3 Types of Blockchain

Blockchains are classified into three types: permissionless (public), permissioned (private), and hybrid.

2.2.3.1 Public Blockchain

Public blockchains, as the name implies, are not owned by anyone. They are available to the public, and anyone can participate in the decision-making process as a node. Users' participation may or may not be rewarded. All users of permissionless or unpermissioned ledgers keep a copy of the ledger on their local nodes and utilize a distributed consensus process to determine the ledger's final state. Both Bitcoin and Ethereum are well-known public blockchains. (Bashir, 2018)

2.2.3.2 Private Blockchain

Private blockchains, as the name suggests, are exactly that: private. That is, they are only accessible to a consortium or group of individuals or organizations who have agreed to share the ledger. HydraChain and Quorum are two blockchains that are currently available in this category. Both of these blockchains can run in public mode if necessary, but their primary use is to provide a private blockchain. (Bashir, 2018).

Hyperledger

Hyperledger is a permissioned, private blockchain that uses no native cryptocurrency. It is an open-source collaborative initiative founded in 2016 by 30 members including IBM, Accenture, BNY Mellon, Intel, and Digital Asset Holdings to improve the usage of blockchain in a variety of industries. Hyperledger was used by more than half of the companies on the Forbes Blockchain 50 list for February 2020. (Hyperledger, 2020).

Membership in Hyperledger is divided into three types: premium, general, and associate. IBM, Intel, Accenture, American Express, Daimler, JP Morgan (premium), Lenovo, SAP, Tencent Cloud (general), Yale University, University of California, Los Angeles (UCLA), and Cambridge University are among the consortium members (associate). (Hyperledger, 2020) These companies are collaborating to create platforms, tools, techniques, procedures, and strategies for enterprise blockchain. (Kshetri, 2021)

One of the primary projects developed under Hyperledger is Hyperledger Fabric. It is a modular blockchain framework that enables enterprises to create blockchain-based goods, solutions, and applications. Consensus and membership services, for example, operate on a plug-and-play basis. (IBM, 2021)

As a result, businesses can perform private transactions without relying on a central authority. In terms of transaction completion speed, Hyperledger Fabric outperforms well-known cryptocurrencies and public blockchains. (Figure 3). For illustration, a single cloud data center running Hyperledger Fabric has a throughput of over 3500 transactions per second (TPS) and a latency rate of less than one second as of early 2018. This compares favorably to the public Ethereum ledgers' 10 to 30 TPS and the 3.3 to 7 TPS of Bitcoin ledgers. (Mearian, 2020)

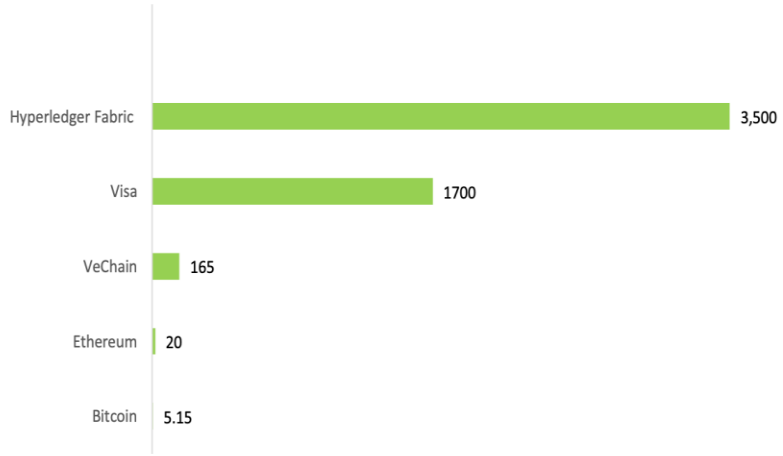


Figure 9: A comparison of throughputs of various blockchains and Visa (TPS) (Kshetri, 2021)

2.2.3.3 Hybrid Blockchains

Part of a hybrid blockchain is private, while the rest is open to the public. The private component of a semi-private blockchain is managed by a group of persons, while the public part is open to anyone.

(Bashir, 2018) Companies use permissioned networks to transact in the background in hybrid blockchains. The transactions are connected to a public blockchain via an application programming interface (API), allowing consumers and others to conduct activities such as money transfers and viewing product information in Supply Chain. (Kshetri, 2021). For businesses in which Supply Chain Management plays a crucial role, consortium blockchains are often beneficial. It can help businesses improve workflow efficiency, exchange information and resources, increase responsibility, and encourage transparency. (Blaha & Katafono, 2020)

2.2.4 Smart Contracts

According to Bashir (2018), smart contracts can be defined as *" a secure and unstoppable computer program representing an agreement that is automatically executable and enforceable."* A smart contract is, in fact, a computer program written in a language that a computer or target machine can comprehend, according to this description. It also includes parties' agreements in the form of business logic. Another essential concept is that when specific criteria are met, smart contracts are automatically executed. They are enforceable, which implies that even in the presence of opponents, all contractual provisions are carried out as described and planned. (Bashir, 2018)

It is safe to say that one of the most transformative applications of blockchain is the implementation of smart contracts. A smart contract guarantees to a party that the counterparty will keep its obligations. In Supply Chain, for example, a smart contract system can be set up to track products and decide ownership rights automatically. (IBM, 2021) Payments can also be released automatically when products are delivered using such a system. Cost savings can be gained with blockchain by incorporating "business logic" in Supply Chain into smart contracts. By eliminating intermediaries and employees, additional cost reductions can be realized. (Holbrook, 2019).

To sum up, the qualities of blockchain technology, which enables smart contracts, benefit them. Therefore, in supply chain activities, digitized self-execution of directions can be visible, traceable, and tamper-proof. (Godfrey-Faussett, 2020). It is possible to start converting data from unconnected supply plannings into a smart supply chain utilizing blockchain methods, which allow participants to verify informations while creating a new copy of the complete database that is encrypted.

2.3 Blockchain and Supply Chain Relations

An expanding number of players throughout the world are producing, transforming, and distributing consumer goods, where visibility and traceability provide deeper insight into assets at every stage of their life cycle. Meanwhile, new and developing technologies enable faster, safer, and more intelligent supply chain design, optimization, and management. Blockchain, which is best recognized as the underlying technology underpinning cryptocurrencies, is one of these emerging technologies. (Kayıkcı, 2020). This section aims to provide the relations between Blockchain and Supply chain, the benefits and limitations of the technology on the field, and analyze the opportunities and challenges of Blockchain application in Supply Chain and Logistics.

2.3.1 Current Status of Blockchain Adoption in Supply Chain

To address the difficulties and improve supply chain efficiency, industries have investigated innovative technologies that facilitate efficient communication and coordination in enterprises. Among these technologies, blockchain has a bright potential since it lets the supply chain deliver improved visibility, transparency, and accuracy of transactions throughout the entire process. Businesses, particularly those involved in supply chain management, have been made aware of the blockchain technology that enables cryptocurrency. (Zhang, 2019).

A study in 2017 has researched that approximately 62 percent of supply chain executives claimed to have used blockchain technology. (Eyefortransport, 2017) Supply chain management has experienced significant growth in the number of companies that uses blockchain-driven solution. According to the International Data Corporation (IDC), global spending on blockchain solutions would reach US$4.1 billion in 2020, a 50% increase over 2019. This organization states that the blockchain solutions market would be worth $17.9 billion by 2024. (Mass, 2020). The COVID-19 pandemic, which exposed several vulnerabilities and weaknesses in the supply chain, financial services, and other industries, has been ascribed by IDC to this rapid expansion. Companies are speedily recognizing the importance of blockchain and distributed ledger technology in tackling these issues in their supply chain and logistics processes. (Mass, 2020). In fact, the market research and business consultancy firm Allied Industry Research predicted that the worldwide Supply chain management market would grow from US$15.85 billion in 2019 to US$37.41 billion in 2027. The incorporation of blockchain into Supply Chain Management software is forecasted to be a major driver of the Supply Chain Management

market's considerable expansion. (Correa, 2020). In addition, Block data discovered that organizations in the Blockchain 50 which is the list made by Forbes to include the world's biggest brands with over US$1 billion in annual revenue that are using blockchain, were more likely to use blockchain for traceability and provenance, both of which are strongly tied to supply chain, than for payments and settlement. (Fenton, 2020) Also, according to Blockdata's investigation, among the Blockchain 50 lists, 15 had employed blockchain solutions for traceability and governance, while 13 had used such systems for payments and settlements. (Knegtel, 2021). Moreover, PwC has identified provenance as the No. 1 use case for blockchain, estimating that the technology has the potential to improve global GDP by US$962 billion by 2030 by assisting firms in verifying the sources of their goods, tracking their movement, and improving Supply Chain transparency. (PwC, 2020).

2.3.2 Blockchain technology benefits

The application of blockchain technology can considerably ease or perhaps remove the aforementioned challenges in today's supply chain. Blockchain technology optimizes supply chain efficacy, efficiency, and transparency while reducing transactional time and cost. Several ways in which blockchain technology benefits the supply chain are covered below.

2.3.2.1 Boosted efficiency

One of the main reasons for deploying blockchain technology is to replace today's inefficient, paper-based operations. The logically centralized data ledger delivers up-to-date local copies to all stakeholders inside the network, which is one of the benefits of digitalization. All transactions are committed and quickly validated by all parties involved, and data is synchronized to each party's local copy automatically. By reducing human error and eliminating the need for third-party intermediaries and local ledger reconciliation, blockchain technology makes it safer and faster to maintain the quality of transactions and associated data. (Verhoeven, et al., 2018). Finally, the self-executing blockchain-based smart contract replaces time-consuming processes and enhances supply chain management flexibility.

2.3.2.2 Increased Traceability and Transparency

Traceability within the supply chain has substantially enhanced as a result of the adoption of blockchain technology, which creates a completely auditable trail of all things moving through the network.

(Zhang, 2019) A blockchain-enabled supply chain, when combined with IoT-based sensors, may capture item-level data on enormous quantities of products in a timely manner. This data is also related to timestamps and collecting sites to create a complete, accurate, and easy-to-access audit trail from the product's origination to the customer. Furthermore, due to the immutability of blockchain and the digital signatures required to confirm information provenance, data stored in this chain gives a safe and comprehensive history of each item throughout the whole supply chain. Improved traceability allows the source of an issue to be discovered more rapidly in the event of a tainted product, which lowers the cost of recalling products and improves stakeholder disruption resolution. Also, stakeholders and customers can have increased confidence in a product's originality and quality which is provided by this beneficial feature. (Zhang, 2019)

By letting all stakeholders know who is executing what actions, at what time, and where, blockchain technology delivers dependable identity management in the supply chain. (Zhang, 2019) This data is saved and shared on distributed ledgers, which can be accessed by all involved and authenticated stakeholders at any time. The interconnectivity of many trading partners will strengthen when physical and digital flows are integrated across the supply chain. (Takahash, 2017). As a result, with its transparent and comprehensive inventory of product flow, a blockchain-enabled supply chain facilitates firms in making better projections and decisions. Furthermore, increased transparency is an effective strategy for preventing fraud and counterfeiting.

2.3.2.3 Enhanced trust

A blockchain-based supply chain's transactions are generated and recorded by peer-to-peer connection, which is verified by digital signatures. Moreover, a trustworthy identity management mechanism enables the collection of time, location, and other data for every activity on a product in the supply chain. (Zhang, 2019) All data is synchronized in real-time with all stakeholders, which boosts trust among supply chain stakeholders.

2.3.2.4 Better security

Hacking attempts, such as those that threaten centralized databases of intermediaries, are practically impossible to harm blockchain technology. When an attack is made to hack into a given block, all preceding blocks in the entire history must be tampered with as well. (Zhang, 2019) Therefore, blockchain offers a more secure method of keeping track of company activity and transactions.

2.3.2.5 Easy compliance

All transactions in a blockchain-enabled supply chain network are precisely recorded, including timestamps, environmental conditions, and location. These reliable, tamper-proof records can be managed to verify a company's data integrity and can be quickly accessed for regulatory and compliance purposes.

2.3.3 Blockchain technology limitation

In spite of its innovative advancements, blockchain can have drawbacks due to its technical limits. (Behnke & Janssen, 2019). The goal of this chapter is to present an overview of the numerous problems that must be overcome before blockchains can become mainstream technology. Even though different use cases and proof of concept systems have been established, and the technology works effectively in many circumstances, several basic constraints in blockchains still need to be addressed to allow this technology to be more adaptive.

2.3.3.1 Scalability

In every blockchain, scalability is usually considered as a critical issue. The technology cannot be scaled due to the capability of network congestion. For example, if the number of transactions is rising exponentially, there would be a high chance that the technology turns inefficient. (Wu et al., 2019). In scenarios when transaction volume is large, the transaction validation procedure may limit the applicability of blockchain and diminish transaction efficiency. According to Wu et al (2019), The technology's capacity to handle and store huge volumes of data is generally limited. Furthermore, the authors claimed that a multi-tier supply chain network mandates the processing of many transactions in a short amount of time, yet blockchain technology can arise inefficiencies and redundancies in terms of transaction processing. In fact, when compared to transaction-based solutions like Visa, the performance of blockchain is currently drastically poor in both speed and volume. (Perboli et al., 2018). Precisely, Visa's highest transaction speed is 65,000 transactions per second, while Bitcoin blockchain's maximum transaction speed is 7 transactions per second. In a centralized architecture, the controlling authority determines the flow; it does not needlessly inform other peers about a transaction, which saves time and improves efficiency. On the other hand, because a majority of nodes

must approve the transaction in the blockchain architecture, validation takes several minutes, resulting in limited scalability. Although numerous solutions are nowadays being developed to overcome blockchain's relatively poor scalability, they are still in the early stages of development.

2.3.3.2 Privacy

Blockchains' transaction privacy is a highly desired characteristic. However, everything is transparent by the technology's nature, especially in public blockchains, which prevents it from being used in fields where privacy is critical. Because there are no privileged users, the privacy settings are limited, and anyone may join the network and access all of the information on the blockchain. According to Zhao et al (2019), managing a blockchain may require an unprecedented level of transparency and visibility of supply chain procedures, potentially endangering confidentiality. Since information will be open and accessible to all members of a network, blockchains may not provide privacy for supply chain players. As a matter of fact, the amount of sensitive data protection and, in some situations, anonymity are crucial factors in the commercial adoption of this technology (Tian, 2017). Therefore, companies may be unwilling to participate in blockchain-based solutions until the risk is addressed if the information is regarded as strategic, sensitive, or secret. (Wu et al., 2019)

2.3.3.3 Security

Despite the fact that blockchains are typically secure and use asymmetric and symmetric cryptography as needed throughout the blockchain network, there are a few limitations that can threaten the blockchain's security. (Bashir, 2018). The blockchain network can be attacked in a variety of ways such as 51% attack, double-spending, DDoS attack, and cryptographic cracking. Thus, supply chain members may suffer huge financial losses due to code faults and security vulnerabilities of blockchain. Wu et al. (2019) indicated that security threats from blockchain can place enterprises at risk of data and revenue loss, whereas Zhao et al (2019) stated that the decentralized architecture of blockchain and its connectivity with a broad peer-to-peer network may lead to several privacy and security issues.

2.3.4 Opportunities and Challenges of Blockchain Integration in Supply Chain

2.3.4.1 Opportunities

Companies, countries, communities, and consumers all benefit from blockchain technology. In this section, the author aims to offer a quick overview of the opportunities presented by this technology.

First, blockchain enables the expansion of customer value as its digital ledger system allows the recording of data from the supply chain. This type of technology can give the end-user useful information and services, which enhances the real-time customer experience and increase product and service quality. In another way, blockchain is being viewed as a critical resource for empowering consumers and increasing their confidence and pleasure. Consumers can independently check product information using blockchain-based traceability solutions. The solutions can enable access to rich and detailed product information, which is likely to boost consumer confidence. For example, customers can access the process of production, reporting of the current status and costs of the items in the supply chain, and probably follow the process from the very beginning. Therefore, companies emerge blockchain as a powerful marketing and branding tool. Firms would be able to communicate with greater legitimacy and trust using blockchain-based databases. Many businesses, for instance, use the provenance blockchain platform to engage with customers, which offers Supply Chain data via in-store QR codes or e-commerce product sites. (NewsLagoon, 2020). Second, the technology is the foundation for automation and other IoT and emerging technologies development in Supply Chain. Blockchain-based solutions can assist provide immediate answers to inquiries such as, "Where is the shipment currently located? When will it reach its destination? Were there any problems along the way, such as excessive heat, excessive humidity, customs delays, physical tampering, and so on? Which Supply Chain participant is accountable for the problem?" However, the system may or may not solve the problems itself. When issues are identified through the system, other inventions on an automatic solution-dealer must be made, for instance. It will be safe to say that when blockchain and other IoT applications collaborate, it allows companies to save on labor costs, ensure data protection and optimize the business processes. Third, blockchain provides a potential method of managing the company ecosystem. Every party can participate in the logistics network and, as a result, manage their actions during the logistical operations. The recipient, carrying businesses, sender, and other companies can view the status and other process information in real-real-time change their processes based on the logistic network state. Hence, the entire business ecosystem will profit from the information supplied by the technology. (Sivula et al., 2021)

2.3.4.2 Challenges

Although blockchain technology is widely accepted as a possible solution to current supply chain difficulties, its implementation involves considerable adjustments in both technological and cultural contexts. Furthermore, more thorough examinations of it are required to reveal and address its shortcomings before the full potential of this innovative technology can be achieved.

The first major difficulty is that there are currently no blockchain-specific regulations or laws. Even though the blockchain might be held by private organizations, public organizations and the government need to offer some laws which can include, for example, some basic information on the parties involved in blockchain and its application. In this matter, government support and policies may serve as a catalyst for increasing technology adoption. Furthermore, the use of blockchain technology should be viewed as a facilitator for regulatory and certification norms, particularly those demanding goods traceability. (Kamble et al., 2019) To confirm the accuracy of the information, the government of the country, for example, may authenticate the company and ensure its identification using its systems. Otherwise, there may be some security concerns about the identity of the companies. The second challenge is standardization. In general, this technology provides a ubiquitous and multipurpose platform for digital data sharing and long-term storage. Surprisingly, one fundamental point remains unanswered: what content and format should be used for transactional data to ease interpretation by all participants? The entire supply chain community must adopt and agree on a data standard. However, no existing standard exists that can be applied for this purpose. (Zhang, 2019). The next challenge is that along with the young present stage of development, blockchains' technological immaturity is a significant major obstacle to their acceptance in SC. (Razzaq et al., 2019) As blockchain in the supply chain is currently at the concept stage rather than the production stage, despite ongoing implementing testing and piloting cases, the technology's immaturity adds to the doubts about its suitability for supply chain tasks. Even though additional research and development are required to make blockchain technology more useful in a variety of fields, this difficulty sadly performs as the main reason why there are a limited number of businesses that are developing blockchain in their supply chain. The involvement of new parties may give additional benefits for the advancement of the technology, yet the majority of firms may hesitate due to its lack of previous successful experiences. Last but not least, implementation struggles related to cost and expertise knowledge may hinder companies from adopting blockchain technology. Manufacturers, logistics operators, and notably small and medium-sized businesses, according to Longo et al. (2019), must engage more resources and money in integrating and managing a blockchain-enabled supply chain. The initial setup and

maintenance costs of blockchain may outweigh its benefits. Companies with scarce financial resources may be unable to improve their adaptability, positioning them at a competitive disadvantage against their competitors. Failure to recognize that blockchain implementation necessitates strong organizational capabilities can lead to serious operational issues. (Rejeb et al., 2020). The usage of blockchain may necessarily entail considerable capital investments in terms of implementation costs (Hughes, et al., 2019). As highlighted by Klerkx et al. (2019), the digitalization of supply chain operations demands the mobilization of a wide range of talents, expertise, and materials to represent digital data and capabilities into improved supply chain management decisions. Because enterprises may be unfamiliar with the blockchain system's concepts, operation, and maintenance, the innovation of blockchain technology generates extra issues (Zhao et al, 2019). Hence, in order to ensure efficient implementation, workers' skills, technical understanding, and organization capabilities must be developed.

2.3.5 The Roles of Blockchain in Attaining Strategic Supply Chain Goals

As chapter *2.1.4 Information Complexity and Related Challenges in Supply Chain* stated, along the complicated current supply chain process, there is a tremendous lack of transparency, traceability, and accountability. On the other hand, from production and processing to logistics and governance, blockchain technology is altering business in many potential different ways. Supply chain management can be a critical use case for blockchain since every step of the process can be tracked and verified, resulting in transparent and immutable data. As a result, the implementation of blockchain technology has the positive power to eliminate inefficiencies found in traditional supply chain management systems. As the matter of fact, many enterprises have integrated the technology to help address some of their ongoing supply chain issues. Figure 9, 10 (Kshetri, 2021) illustrates how blockchain can support important supply chain management objectives including cost, quality, speed, reliability, risk reduction, sustainability, and flexibility.

Supply chain performance dimension	Explanation/context	Example
Reducing costs	• Economic sense to generate a blockchain code even for small transactions. • Elimination of paper records. • Blockchain's traceability makes it possible to easily identify the source of a problem and engage in strategic removals of affected products instead of *recalling the entire* product line.	• Maersk: Significant costs savings by fully digitizing the documents in international SCs. • Walmart: 2.2 s to trace a product.
Assuring quality of products	• Verification of CoC discourages SC partners to use low quality and counterfeit ingredients. • Real-time feedback can improve product quality.	• Alibaba's "Food Trust Framework" aims to improve integrity and traceability of food SC in China. • Quality-related issues were down by 20% in Unilever's tea SC in Malawi.

Figure 10 Summary of how blockchain helps to attain strategic supply chain goals (Kshetri, 2021)

Supply chain performance dimension	Explanation/context	Example
Increasing speed	• Blockchain digitizes communications and other important processes; There is no need for paper documents to be stamped and approved. • The cryptodenominated international commerce.	• Maersk: A simple shipment required stamps and approvals from up to 30 people and included over 200 different interactions and communications. • Cryptocurrency as the means of payment to settle international transaction increasing in developing economies such as those in Africa and Latin America.
Increasing dependability	• Exerting pressure on supply chain partners to be more responsible and accountable for their actions.	• Gemalto's delivery of temperature-sensitive medicines from drug manufacturer to hospitals located in hot climates.
Reducing risks	• Only parties mutually accepted in the network can engage in transactions in specific touchpoints. • Can ensure that software file downloaded has not been breached.	• Validation of the identities of individuals participating in transactions (Maersk). • Foolproof method for confirmed identity can reduce cybersecurity-related risks (Lockheed Martin).
Facilitating sustainable practices	• Promotes transparency and ensure that middlemen and other actors in SCs do not engage in unethical behaviors.	• A project initiated by RecycleGO and DeepDive uses Hyperledger Fabric to identify the entire history of a plastic bottle: creation, collection, conversion back to raw material form, return back to the manufacturer to make another plastic bottle.
Enhancing flexibility	• COVID-19 has forced firms to search for blockchain solutions to increase flexibility.	• SMBC joined komgo and Contour to exchange documents required for LC.

Figure 11 Summary of how blockchain helps to attain strategic supply chain goals-cont'd (Kshetri, 2021)

Some current use cases of blockchain for supply chain in companies are introduced as follow:

2.3.5.1 Maersk

Maersk, a Danish shipping firm, is the world's largest container transporter, controlling 18% to 20% of the global market. Maersk is a well-known example of a corporation that has successfully explored blockchain applications in international logistics. Maersk utilizes the technology to monitor its shipping containers around the world, providing information such as GPS location, temperature, and other factors. (Jackson, 2017)

Back in the journey, Maersk had been looking for a new decent way to track the commodities it transports throughout the world for years. The "mountains of documentation" required with each cargo were a major issue for Maersk. For example, Maersk's storage room in Mombasa, Kenya's coast, was said to have shelves upon shelves of paper documents stretching back to 2014. According to a study by Maersk, in most cases, the containers can usually be loaded onto a ship in a matter of minutes. However, due to lacking paperwork, the process may be delayed in port for several days. For instance, a single container to handle a basic shipment of frozen products from East Africa to Europe may request stamps and approvals from up to 30 persons, including customs officials, tax officials, and health inspectors, which are approximately 200 different encounters and communications. Also, it was highlighted that transporting and keeping track of all the necessary papers could cost as much as moving the containers themselves. In the worldwide supply chain system, fraud may be ubiquitous. The bill of lading, for example, is frequently tampered with or replicated.

Therefore, Maersk decided to cooperate with IBM in the effort of building a more efficient supply chain in terms of cost, speed, and risks. The solution is called TradeLens which is mainly based on the Linux’s Foundation’s open-source Hyperledger Fabric. The project was finally completed in 2017, involving multiple partners along the chain such as terminal operators, freight forwarders, transport, logistics companies, and customs authorities, which resulted in the cost of paperwork reduction, shipping times decrease and the number of steps for answering basic operational questions decline.

2.3.5.2 Toyota

Toyota issued a four-million-vehicle recall in 2009 because of defective gas pedals. The recall is believed to cost $2 billion in the United States. Many different suppliers sent pedals to Toyota; however, it lacked the necessary tools to trace the suppliers who were accountable for the flawed products. As a result, it was unsolvable to identify which cars had faulty pedals.

Acknowledging the benefits of the technology, Toyota Financial Services joined the R3 blockchain consortium in June 2016, which was the consortium's first financial services provider for the automotive industry. Toyota then began utilizing blockchain to track auto parts in numerous markets, factories, and suppliers, as well as to provide and exchange real-time information among producers, finance companies, insurers, service providers, regulators, and customers. (Gantait et al., 2017) A blockchain system was used to store IoT data from automobile parts, which intended to reduce the number of recalls and counterfeit items, as well as improve consumer safety.

In summer 2019, the Japanese automaker, established the Toyota Blockchain Lab, intending to advance blockchain-based initiatives with external partners. The project was divided into four main sections, including identity and access management, controlling the life cycle of a car, supply chain management, and tokenization of ownership. (Insights, 2020)

2.3.5.3 Unilever

To solve the challenges of sustainability in SC which is cited as one of the most problematic procurement management issues in a supply chain forum in 2017, Unilever decided to cooperate with Provenance by utilizing their platform and applying data, technology, and analytics into tea leaf supply chain in Malawi.

The project aimed to improve quality control of tea leaf, and also guarantee fair payment for tea leaf farmers, which was reported by Greenbiz that it reached up to 10000 farmers within the area. Moreover, Unilever can use the information to boost the finance situation of manufactures and lower the overall expenses of their supply chain. Subsequently, savings are re-invested in small farmer communities to further educate farmers about sustainable farming techniques and enhance their productivity and social impact. Marc Engel, Unilever's Chief of Supply Chain Officer, highlighted real-time

information as a tool to discover answers to supply chain issues during an investor event earlier in 2017, claiming that "response times were reduced in half, and quality problems were down by 20%."(Kapadia, 2017). Also, product quality control and relationship quality with external partners such as suppliers, processors, farmers, and customers have improved as a result of real-time feedback.

2.3.5.4 Walmart

According to a PwC report in 2016, food fraud is a global problem that costs the worldwide related industry approximately between $30 and $40 billion per year, leading to a substantial influence on customer confidence regarding food purchase decisions. In 2018, there were estimated that at least 18 foodborne illness outbreaks, sadly, occurred in the United States, including the E. coli outbreak linked to romaine lettuce. Indeed, the food supply chain, on one hand, likewise other industries' supply chain, is greatly complicated, yet on another hand, can be differed from other brands of supply chains due to its unique requirements such as quality, safety, and freshness in a short period of time, which makes it more challenging to manage. (La Scalia et al., 2016)

Reported regarding Walmart's case in adopting blockchain in their food supply chain, Walmart Case Study – Hyperledger Foundation (2020) stated that:

> When a food-borne disease outbreak exists, it might take days, if not weeks, to track down the source. When investigators are unable to pinpoint a single farm or farms, the government normally advises consumers to avoid items cultivated in that area (as was the case with romaine lettuce from Yuma, Arizona), or even to avoid the product category altogether. Millions of bags or heads of lettuce had to be removed, according to Walmart, and consumers lost faith in romaine lettuce altogether. Improved traceability could save lives by allowing firms to respond more quickly and maintain farmers' livelihoods by only dumping produce from damaged fields.

For this matter, Walmart decided to choose blockchain as a focused tool to deal with transparency and traceability in food systems, which was then followed by two proof-of-concept (POC) projects cooperating with IBM. One project intended to track mangos sold in Walmart stores in the United States, while the other was to track pork sold in Walmart stores in China. As a result, the Hyperledger Fabric blockchain-based food tracking system was successfully implemented. It enabled the uploading of certificates of authenticity to the blockchain for pork in China, adding additional trust to a system where that was previously a major concern (Hyperledger Foundation, 2019). Also, surprisingly, the time it processed to track the provenance of mangoes in the United States fell from 7 days to 2.2 seconds.

To sum up, nowadays in Walmart, it is totally proudly traceable of the origins of over 25 products from five separate suppliers thanks to a Hyperledger Fabric based solution. In the near future, the company aims to expand the system to include more products and categories.

3 RESEARCH METHODOLOGY

In this chapter, the research process including research purposes, research methodologies, and data collection will be presented. As stated in the beginning of the thesis, the research problem and thesis questions are the decisive foundation for the methodological choices. The aim of this methodology chapter is to explain the relevance of the author's research approaches and the goals of the thesis, which enables readers to evaluate the scope and limitation of the research.

3.1 Research Purpose

According to Singh (2019), the research purpose is a statement that explains "why" the investigation is being conducted or what the examination's primary objective is. A research's purpose may be to differentiate or describe an idea, to explicate or forecast a situation, or to provide a solution for a situation that demonstrates the type of focus to be directed. (Hill, Campiglia, Beckingham and Brandes, 1974).

In the matter of the thesis's goals and questions, the research is a combination of exploratory, descriptive, and explanatory approaches. First, the thesis aims to explore a well solid understanding of what is blockchain's benefits and limitations in supply chain management. Second, the descriptive approach is used for investigating some companies' current cases and a case study is also examined. Finally, the conclusion and recommendation for the supply chain – blockchain relationship can be considered as an explanatory approach. Due to the nature of the study, which is relatively new and unsolved, the main goal is to gather useful knowledge for companies, or any people fascinated about the topic. Hence, the research characteristically focuses on an exploratory way.

3.2 Research Method

For addressing the key objectives of the research, inductive methods (qualitative methods) and deductive methods (quantitative methods) are the two types of data collection methodologies (DiscoverPhDs, 2020).

Adapted from (Hignett * and Wilson, 2004), Figure 12 highlights different dimensions of qualitative methods and quantitative methods.

Qualitative dimensions	Quantitative dimensions
Words, understanding	Numbers, explanation
Purposive sampling, inductive reasoning	Statistical sampling, deductive reasoning
Social sciences, soft, subjective	Physical sciences, hard, objective
Practitioner as a human instrument to gather data, prescriptive, personal	Researcher, descriptive, impersonal
Inquiry from the inside	Inquiry from the outside
Data collection and analysis intertwined	Data collection before analysis
Creative, acknowledgement of extraneous variables as contributing to the phenomenon	Predefined, operationalised concepts stated as hypotheses, empirical measurement and control of variables
Meanings of behaviours, broad and inclusive focus	Cause and effect relationship
Discovery, gaining knowledge, understanding actions.	Theory/explanation testing and developme

Figure 12 Different dimensions of qualitative and quantitative methods (Hignett * and Wilson, 2004)

The fundamental knowledge of what is qualitative or quantitative method enables the author to choose the main research method for this paper, which is the qualitative method. Qualitative research can be defined as *"the study of the nature of phenomena",* containing *"their quality, different manifestations, the context in which they appear or the perspectives from which they can be perceived"*, yet not including *"their range, frequency and place in an objectively determined chain of cause and effect"* (Philipsen and Vernooy-Dassen, 2004). Qualitative research captures the opinions and viewpoints of study participants as they emerge from the real world. (Yin, 2016). Furthermore, according to ResearchGuide, the form of qualitative research can be used to discover out how or why issues need to be addressed, analyze events, and describe activities, which is suitable for the author to gain enough knowledge and information to reach the aims of this paper.

3.3 Data Collection

Data collection is considered as a systematic procedure of obtaining observations or measurements, which then allows one to solve relevant challenges and comprise outcomes. (Bhandari, 2021). In research, data can be classified into primary and secondary data. Briefly, primary data is the kind of data that is collected directly from the data source without going through any existing sources, while secondary data is one that has already been acquired by someone else but has been made available for use by others. (Formplus Blog, 2021). Figure 13 adapted from KeyDifferences.com (2020) will illustrate the comparison between these two types and emphasize their characteristics. In this research, both types of data sources are constantly adopted.

BASIS FOR COMPARISON	PRIMARY DATA	SECONDARY DATA
Meaning	Primary data refers to the first hand data gathered by the researcher himself.	Secondary data means data collected by someone else earlier.
Data	Real time data	Past data
Process	Very involved	Quick and easy
Source	Surveys, observations, experiments, questionnaire, personal interview, etc.	Government publications, websites, books, journal articles, internal records etc.
Cost effectiveness	Expensive	Economical
Collection time	Long	Short
Specific	Always specific to the researcher's needs.	May or may not be specific to the researcher's need.
Available in	Crude form	Refined form
Accuracy and Reliability	More	Relatively less

Figure 13 Comparison between primary and secondary data (KeyDifferences.com, 2020)

Regarding primary data, the information was collected from a case study which is based on SmartLog Project - a blockchain-based pilot project regarding transportation in SC within Baltic/North Sea region. The techniques used for collecting data in this case study were from an in-depth interview with Mika Lammi - Head of IoT Business Development, Kouvola Innovation Oy which was the leading party of the project, and archival document reviews through the project's materials, and final report. Due to the far distance between Kouvola and Vaasa as well as the complex situation of Covid-19, the interview was carried out online in approximately 1 hour. A semi-structured interview was followed, in which the framework of the questions was held by the researcher, yet it still encouraged both parties to openly discuss related matters for developing the core themes if they arise.

Regarding secondary data, information from books, journals, articles, reports, and internet websites was gathered. A mixed literature review method between narrative and integrated one was used to analyse the information from the theoretical framework. The literature review aimed to report the

theory findings, structure conceptually of the theory, and synthesize the knowledge on the thesis topic. The steps of the literature review process are presented in Figure 14.

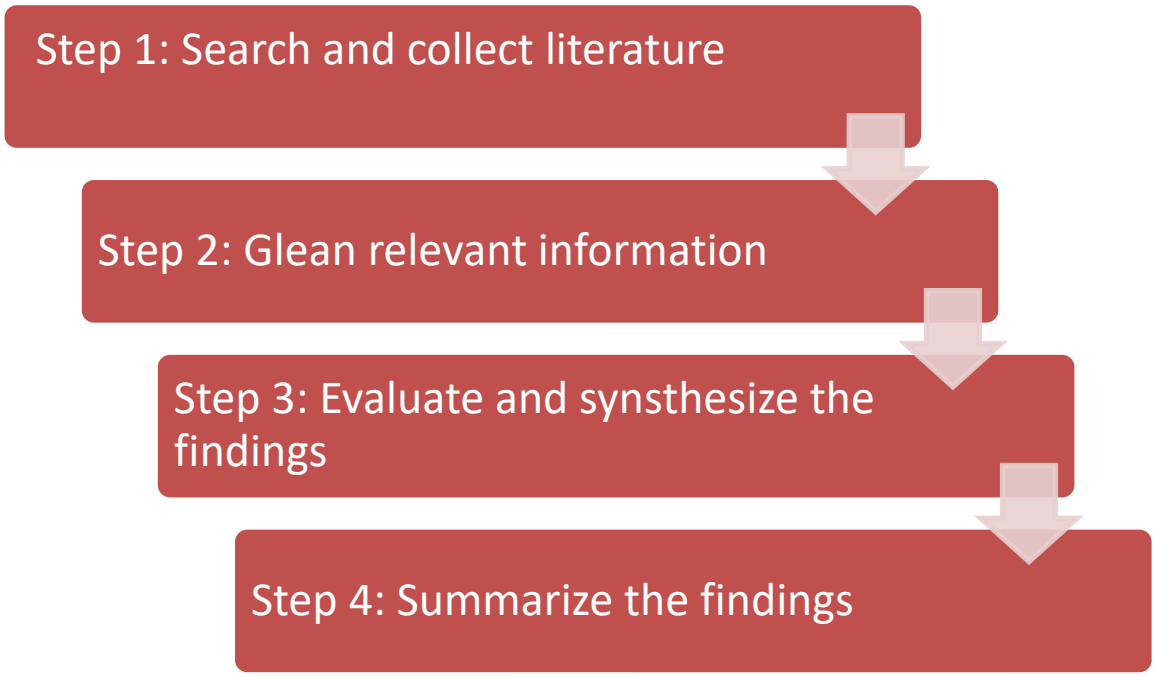


Figure 14 Literature review steps

4 RESULTS

This chapter will describe the results from collecting two sources of data: primary data and secondary data. The key findings from a case study and literature review will be comprised along with answering the thesis's investigate questions.

4.1 Case study – SmartLog project

4.1.1 Case introduction

The SmartLog project is a blockchain-enabled experimental one that aims to decrease overall cargo unit transport times in the Baltic/North Sea region in compliance with the EU's targets for road, rail, air, and water transport networks which were being performed as part of the TEN-T (Trans-European Transport Networks) program. (Porttechnology, 2017)

Transportation expenses and delivery time are significant factors for most industries, therefore, adopting innovative technology to improve transportation efficiency helps lower total costs and delivery time (Smart Logistics and Freight Villages Initiative | Central Baltic Project Database, 2021). Thus, it is critical for transportation management services, warehouse management systems, and other parts of the logistics and supply chain to use technologies in order to meet the changing expectations of end customers. In this matter, SmartLog was launched with the goal that this new solution would optimize all aspects of integrated supply chains including transportation, warehousing, cross-docking, inventory management, packaging, and freight forwarding by removing the need for routine human work with computer systems and providing access to vast amounts of anonymized data outside of an organization (Smart Logistics and Freight Villages Initiative | Central Baltic Project Database, 2021). Therefore, organizations' operational costs are lowered, as is the time taken for delivering goods.

The project involves six partners who represent logistics firms, regional/local governments, and research organizations and cover the regions along two transport corridors. All partners have good access to the project's key target group - logistics and transportation enterprises along the two routes:

- Kouvola Innovation Oy, Finland
- Region Örebro county, Sweden
- Transport and Telecommunication Institute, Latvia
- Valga County Development Agency, Estonia

- Sensei LCC, Estonia
- Tallinn University of Technology, Estonia

In total, 648 companies were approached, and detailed studies were undertaken in 151 companies operating along the aforementioned corridors. The goal of these connections was to obtain input into software design, to understand and map their processes, and to develop an understanding of the maturity level of hard- and software, as well as their sensitivity to new technologies. In 48 companies, detailed process maps were created, and simulations employing these measuring points were performed. Finally, the built software was linked to the IT systems of 12 different organizations, and real-time data was collected and analyzed. (Kaare, Pilvik and Koppel, 2020)

As a result, in today's business circumstances, trust regarding security and privacy were discovered as major concerns in adopting new technologies in supply chains. As small and medium-sized companies both have very poor levels of digital maturity; the emphasis should be on big corporations. (Kaare, Pilvik and Koppel, 2020) Their operations have been better structured and digitalized, their financial investment and know-how capabilities have improved, and their IT systems have advanced. Also, the project found out that the use of restricted and private platforms, as well as bilateral integrations, in enterprises endangers standardization. The number of competing platforms is growing, which adds to the complexity. Early data transmission standards in supply chains and logistics have been developed, however, they are still likely to be modified and competed with other similar advancements.

Through the piloting project, blockchain has generated above-average interest and perceived value in the logistics business. Time savings along the two targeted routes were 6.3 percent based on process simulations and 3.8 percent based on data analysis. (Kaare, Pilvik and Koppel, 2020) Larger time savings can be predicted as staff becomes more accustomed to the benefits of the new software solution (Smart Logistics and Freight Villages Initiative | Central Baltic Project Database, 2021). All in all, according to the modeling, the enhanced blockchain-based system can clearly save transportation time, potentially leading to cost decrease and other strategic objectives achievement in the supply chain.

4.1.2 Interview outcomes

The interview was conducted with Mika Lammi who is the Head of IoT business Development of Kouvola Innovation Oy – the leading partner of SmartLog project. He has had great experiences in digital and creative industries business development as well as education for the past 18 years, and currently been working as Chief Technology Officer at DBE Core Ltd – a blockchain-based system provider to a wide range of industries. (Lammi, 2021). For this individual interview, the author built a question framework in which the thesis's investigate themes were covered to understand the advantages and disadvantages of blockchain technology in supply chain management, and also discover the possible solutions and recommendations. (Appendix 1) The results based on each investigation question are explained as follow:

4.1.2.1 Advantages of blockchain itself and benefits of blockchain adoption in supply chain management

According to Lammi (2021), blockchain can boost the communication within parties in the supply chain predictably, accurately, and reliably in a timely manner. "Blockchain is a kind of glue that binds all the other technologies together and takes care of the intercommunication between each actor" – He stated. In fact, there are numerous communication channels and standards in use at all times and throughout the logistics and supply chain business. Phone calls, text messages, structured and unstructured emails, faxes, and the different information management systems in use — not just one per company, but frequently several inside a single organization (Porttechnology, 2017). It seems to be impossible to generate feasible integrations between firms' systems and operations, resulting in a situation in which all critical information is already available, but is locked away in small boxes maintained by individual companies with no motivation to share, therefore the industry's difficulty arises from a weakness of not able to share transaction-based information efficiently enough. (Porttechnology, 2017). "With blockchain, the possibility and probability of data delay are minimized. Blockchain can connect the dots, very efficiently share the secured information and offer multi-parties transparency and trust" -told by Lammi. In this circumstance, as highlighted by Lammi (2021), the whole supply chain ecosystem benefits from blockchain adoption, especially transportation providers and end consumers. "Transport service providers need predictability above all other things in order to make good business. Anything that surprises their timetables is always a loss in their books. Block-

chain brings predictability and transparency, so these transport service providers are capable of planning their operations with much more accuracy." – he emphasized. Also, he mentioned that end customers can obtain considerably from blockchain integration if the information about real-time status can be maximized, which is also advantageous for companies as satisfying customers is one of the core missions in supply chain management. He compared the application of blockchain as fax machines, once it is widely spread, "it will be cheap, cost-efficient, convenient and become a game-changer".

4.1.2.2 Disadvantages of blockchain itself and challenges of blockchain adoption in supply chain management

From Lammi's view, the difficulty of blockchain adoption in SCM is that companies are afraid of making adjustments in their management system. He said that innovation brings expenses to the table and it can be one of the biggest barriers for enterprises. Also, "as the blockchain, to some extents, is still not familiar enough, and most people do not have a comprehensive understanding about the technology" he explained. Thus, lack of expertise information can hinder blockchain from being integrated. In addition, the lack of proper rules, regulations, and policies from the government is another reason for the blockchain adoption challenges. Indeed, government support and legal framework is a concrete foundation for any digitalization technology development.

4.1.2.3 Recommendation for successfully adopting blockchain in SCM

Lammi agreed that, sadly, there have not been any proper solutions to tackle the challenges of blockchain adoption in SCM, yet. However, he suggested that a legislative framework should be built by the government for companies to see the approval and encouragement from the government and use it as the groundwork for applying blockchain in their supply chain operations in the future.

4.2 Literature review

For the literature review, the total number of literatures, as well as years of research materials, were recorded (Figure 15, 16). The literature review aims to be an evaluation of the theoretical framework, which demonstrates and constitutes the key findings in alignment with the thesis's investigate questions, thus it will not describe any further details, yet focus on the encapsulation purpose.

Document Type	Count	Percentage
Article	42	45,16 %
Book	7	7,53 %
Case study	4	4,30 %
Report	7	7,53 %
Thesis	2	2,15 %
Blogpost	4	4,30 %
Website	27	29,03 %
Total	**93**	

Figure 15 Total number of documents

Year of documents	Count	Percentage
2021	26	27,96 %
2020	20	21,51 %
2019	15	16,13 %
2018	5	5,38 %
2017	7	7,53 %
2016	3	3,23 %
2014	1	1,08 %
2011	1	1,08 %
2007	1	1,08 %
2004	1	1,08 %
2004	1	1,08 %
2001	1	1,08 %
1999	1	1,08 %
1998	1	1,08 %
1997	1	1,08 %
1996	1	1,08 %
1994	1	1,08 %
1993	1	1,08 %
1990	1	1,08 %
1988	2	2,15 %
1974	1	1,08 %
1973	1	1,08 %
Total	**93**	

Figure 16 Years of documents

4.2.1 Advantages of blockchain itself and benefits of blockchain adoption in SCM

As summarized from the literature, figure 17 will give concise information about the advantages of blockchain itself and the benefits of blockchain adoption in SCM.

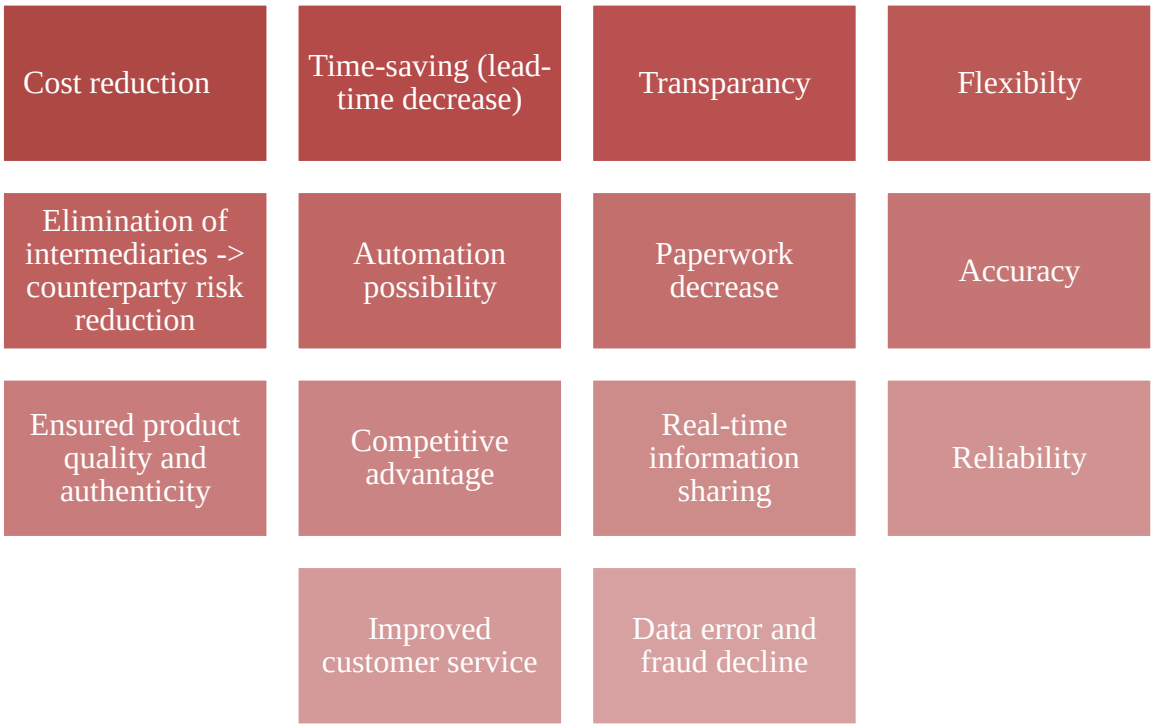


Figure 17 Summary on blockchain's advantages and benefits of its adoption in SCM

4.2.2 Disadvantages of blockchain itself and challenges of blockchain adoption in SCM

As summarized from the literature, figure 18 will list fundamentally the disadvantages of blockchain itself and challenges of blockchain adoption in SCM

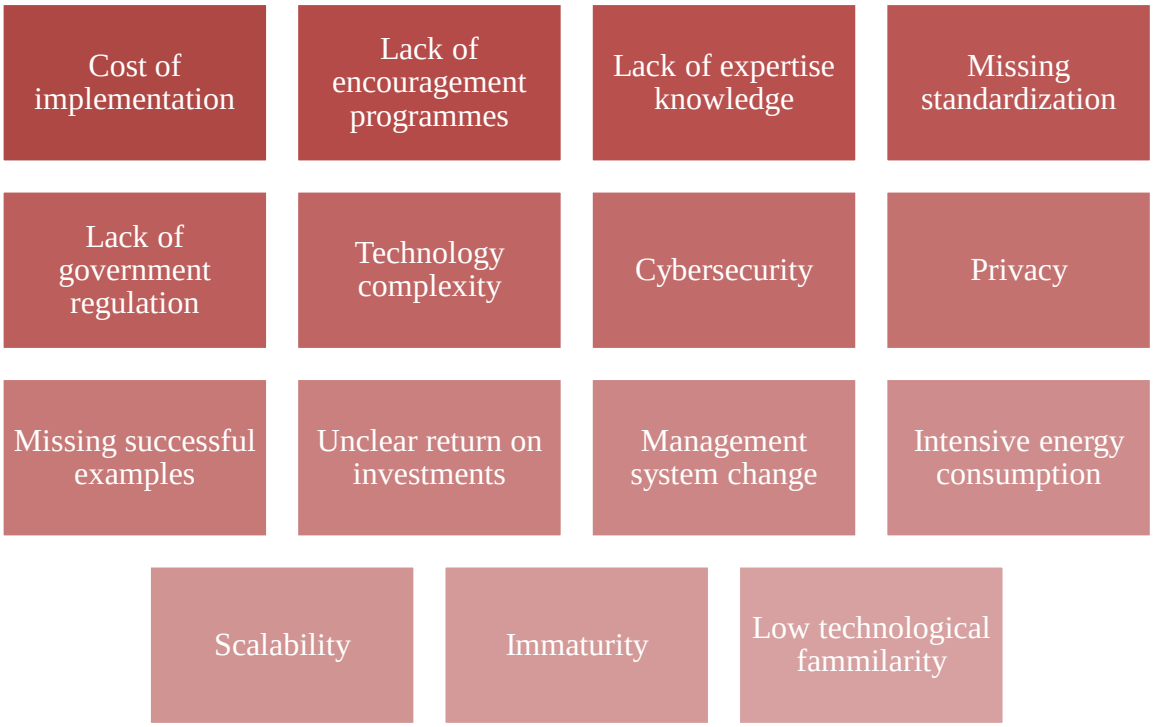


Figure 18 Summary on blockchain's disadvantages and challenges of its adoption in SCM

4.2.3 Recommendation for successfully adopting blockchain in SCM

There is no such a complete solution package for all types of supply chain from every enterprise, instead, for successfully deploying the technology, a tailored know-how strategy should be developed case by case. Thus, the following recommendations should be viewed in a general nature, in which steps can be adjusted depending on different business cases.

Overally, according to Tarasenko (2020), first, for starting blockchain implementation, determination of use case is necessary. A holistic description of the blockchain's "reasons for application" and the goals to be attained should be prepared. The next step is focusing on architecture development, which is used for analyzing which types of blockchain that companies should adopt. The third step is for application approach selection. In this phase, companies need to resolve who/ what should be engaged in the adopting process as well as how they should implement the technology in their supply chain. Finally, the execution phase can be entered where further support and development during the ongoing project can be considered. From a successful case – Walmart, letting the business lead the project,

deeply understanding business case, having good human resources, a story-telling vision, participating in technological forums, and starting small with a POC are practical advices that was shared by Frank Yiannas - former Vice President of Food Safety in Walmart (Walmart Case Study – Hyperledger Foundation, 2021). Because well-perceiving business cases and being able to select the right type of blockchain that is suitable for the firms' needs are significantly important, a decision framework adapted from Unnu, K. et al. (2019) is presented below.

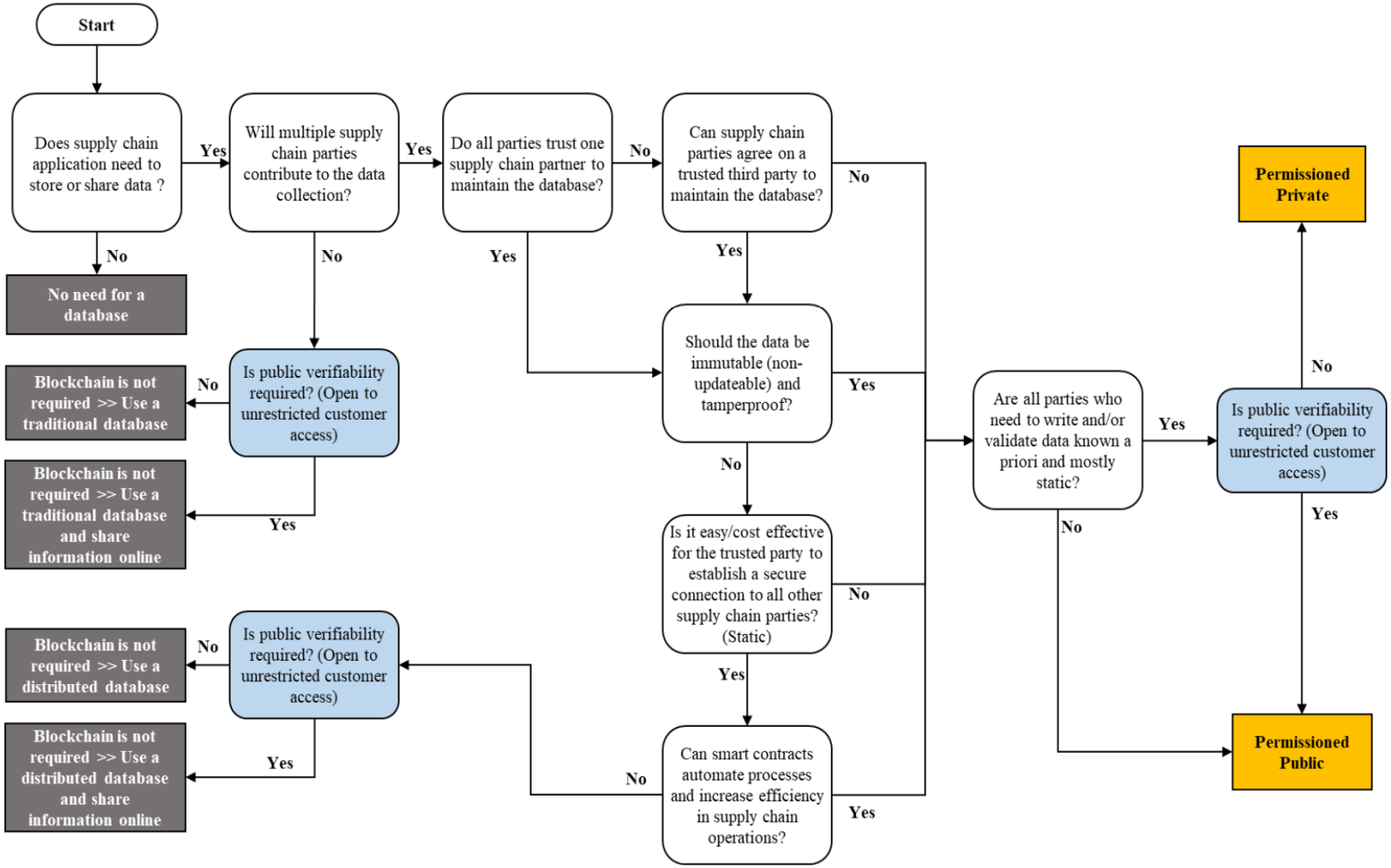


Figure 19 Decision Framework for selecting blockchain in supply chain (Unnu, K et al., 2020)

5 CONCLUSION

In this concluding chapter, the combination of main findings from primary and secondary for fully answering investigate questions will be discussed. In addition, the reliability, validity, limitation of the thesis will be deliberated, also recommendations for further research will be suggested.

5.1 Discussion

What are the advantages of blockchain technology itself and the benefits of blockchain adoption in SCM?

Regarding this question, after analyzing the case study and adopting knowledge from the theoretical framework, it is safe to say that blockchain technology offers various benefits to SCM. With its advanced technology, blockchain technology has formed its unique essential characteristics. The technology is a secured-centric decentralized complex system, which allows the stored data to be transparent, anonymous, auditable, and immutable in a time-stamped nature. All of these distinct attributes have provided valuable assets for a sustainable SC. Many of these helpful advantages can be viewed from Figure 17. For illustration, with the better information sharing across SC ecosystem offered by the blockchain-based solution, the tracking process of products and distribution assets through the system, will be completed in a much faster and more accurate than ever before, which generates traceability, trust, and transparency. Additionally, a comprehensive audit record of every product movement or financial transaction from its origin to its final destination will be ensured, limiting the possibility of fraud in the process. Moreover, trade-related information can be communicated in real-time and associated errors appear to be minimized as a result of less manual reconciliation. Thus, these benefits lead to a significantly desired outcome in any kind of business: cost reduction, in which the network may become much more efficient, time-saving, and visible. From the enterprise management's point of view, adopting this innovative technology can bring improved business performance including profitability, adequate customer service, a high level of management and operational processes integration, and an extraordinary competitive advantage. Considering a sustainable SCM as a future of business, once the blockchain is fully implemented, it can be promised to be the acceleration for further technological improvement in the ecosystem. In fact, the potential of process automation can be one of the key further steps of the innovation, because thanks to the blockchain-based foundation, sharing, upgrading, and responding to information-based actions can be automated to a high degree virtually instantaneously, hopefully for a human-free system in the future.

What are the limitations of blockchain technology itself and the challenges of blockchain adoption in SCM?

According to the main findings (Chapter 4: Results), the obstacles of blockchain technology application in SCM can be classified into three categories of difficulty sources: technology, company, and government. The list of difficulties can be seen from Figure 18. First, from the technology itself, the drawbacks may derive from the limited maturity, and scalability as well as the complexity of blockchain. Also, the security and privacy concern may increase the enterprise's resistance towards the technology. Still, the question regarding "to what extent will my information be protected" remains unsolved for blockchain technology. Second, regarding obstacles from companies, the extensive adopting cost seems to be the biggest challenge, whereas companies cannot be ensured with the solid return in investments due to the limited successful examples. In addition, inter-organizational hurdles from collaboration efforts, hesitance in changing management systems, and lack of expertise workforces negatively affect blockchain technology adoption. Last but not least, the constraint on fundamental legacy frameworks is a remarkable disable for blockchain integration. Furthermore, the slow process in perceiving new concepts and building policies for this technology from the government challenges companies in adopting blockchain in SCM. Indeed, encouragement programs for blockchain innovation should be boosted more by authorities for increasing the current imprecise knowledge towards blockchain technology.

What are recommendation for companies to successfully adopt blockchain technology in the supply chain management, if any?

In the author's opinion, despite the limitations of blockchain technology, such a technology is still powerful in helping companies to achieve a sustainable supply chain and improve their business performance. Nonetheless, the successful scenario cannot be guaranteed for every enterprise, since the technology necessitates not only a profound knowledge but also a thorough adopting preparation based on carefully analyzing each business case. Thus, the recommendations collected from literature and a case study hold an overall nature in which customization is crucial. Generally, in the pre-adoption phase, a deep understanding of the technology and the business problem is significantly important. Subsequently, synchronizing between the characteristics of the technology and the main aims of implementation can help to decide the right type of blockchain system for SCM. Figure 19 can be employed as a reference during the selection process. During the mid-adoption and post-adoption

phases, it can be mindful to note that modifying and upgrading to an extensive degree may be necessary. Since blockchain technology has constantly been emerging and to some extent, different aspects have been staying unexplored, the adoption of blockchain in SCM has strong prospects in affirming an innovative sustainable outcome for corporations. In the scenario that blockchain has been introduced for over 10 years, the technology by itself has proved its meaningful existence in different industries. Therefore, for the government, a comprehensive regulatory framework for protecting involving actors' rights and managing different parties' responsibility in such a complex network is undoubtedly imperative.

5.2 Reliability, Validity, and Limitation

To begin with, according to Lincoln & Guba (1983), reliability and validity in qualitative research can be associated with the following terms: "creditability", "neutrality" or "confirmability". "consistency" or "dependability" and finally "applicability" or "transferability". In this matter, there is a considerable amount of literature collected and analyzed carefully by the authors (Figure 15+16) which is based on a fully structured theoretical framework and a case study with a variety of involving companies in the industry as well as the interview from a greatly experienced expert in the field, thus, it proves a good sign of valid applicable information and reliable source of data. Also, the selected research method offered the author a rational approach design, which successfully contributed to final precise information for the investigating questions, as the data were gathered not only from trustworthy theory but also a realistic case study and constructive interview. In addition, after the interview, for enhanced accuracy purposes, a detailed note was formed thanks to the recording file and digital transcribing tools. The saturation had already been detected in the findings of both primary and secondary data with some similar perspectives in particular areas of investigating the question, hence, the same outcomes began to reappear. Indeed, when considering the results of this thesis and other similar studies, similar insights can be viewed, convincing that the thesis was generally conducted in a reliable and valid concept.

Regarding the limitation of this thesis, even though the data of this study consists of 93 sources of references, as well as a case study in which there are 151 involved companies within the Baltic region, the results cannot be fundamentally generalized. In another way, as mentioned in the above chapters, due to the complexity of SCM and the blockchain technology, as well as the difference of each business case, the results of this study cannot either represent all of the existing advantages and disad-

vantages of the blockchain adoption in SCM, or ensure that the recommendations will be fully applicable in every operational circumstance. Moreover, as blockchain is in the development stage and will potentially evolve significantly in the future, the accuracy of this thesis results cannot be ensured over time.

In short, despite the limitation of this thesis, overally, the results can be believed to fully cover the investigating questions and achieve the thesis's aim of the researcher where benefits and challenges on blockchain adoption in SCM were studied and recommendations for a successful deployment were compiled. This thesis can be useful for organizations that are interested in the technology and its application's benefit and limitation in SCM.

5.3 Recommendations for Further Research

For suggestions of further research, this thesis can be served as the essential base for further investigation on blockchain adoption from other business industries and perspectives. For example, a specific process in SC can be explored in alignment with how blockchain applications can affect it. Also, a detailed successful example can be discovered to give deeper understandings of how to implement the technology in SCM with a favorable outcome. Additionally, the blockchain application process for various partners in the network including processors, producers, transportation providers, distributors, wholesalers, and retailers can be considered as further research, in the effort of spreading the profound understandings about blockchain to potential participants and as a result, enhance the blockchain adoption in SCM.

As noticed from the literature and case study, there is not much information regarding the economically efficient of blockchain in SCM, even though a great number of data show that cost reduction appears to be an attractive advantage from blockchain applications. Thus, a further study regarding the impacts of blockchain implementation on the economic performance of companies can be explored.

Moreover, another interesting topic for future research can be further technological improvements combined with blockchain, for example, automation, big data, AI, e.g., which studied on the much more advanced systems to solve SCM's major challenges in the near future.

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APPENDICES

Appendix 1: Semi-structured interview questions

1. Can you tell briefly about the project background and project outcome?
2. Why Blockchain was chosen to be the main technology for solving supply chain problems in the project?
   (Themes: Advantages of blockchain technology, Benefits of blockchain adoption in SCM)
3. Who are the stakeholders that can benefit from the integration of blockchain in supply chain?
   (Themes: Advantages of blockchain technology, Benefits of blockchain adoption in SCM)
4. What obstacles can hinder companies from adopting blockchain-based solution?
   (Themes: Limitations related to blockchain technology, Challenges on blockchain adoption in SCM)
5. Can you suggest any possible solutions to tackle the challenges that you mentioned, if any?
   (Themes: Recommendations for blockchain adoption in SCM)
6. What can companies do/ prepare in order to successfully adopt blockchain technology in their SCM?
   (Themes: Recommendations for blockchain adoption in SCM)