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Potential of blockchain in supply chains

Case of transportation companies

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Abstract

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This research-oriented thesis investigated potential applications of blockchain technology in the transportation industry. At first, it explored the capabilities of blockchain technology in international supply chains through reviewing the latest theory in the field. Qualitative cross-case analysis was utilized to test theory against cases of three different transportation companies: a fuel importer, an express road carrier and a freight forwarder. Data collected through semi-structured interviews revealed the challenges of the case companies, identified their current responses to those and potential improvement directions.

Based on the interview data the research focused on identifying strong use cases for blockchain implementation and potential obstacles hindering it. The analysis pointed out that the studied cases in general reflected what was discussed in the literature. However, some exceptions were recognized regarding trust issues, attitude to Electronic Data Interchange (EDI), coopetition and the perception of the business environment. The validity of the identified use cases was verified through a decision tree released by the World Economic Forum for determining the suitability of blockchain technology for a case.

As a result of the evaluation, case companies – due to different circumstances – were advised to take a waiting position regarding blockchain implementation. The research revealed that case companies were not sharing the enthusiasm and optimism typical of the literature. The report was concluded by listing limitations and directions for further research.

Keywords
Blockchain, Supply Chain Management, Logistics, Transportation, Smart Contract, Electronic Data Interchange (EDI), Coopetition

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1 Introduction

“At this point, blockchain is still a largely unproven innovation in the supply chain field. However, it's also one that companies can't afford to ignore.” This thesis aimed to investigate if this statement of Ken Cottrill from 2018 was still valid in 2021. The following subchapters give further details about the context of this report. First, reasons are highlighted, why this topic is worth researching. After that, the thesis topic is specified and demarcated. Finally, some key concepts and the case companies of the research are introduced briefly.

1.1 Background

MHI (previously known as Material Handling Industry of America) joined by the management consulting company Deloitte, has prepared several Annual Industry Reports in a row by surveying professionals from the field of material handling, logistics, and supply chain. In the report of 2017, 80% of the respondents were of the opinion that digital supply chains would be the predominant model within five years (Michel 2017). The annual report from 2018 identified 11 key technologies playing a crucial role in the supply chains of the future. Blockchain was one of those driving forces. (Blanchard 2018.) Salviotti and colleagues (2018, 3467) also identified blockchain as ”one of the most promising technologies in the digital arena”.

Schmidt and Wagner (2019) highlight that there is a need for academic research on how and when blockchain can create value for businesses. At the same time, they perceive that companies are under pressure to act upon the vivid discussion around blockchain technology. Controversially, supply chain professionals have a limited knowledge of this topic. The same 2018 report from the MHI-Deloitte series revealed that nine out of ten supply chain leaders didn’t have understanding of the technology, and only 11% of the 1100 surveyed professionals reported that they had a working understanding of blockchain technology and its applications (Blanchard 2018). Still in 2020 Van Hoek and colleagues (2020) experienced similar attitudes when citing “I don’t really understand it. I don’t really know what to do with it” as typical phrases from discussions with supply chain practitioners about blockchain.

In such a setting, where companies are pushed to act proactively while lacking the understanding of the topic, this thesis intended to give the most value to the commissioning company by introducing this topic in an easily comprehensible way. It aimed to focus on

the business value and not to involve the technical implications. It is important to emphasize how misleading and harmful to blockchain's implementation is to present it as a universal solution to everything. Even though there is a high number of such "evangelists" – as Mulligan and colleagues (2018, 3) point out – an objective approach is necessary to the topic. This thesis strived to introduce advantages and disadvantages as well in a balanced way.

1.2 Thesis topic

This thesis explored what opportunities the application of blockchain technology could bring to international supply chains and especially to transportation sector. It aimed to reach that target by answering the following investigative questions (IQs):

- IQ 1: What are the major challenges transportation companies are currently facing?
- IQ 2: What tools transportation companies are using to address those challenges?
- IQ 3: How could transportation companies' operations be improved by the usage of blockchain technology?
- IQ 4: What obstacles would hinder transportation companies from introducing a blockchain based solution?
- IQ 5: What recommendations can be given to transportation companies regarding blockchain implementation?

Table 1 below represents the theoretical framework, research methods and results chapters for each investigative question.

Table 1. Overlay matrix

Investigative Questions (IQs)	Theoretical Framework (chapter)	Research Method(s)	Results (chapter)
IQ 1: What are the major challenges transportation companies are currently facing?	2.2.2 Latest trends and challenges in supply chains	Qualitative (code) analysis of open interview questions to interviewees	4 Suitability of blockchain technology for the case companies
IQ 2: What tools transportation companies are using to address those challenges?	2.2.2 Latest trends and challenges in supply chains	Qualitative (code) analysis of open interview questions to interviewees	4 Suitability of blockchain technology for the case companies
IQ 3: How could transportation companies' operations be improved by the usage of blockchain technology?	2.3 Using blockchain technology in supply chains	Qualitative (code) analysis of open interview questions to interviewees and combining outcome with findings from the literature review	4 Suitability of blockchain technology for the case companies
IQ 4: What obstacles would hinder transportation companies from introducing a blockchain based solution?	2.3 Using blockchain technology in supply chains	Qualitative (code) analysis of open interview questions to interviewees and combining outcome with findings from the literature review	4 Suitability of blockchain technology for the case companies
IQ 5: What recommendations can be given to transportation companies regarding blockchain implementation?	3.1.4 Toolkit for determining the suitability of blockchain technology for a case	Applying the toolikit to the use cases identified in relation to IQ3.	4 Suitability of blockchain technology for the case companies

The report first approached the topic from the level of supply chain management. It is necessary so that the potential of blockchain technology can be introduced thoroughly enough. Blockchain technology solutions typically have a coverage over complete supply chains, not only single actors, such as the transportation companies. Thus, the understanding how blockchain technology is affecting the whole supply chain is required for the transportation companies as well. Later on however, the scope was narrowed down to logistics and finally to the transportation industry. The thesis focused on the business implications of blockchain technology applications, technology background was not making part of this study. As the report aimed to introduce the technology on a general level, it is not looking into particular platforms (softwares, solutions) or specific applications (smart contracts or combinations with IoT) either in detail. The conceptual image of the theoretical framework is displayed in figure 1 below.

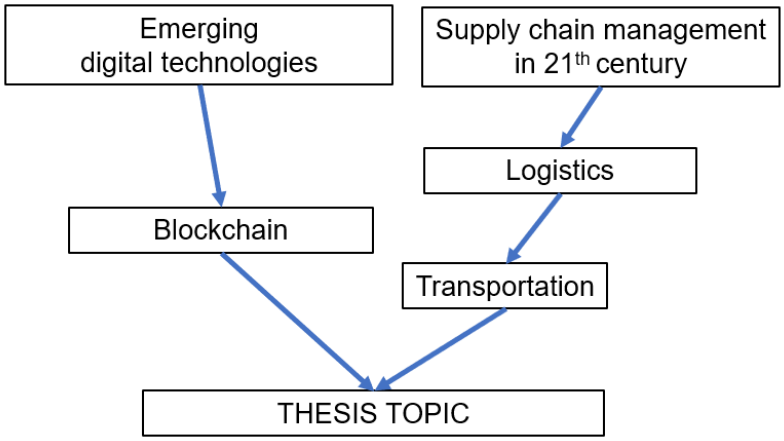

Figure 1. Conceptual image of the theoretical framework

1.3 Key concepts

Key concepts used in the thesis are listed below.

Blockchain is a database or ledger, where a set of data is stored in a distributed manner on a network of computers. It is secured by cryptographic technology, while data-blocks are linked together chronologically, like links in a chain. Thus, the name of the concept.

According to the Council of Supply Chain Management Professionals (2006 in Murphy & Knemeyer 2018, 21; Sadjady in Farahani et al. 2011, 11; Waters et al. 2007, 2) “supply chain management plans, implements and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers’ requirements”.

Logistics is the “process of strategically managing and optimizing the movement and storage of materials, parts and finished inventory” (Christopher 2016).

Transportation is “the actual, physical movement of goods and people between two points” (Murphy & Knemeyer 2018, 222).

Electronic Data Interchange, or EDI is a tool that integrates data systems of different companies and enables automated interfirm data transfer.

Coopetition is a sort of horizontal cooperation between companies, when competitors work together for commonly beneficial purposes (Christopher 2016).

1.4 Case companies' introductions

In the research part of the thesis three cases companies were examined. The names of the companies were not revealed due to confidentiality reasons. Throughout this report, they were referred to in the same order, as interviews at the case companies have been conducted: Company X, Company Y and Company Z. All three companies' core activity concerns transportation, however their geographical and product focus is different. It made possible that the thesis topic was examined from various angles and in multiple settings.

1.4.1 Company X: a Nordic fuel supply and distribution company

Company X is specialized in the transportation and wholesale of oil and bioproducts. It is headquartered in Finland but has operations through sister companies in other Nordic countries also. It operates in a highly concentrated oligopolistic market and is responsible for roughly 50% of the fuel supply and distribution in Finland. Company X is a small and innovative company, which embraces new technologies. It has around 50 employees in Finland. The company's turnover was approximately 5,5 billion EUR in 2019. It is privately held and has a history of nearly 20 years.

The company hires time chartered and spot vessels for the transportation of the fuel products between refineries and destination countries. It operates six distribution terminals around the seashore of Finland. In these terminals, the imported fuel is stored and filled to trucks that provide it to service stations around Finland. Company X uses its subcontractors to take care of the related road transportation. (Company Xa 20 April 2021; Company Xb 20 April 2021; Interviewee X 8 April 2021.)

1.4.2 Company Y: an express road carrier focused to northern Europe

Company Y is operating in the international express package delivery business. With an own network of terminals and warehouses, fleet and staff in six countries of northern Europe, it provides the fastest overnight solution in its own operational region. It also takes on shipments to farther destinations. Outside its operational region, Company Y keeps the same service promise with the help of its extensive and reliable partner network. Unlike traditional road carriers, this company has departures to its destinations on a daily basis. In contrast to express air couriers their shipments have no limitations in terms of size or weight, and they can handle dangerous goods too. Unlike Company X, Company Y operates in a market of monopolistic competition, where numerous actors compete.

Company Y is a privately held, family-owned company with over 30 years of history. It has 200-500 employees, and it operates a fleet of over 250 road vehicles. Its turnover was approximately 5,6 billion EUR in 2019. (Company Ya 20 April 2021; Company Yb 20 April 2021; Interviewee Y 8 April 2021.) Being at the start of their journey with technology (Interviewee Y 8 April 2021), this company is acting as the commissioning company for this thesis.

1.4.3 Company Z: Finnish branch of a globally operating freight forwarder

Company Z is the Finnish division of one of the globally operating freight forwarding companies. It provides air, ocean, rail and road transportation solutions to its customers by being a broker between customers and freight carriers. It also operates in an oligopolistic market, however it is not as concentrated as in the case of Company X. The parent company is amongst the global leaders in both air and ocean freight and the case company has around 25% market share in Finland. The global firm has a geographical coverage of over 220 countries and territories. In terms of personnel, the Finnish branch has approximately 150 employees, making part of an around 43000 people staff globally.

Company Z is the biggest of all three case companies, in terms of financial results, number of employees, geographical reach or even the history of the company. It is also different in the sense that by being a Finnish division of a global concern, its decision-making capabilities are limited. The parent company is a publicly listed firm, not a privately owned one, like Company X and Y. (Company Za 20 April 2021; Company Zb 20 April 2021; Interviewee Z 8 April 2021.)

2 The potential of blockchain technology in supply chains

This chapter introduces the literature review of the thesis. First, it defines what blockchain technology is, and gives a basic understanding of its attributes, types and capabilities. In the second section the relationship of supply chain management, logistics and transportation industry is discussed, and latest trends from these sectors are listed. In the third part the first two topics are combined, revealing the potential of blockchain technology in supply chains.

2.1 Blockchain technology

To be able to examine the potential applications of blockchain technology in supply chains, the concept of blockchain needs to be understood first. The following subchapters define the concept of blockchain, introduce its attributes, advantages and limitations. Different types of blockchain exist, those are described as well. Some additional concepts related to blockchain are explained also, such as consortia, smart contracts and oracles. Finally, the overall potential of blockchain is highlighted by introducing use cases from different sectors and industries.

2.1.1 Approach to the concept

Understanding the concept of blockchain for the layman (logistics professionals included) might be challenging. It is still closely linked to technology that many feel uncomfortable with. Common use-cases are not yet available in everyday life that would make it tangible and easier to comprehend. Some put it in parallel with the internet, in more senses though. Internet has been transformative and revolutionary in its own time and it has changed many aspects of our lives fundamentally. (Schmidt & Wagner 2019.) One does not have to understand the technology behind it, in order to be able to use it and enjoy the benefits of it. Everyday people just learn to handle the user interface and not even think about how it works in the background. In this chapter, this report aimed at defining blockchain in a similar manner that focuses on the practical implications, not the technical aspects.

2.1.2 Definition, attributes and advantages

It is difficult to draw a line between the concept, the attributes and the benefits of blockchain technology. Literature often incorporates attributes into the definition and some of blockchain's main features are inherently advantageous. Figure 2 below illustrates the concept itself in round shapes, while the (positive) attributes of the blockchain are listed

and organized in square shapes. The definition of Liotine and Ginocchio (2019, 87-88) concisely describes what blockchain technology is capable of: it “securely synchronizes the same information across a distributed network of partners”. The following paragraphs aim to make this definition easy to comprehend to those ones as well, who are new to the concept.

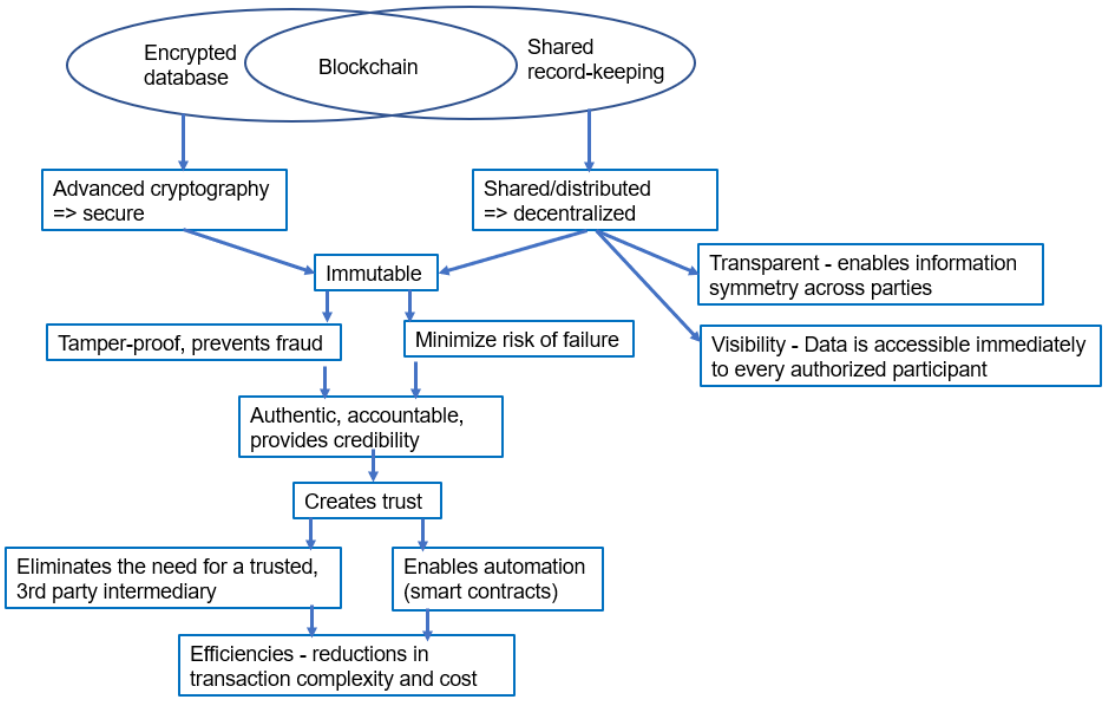

Figure 2. Attributes and advantages of the blockchain technology

Many use the word database (Notheisen et al. 2017; Cottrill 2018; Tapscott 2016) or ledger (Carson et al. 2018; Salviotti et al. 2018, 3467; Pilkington 2016; Leonard 2017, 2; Owyang & Szymanski 2017, 3), when describing blockchain technology. In fact, it is a huge set of data (can be any kind of data), organized together and stored by the underlying technology. This technology is securing the data by using cryptography and linking the different data-blocks together chronologically. Just in the same manner, as the links are located in a chain. Thus, the name of the concept. Anyway, the data-linking would not make blockchain unique in itself. When it is combined with a decentralized data-storing method, the database is provided with such attributes that make it unmatched, compared to any other database.

Enhanced security is enabled through advanced cryptographic techniques. (Carson et al. 2018; Cottrill 2018; Nazarov 2020.) Introducing the technical details was not an objective of this report, thus the subject is not discussed further here.

As described above, data is not stored in a single location (for example a central server), which would act as the single source of truth and eventually could be the single source of failure as well. Rather it is shared across so called nods, which are technically computers in a network. (Salviotti et al. 2018, 3467.) As Liotine and Ginocchio (2019) have put it, blockchain “provides a social source of truth versus a single source of truth through a shared decentralized database model instead of a single centralized database system.” All computer nods have the most recent version of the complete database. (Carson et al. 2018.) When a new link, namely a data-element is being added to the chain, all the nods on the network will verify it and add it to the chain only if it completely matches to the latest link of the chain in the complete community.

Such a decentralized manner makes it genuinely transparent and accessible for the participating parties. Everyone can have immediate and same level of access to the information stored on the blockchain. (Owyang & Szymanski 2017, 4; Schmidt & Wagner 2019; Cottrill 2018; Carson et al. 2018; Nazarov 2020; Liotine & Ginocchio 2019, 87-88; Van Hoek et al. 2020.) However, there are several types of the blockchain, based on the number of the participating, authorized parties. More on this subject is in subchapter 2.1.4. “Types of blockchain”. Credentials can also be set limiting, who can access what information. This flexibility combined with the high level of security helps to give everyone unlimited access only to that information that concerns the party in question.

As a further consequence, the database is also immutable (Owyang & Szymanski 2017, 3; Coletti 2015 in Pilkington 2016; Carson et al. 2018; Liotine & Ginocchio 2019, 63-64). All new links (data-elements) added to this chain incorporate in themselves all the data-record that has been added before. This characteristic enables that nods verify the links, before adding them to the chain. If a new link contains amended data-record, it would be simply refused by the nods.

Consequently, it is tamper-proof. This verification process makes it impossible to go back to the database and insert, modify or delete any record, once it was added to the chain. (Schmidt & Wagner 2019; Nazarov 2020; Cottrill 2018; MIT Center for Transportation and Logistics 2018, 9; Carson et al. 2018; DuPont 2019, 39-41; Schmidt & Wagner 2019; Nazarov 2020.) Obviously, it does not mean that the data cannot be corrected, but any correction will be seen as a correction, not the simple rewriting of old data. (MIT Center for Transportation and Logistics 2018, 9.)

Having multiple copies stored at multiple independent parties reduces the risk of failure to the minimum as well. If data is immutable and new data-blocks are verified against the

history at all nods, there is no longer a single point of failure, nods support each other in having the same correct records on their own version of the chain. (MIT Center for Transportation and Logistics 2018, 9; Carson et al. 2018; Nazarov 2020.)

As a result of all the above features, data on the blockchain is authentic (DuPont 2019, 39-41), accountable (Owyang & Szymanski 2017, 4), and creates the environment of credibility (Leonard 2017, 2) and trust. This last one is a fundamentally important feature of blockchain (Pilkington 2016), because it can provide an answer of a relevant business problem: the existence or lack of trust between the parties. It is having financial implications as well, so all in all it affects the businesses' bottom lines. Historically companies have been using trusted third parties (state authorities, banks etc) in order to secure their different transactions etc. With blockchain, "trust is put in software and complex mathematics" (MIT Center for Transportation and Logistics 2018, 9) and "system trust replaces personal trust" (Schmidt & Wagner 2019). Having such a reliable platform, like blockchain in between, makes it unnecessary to involve any intermediary. Thus, the usage of blockchain-based platforms eliminates the costs related to the middlemen as well. (Owyang & Szymanski 2017, 3-4, 6; Tapscott 2016; Carson et al. 2018; Schmidt & Wagner 2019; Liotine & Ginocchio 2019, 63-63, 87-88.)

Such a trustworthy environment also makes it possible to decrease the complexity of transactions (Carson et al. 2018) and increase the number of automations (Nazarov 2020). If all data is reliable, automated, self-executing transactions (Liotine & Ginocchio 2019, 67), so called smart contracts can be securely utilized. It dramatically reduces time and costs related to the verification of different data, linking them together and starting the transactions manually. Smart contracts hold an immense potential for the effectiveness of future industry and economy. (Van Hoek et al. 2020.) More on this subject is discussed in subchapter 2.1.5 "Important terms for business implementations".

What anyone, who is considering the use of any application built upon this technology needs to know and understand, is rather the above-described attributes, not the technology itself. Namely that the data in the system is secured, protected against fraud and failure and can be securely, transparently and immediately shared amongst the right parties in a highly cost-effective and trustful manner.

2.1.3 Critics and limitations

Besides plenty of advantages, there are also critics and disadvantages of blockchain technology. This subchapter introduces those ones, referring to the advantages discovered in the previous subchapter as well. One of the most commonly raised critics is that traditional databases (eventually combined with cloud technology) can perfectly serve the businesses' needs, in a more efficient way, than blockchain does. It is to be remembered that blockchain technology is exceptionally powerful in such environments that lack trust. These are the use cases, where it can excel traditional databases. (MIT Center for Transportation and Logistics 2018, 4; Carson et al. 2018.) ElMessiry and colleagues (2019, 163-164) highlight also that blockchain is less corruptible and better-automated compared to centralized databases.

Another very common point is that no single platform or application has so far emerged as a commonly accepted one (DuPont 2019, 10). There are still very few successful applications (Schmidt & Wagner 2019; Owyang & Szymanski 2017, 3, 9). While blockchain's benefits can be most utilized, when there are many participants on the chain, low adoption rate is not an incentive for new ones to join. Being a not established technology yet, many consider it risky an uncertain to get engaged with. Furthermore, senior management has a limited understanding of the technology, not helping with adoption. Industries are also missing talent: there are not enough professionals having the necessary know how. (Seth 2019.) On the other hand, one of the experts in the field, Tapscott (2016) sees it potentially as an "ultimate job-killer", due to its ability to automate transactions.

Others raise that there are several barriers to implementation. Common standards are missing, regulation cannot keep up with the pace of the developments (Tapscott 2020; Owyang & Szymanski 2017, 9) and also different governments are having different attitudes to the technology (Pawczuk et al. 2020, 17). This last one is making it difficult to take the same application into use globally, especially because transactions very often happen across borders. (DuPont 2019, 144-147.) Integration with existing systems needs to be solved and switching costs need to be considered. System and data-processing constraints are unveiling a scalability issue (Liotine & Ginocchio 2019, 88; Owyang & Szymanski 2017, 8), which might be solved on the other hand by connecting more platforms together (Tapscott 2020). (Partida 2018; Carson et al. 2018; Owyang & Szymanski 2017, 3; Seth 2019; Schmidt & Wagner 2019.)

Some also question if blockchain is completely tamper-proof. In fact, one has to have control over more than 50% of the network and rewrite all past records in order to have the

data faked. It is not impossible, but pretty impractical. (Nakamoto 2009, 1.) However, there is no protection against having such data on the chain that is inherently faulty. Quality of the added data is crucial, so that the data secured on the blockchain is correct. (Carson et al. 2018; Schmidt & Wagner 2019.)

Many has concerns about data security (Tapscott 2020) and privacy (Schmidt & Wagner 2019) as well. Companies store sensitive data in their databases and are not eager to share it to a common platform in a transparent way. This one highlights one further barrier, which is hindering blockchain, the so called “coopetition paradox”. In order to benefit from the network effects (Schmidt & Wagner 2019) the usage of this technology requires such parties to cooperate that otherwise compete in the market by nature. In such cases there might be even less willingness to join a common incentive. (Owyang & Szymanski 2017, 9-10; Deloitte Ireland LLP 2020, 11-12.) Furthermore, overall security of the blockchain is not only affected by if the data is secured on the chain or not. System security in fact depends on the security-level of the applications. It is also an important aspect to consider. (Carson et al. 2018.)

Interestingly, environmental concerns have also been raised, as the vast computing requirements call for natural resources. That can be the case, when networks are completely open (cryptocurrency applications), but private blockchains are much less affected by these implications. (Carson et al. 2018; DuPont 2019, 83.) At this point it is good to clarify the different types of the blockchain (public of private), in order to understand these aspects better. The following subchapter is aiming to cover these concepts.

2.1.4 Types of blockchain

In literature there are slightly different ways, how authors approach types of blockchain. Figure 3 below aims to find a synthesis between those. Some differentiate based on the ownership of the blockchain platform: between public and private blockchains. This approach focuses on who can access a network: anyone with the necessary technical background (public), or only authorized parties (private). Others put more emphasis on the rights of the participants: does everyone have rights to write and verify data (permissionless), or only limited credentials are given (permissioned), perhaps for reading only. (Schmidt & Wagner 2019.) Anyhow, it would be more accurate, to look at those attributes, as two opposing ends of scales, on which many different implementations are possible, with different number of participants or different levels permissions. (DuPont 2019, 109.) It creates the below matrix of applications, where the most relevant combinations are public

permissionless networks (in the left bottom corner) and hybrid private permissioned solutions (in the upper right corner) (Carson et al. 2018; Deloitte Ireland LLP 2020, 4).

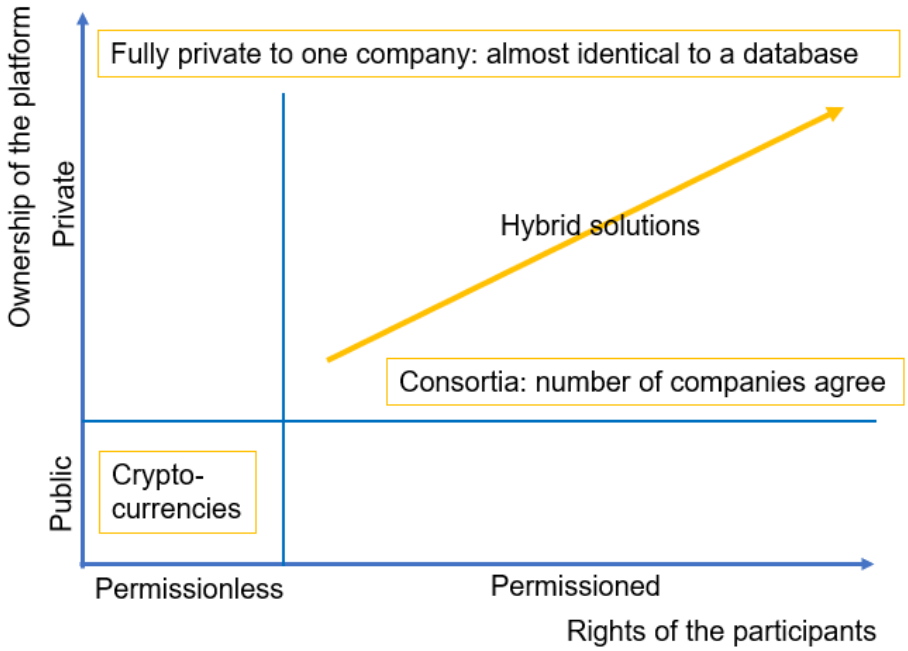

Figure 3. Different types of blockchain, based on the ownership of the platform and the rights of the participants (adapted from Carson et al. 2018; Deloitte Ireland LLP 2020, 4.)

Public permissionless chains are fully decentralized and are without any central authority. These are blockchains in their most genuine form, serving typically as platforms for different cryptocurrencies. Due to their completely open form, operation costs are higher and speed is lower than on private chains. Public permissioned networks also exist, where actors have to meet some certain criteria in order to be able to join. Some agree that these forms can no longer be considered real blockchains, as some trust is already needed between the parties and a central actor is responsible for granting the permissions (MIT Center for Transportation and Logistics 2018, 9). On the other hand, in fully private networks, one has full control of the data and only pre-approved members have right to read it. Due to its largely centralized and strictly permissioned nature, it is capable of high speed and enhanced efficiencies. However, these setups are almost identical to traditional databases. (Carson et al. 2018; Dhuddu 2019; DuPont 2019, 109, 111; Buterin 2015; Salviotti et al. 2018, 3470; Owyang & Szymanski 2017, 5; Cottrill 2018; Leonard 2017, 3.)

Private permissioned networks offer the most promising combination for enterprise applications (DuPont 2019, 180). Some even consider it a third, hybrid type (Owyang & Szymanski 2017, 6) of blockchains (besides public and private ones), or call it “consortia” (DuPont 2019, 109; Owyang & Szymanski 2017, 6; Buterin 2015; Leonard 2017, 3), when

multiple companies agree to share data securely on the same platform (DuPont 2019, 110). It is located on private computer network, so only authorized users can participate. Almost endless combinations are possible by granting permissions: what is shared, by whom, with whom and when. (Carson et al. 2018.) It is considered to be a good compromise between the restrictiveness of fully private blockchains and the dangers of open blockchains (DuPont 2019, 110). Furthermore, it offers greater efficiency and faster transactions, than public chains (Buterin 2015 in Pilkington 2016; Kshetri 2018). With this solution, companies can maintain some control over the data, when they need to work with trusted outside parties (DuPont 2019, 110). It can be essential in such fields that are pretty conservative about data sharing: like healthcare, finance, government or industry regulations. Some raise attention towards the European Union's General Data Protection Regulation (GDPR) as well, as it is highly restrictive on the access and control of private and sensitive data. Compliance with it must be considered, when designing blockchain based solutions. (DuPont 2019, 110, 145; Liotine & Ginocchio 2019, 79.)

2.1.5 Important terms for business implementations

There are some important concepts one might come across if wants to understand more about the business implementations of this technology. The following ones are covered in this subchapter: consortia, smart contract, oracles.

In chapter 2.1.4 "Types of blockchain" consortium has already been introduced as a private permissioned type of a blockchain (DuPont 2019, 109; Owyang & Szymanski 2017, 6; Buterin 2015; Leonard 2017, 3). The concept is opened up further now, as it can get really important, when industry-wide implementations are concerned. As a Deloitte (2019) report puts it, consortia are "coming together with others in your horizontal or vertical ecosystem, in common purpose". With regards to blockchain it means different kinds of actors within an industry joining forces to implement a commonly used blockchain solution (including industry-wide regulations) and to come over the vast complexities of such an endeavour together (Pawczuk et al. 2020, 20). Anyhow, it is closely related to the coopetition-paradox (already discussed earlier), meaning that natural competitors are quite reluctant to cooperate for a common purpose. Leaders are concerned about how consortium is run, governed and what settles profit-sharing. It is considered to be one of the biggest barriers to blockchain's implementations, but trends show that opposition towards consortia is decreasing. (Pawczuk et al. 2020, 20.) The relevance of such solutions is also underlined by the results of a Deloitte survey conducted in 2019. They have found that "the overwhelming majority (92 %) of the respondents say they either belong to a consortium or plan to join one in the next 12 months" (Deloitte 2019). However, joining forces is not the

only approach to blockchain implementations. Dhuddu (2019) - based on his experience in implementing blockchain for several industries globally - encourages companies, not to wait for others to take the lead and establish a consortium that they can join later on, but to engage in creating their own chain.

The concept of smart contracts has already been defined too in chapter 2.1.2 “Definition, attributes and advantages” as automated, self-executing transactions (Liotine & Ginocchio 2019, 67). However, smart contracts are such cornerstones of blockchain based enterprise solutions (Salviotti et al. 2018, 3470), especially in supply chain use cases (Liotine & Ginocchio 2019, 67) that it is worth studying their infinite potential (Salviotti et al. 2018, 3470) further. Cotrill (2018) defines it in a more comprehensive way, as a “computer code housed on a blockchain that defines and executes the terms of an agreement between parties”. So, in practice, if certain conditions are met, a transaction is automatically triggered. Common example is: if an insurance claim meets pre-determined conditions, payment is automatically transferred, without requiring any third party verifying or acting upon anything (Carson et al. 2018). Or from supply chain field: if a shipment arrives and complies with the contractual terms, pay-out is automatically triggered (Cottrill 2018).

What is so ground-breaking about smart contracts is that those can take over the role of the central authority (MIT Center for Transportation and Logistics 2018, 15; Salviotti et al. 2018, 3470; Owyang & Szymanski 2017, 5). Furthermore, they can drastically reduce or eliminate manual, error-prone documentation needs, enhance speed and reduce costs. However, some warns to be cautious about smart contracts, as those still belong to the gray area of legislation (Cottrill 2018) - are they real legal documents or just a set of mechanism (MIT Center for Transportation and Logistics 2018, 14). In addition, if not configured carefully enough, or subject to malicious intentions, they can very quicky cause huge and irreversible losses. (Schmidt & Wagner 2019; MIT Center for Transportation and Logistics 2018, 14; Cottrill 2018.)

Amongst the barriers to blockchain adoption, costs of entry and the integration-capacity of blockchain with existing systems have been discussed. The solution might be blockchain oracles, “the infrastructure that securely connects blockchains to external systems” (Nazarov 2020). It is such a gateway enabling that for example on-chain smart contracts extract data from off-chain sources, execute transactions and further transmit data to off-chain locations. Interoperability requires that oracles act as a middle layer, securely connecting any enterprise system to any of the blockchain environments. (Nazarov 2020.)

2.1.6 Blockchain 2.0

After getting some understanding about the concept of blockchain throughout the previous subchapters, this subchapter aims to put blockchain in prospective. Some historical background of the past 10+ years of blockchain leads to the introduction of those industries that might be disrupted by this technology in the near future. As stated before, blockchain technology has a relatively short history. A still unknown developer, by the name of Satoshi Nakamoto started developing it in 2007-2008, and the first transaction of Bitcoin was executed in 2009 (DuPont 2019, 56; Salviotti et al. 2018, 3567). In the early times, the concept of blockchain was closely related to cryptocurrencies, the dark web and anarcho-capitalist movement of the cyberpunk: a group of such developers that aimed to operate beyond authorities' constraints. It took quite a long journey to deprive the technology from these preconceptions. (DuPont 2019, 41.) Nowadays, such technical giants experience with blockchain, like IBM, Microsoft or Intel. It shows that the technology is being matured and established. However, many still confuse blockchain technology with the cryptocurrency Bitcoin (Leonard 2017, 2; MIT Center for Transportation and Logistics 2018, 5). It is not improving its reputation either, as Bitcoin is often associated with speculative investments, rallies of currency rates, rapid wins and big losses (Carson et al. 2018). However, blockchain is just the underlying technology behind Bitcoin and most cryptocurrencies. (Schmidt & Wagner 2019; Salviotti et al. 2018; DuPont 2019, 49.) It is true that Bitcoin has so far been blockchain's most successful application (Salviotti et al. 2018, 3474), but it is not the only one. Its massive capabilities have been discovered later on.

Nakamoto himself disappeared in 2011, but he has left the open-source software available for the online community (DuPont 2019, 56). In 2015, a 19-year-old Canadian-Russian computer science student, Vitalik Buterin launched Ethereum. This platform proved that not only financial, but any other data can be stored and shared on the chain and that different functions can also be coded to the system, enabling future automations (smart contracts). These features opened up the way for blockchain to enter further industries as well, far beyond cryptocurrencies. (Leonard 2017, 1; MIT Center for Transportation and Logistics 2018, 6.) Actually, DuPont (2019, 51) brings our attention to the fact that Bitcoin is not suitable for its original purpose: being used as money, due to its volatility and impracticality. Rather other attributes of blockchain have been in focus recently. The rest of this chapter gives an insight to the potential of blockchain in different industries.

One major strength of the technology is that its use cases can concern any kind of data. There is no restriction on which industry is generating or using that data. Blockchain is just

the “technology for data sharing” (MIT Center for Transportation and Logistics 2018, 6) and represents a shift in how any industry will store, share (Partida 2018) or manage data (Owyang & Szymanski 2017, 3). Salviotti and colleagues (2018, 3467) introduces the term “Blockchain 2.0”, to describe all blockchain based applications that are being introduced recently. The common element in these applications is that they solve the issue of trust and protect the identity of the participants, while transactions happen.

As rapidly as blockchain technology has evolved since the white paper of Nakamoto in 2018, blockchain started entering new industries at a similarly advanced pace (DuPont 2019, 51). Nevertheless, it is still the financial sector, which has almost 50% of the current applications, even if we take cryptocurrencies out of the scene (Salviotti et al. 2018, 3474). Blockchain is suitable for facilitating transfers between banks and financial institutions (MIT Center for Transportation and Logistics 2018, 6; Liotine & Ginocchio 2019, 64-65), cross-border peer to peer payments (Carson et al. 2018) and for example providing innovative solutions for crowdfunding (Salviotti et al. 2018, 3472-73), donations and charity (DuPont 2019, 113).

Besides the financial sector, Seth (2019) has identified the e-government services as a ripe sector for blockchain to become widespread. Digital identities, digital voting and different registries (citizenship, land titles, criminal records) are promising applications for blockchain technology (DuPont 2019, 56, 113; Carson et al. 2018; Salviotti et al. 2018, 3471-3473). Estonia is already experimenting with blockchain based solutions in the governance (Owyang & Szymanski 2017, 14-15).

Apart from the above two examples, Carson and colleagues (2018) find the healthcare sector also suitable for implementing blockchain based solutions. The confidential attributes of medical data make it a good match with the security potentials of blockchain. The different permissions could help in sharing just that specific patient records with specific healthcare providers that those need, but still making those data immediately available, when needed. (Owyang & Szymanski 2017, 17.) Track and trace possibilities of pharmaceuticals is another promising application of the technology in this sector (Liotine & Ginocchio 2019, 66). (DuPont 2019, 56, 113.)

In fact, blockchain is not only tremendously powerful in tracking and tracing medical substances, but any other commodity (DuPont 2019, 51; Salviotti et al. 2018, 3471-3473). Combined with Internet of Things (IoT), sensor data can directly be added to the chain. It represents an exceptionally competent solution in the field of supply chain management and especially logistics. (MIT Center for Transportation and Logistics 2018, 6; Salviotti et

al. 2018, 3473.) A Deloitte (2020) report on blockchain identified particular interest in this field towards blockchain based solutions. The challenges related to the provenance of the goods in the field of food safety (Carson et al. 2018; MIT Center for Transportation and Logistics 2018, 6), pharmaceuticals (DuPont 2019, 113; Liotine & Ginocchio 2019, 66) or luxury goods (DuPont 2019, 113; Owyang & Szymanski 2017, 16) can be addressed by using blockchain technology. This industry is examined further in detail in chapter 2.3 “Using blockchain technology in supply chains”.

Notwithstanding the exciting experiments in the above industries, Salviotti and colleagues (2018. 3474) identified consumer services as the industry with the second highest ratio of blockchain based applications in the non-cryptocurrency scene, after financial services. These two together account for more than three-quarters of the implementations. Applications here manage different certifications through the blockchain. The sector with the third highest ratio of implementations is the technology industry (Salviotti et al. 2018, 3474). A Deloitte (2020) report on blockchain expect further increase in this field. Platform development applications are working on providing blockchain-as-a-service (BaaS) solutions (Salviotti et al. 2018, 3474; Carson et al. 2018), further implementations concern for example cloud storage (Salviotti et al. 2018, 3471-3473) or IoT (DuPont 2019, 113).

Besides the above listed ones, there are further interesting and exciting initiatives in other industries as well. From energy management and distribution (Salviotti et al. 2018, 3471-3473; Liotine & Ginocchio 2019, 65; Owyang & Szymanski 2017, 15), through law - with vast capabilities in smart contracts - (DuPont 2019, 51; Liotine & Ginocchio 2019, 65; Owyang & Szymanski 2017, 13) and registries of intellectual properties (MIT Center for Transportation and Logistics 2018, 11) to peer to peer content distribution in arts (Salviotti et al. 2018, 3473; Liotine & Ginocchio 2019, 67; Carson et al. 2018) possibilities are infinite. Gaming (Salviotti et al. 2018, 3473), gambling (DuPont 2019, 113), investments (Carson et al. 2018), insurances (Carson et al. 2018; Owyang & Szymanski 2017, 18), education (Owyang & Szymanski 2017, 19), retail (Owyang & Szymanski 2017, 16), travel (Owyang & Szymanski 2017, 18) or advertising (Liotine & Ginocchio 2019, 67) also sees potential in this technology to reshape its future. Table 2 below gives a summary of all possible use-cases listed in the above paragraphs.

Table 2. Possible use-cases of blockchain in different industries

Sector	Application
Finance	Facilitate transfers between banks and financial institutions, crowdfunding, donations, charity.
E-Government	Digital identity, digital voting, government records of citizenship, land title, criminal records.
Health care	Patient records, tracks and trace pharmaceuticals.
Supply chain & Logistics	Tracking, sensor data, provenance: food safety, pharmaceuticals, luxury goods.
Consumer services	Certifications
Technology	Platform development (BaaS), cloud storage, IoT.
Energy management	Energy management and distribution, P2P micro-transactions.
Law	Smart contracts, notary services.
Arts	P2P content distribution, digital rights management.
Intellectual property	Registries.
Entertainment	Gaming, gambling.
Investments	ICO-initial coin offerings.
Insurance	Claim-payouts.
Education	Digital records of degrees, transcripts.
Retail	P2P payments, origin of goods.
Travel	Passenger ID.
Advertising	Consumers monetize parts of their ID to advertisers .

2.2 Logistics in 21st century supply chains

This chapter introduces the sectors, where the potential of blockchain technology is examined in the rest of this report. First, a definition of supply chain management is given, afterwards scope is narrowed down to logistics, and finally focus is placed on transportation. The reason behind that last step is that interviews are conducted with companies specifically from the field of transportation. However, currently blockchain theory is mostly available from the fields of supply chain management and logistics. After the definitions, latest trends and most pressing issues from these fields are introduced.

2.2.1 Supply chain management, logistics and transportation

There seems to be a common understanding in literature that transportation makes an important part of supply chains and logistics (Zakery in Farahani et al. 2011, 100; Khooban

in Farahani et al. 2011, 109; Murphy & Knemeyer 2018, 34, 222). However, different approaches have been identified regarding the relationship between supply chain management and logistics. Logistics has already been recognized since the 18th century (initially as a crucial component of warfare), while the term supply chain management first appeared in the 1980's. (Rowbotham et al. 2007, 316; Christopher 2016; DuPont 2019, 187.) Consequently, traditionalists argue that supply chain management is an add-on to logistics. Originating from similar roots, re-labelling approach states that logistics has in fact been just re-labelled recently as supply chain management. Intersectionists believe that there is some overlap between these fields, but both of them are distinct fields of expertise. While according to the most common unionist view, logistics makes part of the much wider supply chain management concept. (Mangan & Lalwani 2016, 12-13.) This report was following this last approach as well, see figure 4 at the end of this subchapter. As Christopher (in Waters et al. 2007, 23; 2016) has concisely put it, the purpose of logistics is to optimize flows within an organization, while supply chain management externalize these processes to the complete supply chain involving all companies concerned. The following paragraphs elaborate these terms more precisely.

The most commonly referred definition of supply chain management is the one, provided by the US-based Council of Supply Chain Management Professionals (2006 in Murphy & Knemeyer 2018, 21; Sadjady in Farahani et al. 2011, 11; Waters et al. 2007, 2). According to its interpretation: "supply chain management plans, implements and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements". Other authors (Slack et al. 2004 in Rowbotham et al. 2007, 316; Waters et al. 2007, 2) also emphasize that the scope of supply chain management reaches from raw material supply to end customer, including both upstream and downstream organizations (Mangan & Lalwani 2016, 11; Christopher 2016). It requires the cooperation of supply chain partners (Waters et al. 2007, 2), thus it that can rather be viewed as a supply network, not only a chain (DuPont 2019, 187-188). While the above definition highlights only the activities of flow and storage, others specify more precisely procurement, manufacture, assembly, distribution and waste disposal as indispensable elements of supply chain management (Slack et al. 2004 in Rowbotham et al. 2007, 316; Waters et al. 2007, 2). As a purpose of supply chain management, other definitions also emphasize efficiency and customer satisfaction (Rowbotham et al. 2007, 316; Mangan & Lalwani 2016, 11; Christopher 2016; Waters et al. 2007, 2).

The extended version of above referred definition by the Council of Supply Chain Management Professionals identifies logistics as part of supply chain management (Murphy &

Knemeyer 2018, 21; Sadjady in Farahani et al. 2011, 11; Waters et al. 2007, 2). Waters and colleagues (2007, 2) specify logistics, as “the function responsible for moving materials through supply chains”. While Sadjady in Farahani and colleagues (2011, 11) takes a practical approach when saying that “logistics deals with the moving of materials into, through and out of a firm”. On the other hand, Rossiter (2014 in DuPont 2019, 188) warns that logistics involve more than just the physical movement of goods. He extends it to the control and analysis of production, financing, location and time. Christopher (2016) includes the “process of strategically managing and optimizing the procurement, movement and storage of materials, parts and finished inventory”. The Chartered Institute of Logistics and Transport (1998 in Waters et al. 2007, 2) also emphasizes the feature of optimization, when defining logistics as “time related positioning of resources”. Murphy and Knemeyer (2018, 33-34) consider the following activities logistics-related as well: customer service, demand forecasting, order management, packaging, inventory- and warehousing management.

In contrast to the comprehensive definitions of supply chain management and logistics, the definition of transportation is much more demarcated. Murphy and Knemeyer (2018, 222) put it as “the actual, physical movement of goods and people between two points”. Khooban (in Farahani et al. 2011, 109) specifies these two points as the origin and destination, adds the means: by vehicles, and activities: such as design, arrangement, set up and scheduling of transportation orders.

So far, we have been focusing on the movement of goods. However, it is essential to state that supply chain management and logistics are not only concerned with the physical (or material) flow. There are two other similarly important flows: information flow and financial flow (Mangan & Lalwani 2016, 11; Waters et al. 2007, 2). As illustrated in figure 4 below, these three flows take place both upstream and downstream in the supply chain (Sadjady in Farahani et al. 2011, 11-12). DuPont (2019, 187-188) takes an even more complex approach when defines supply chain as a “never-ending feedback loop that connects the supplier, market and consumer”.

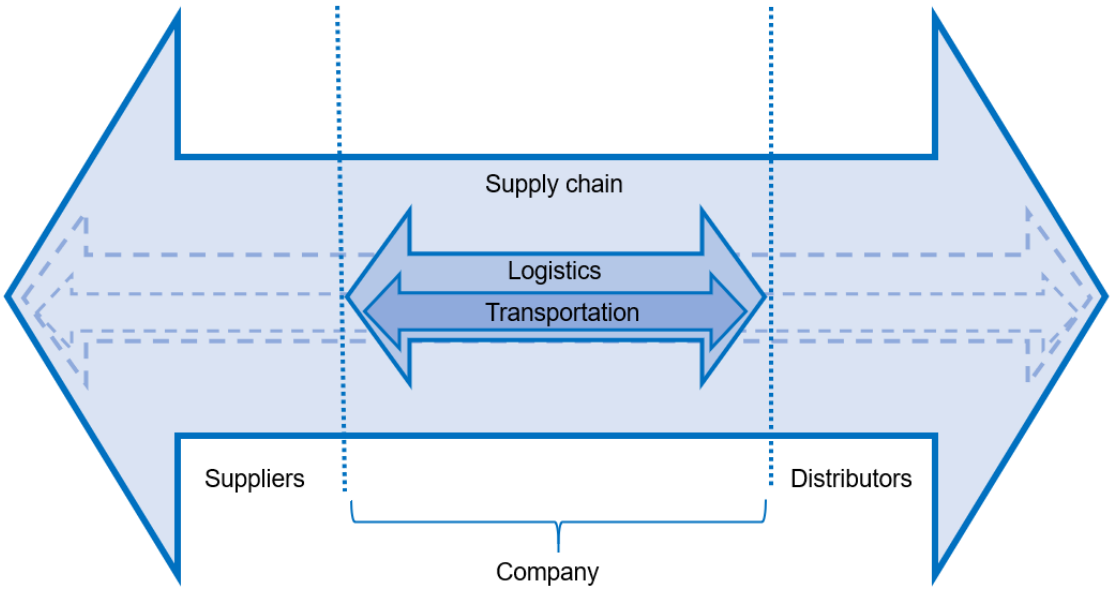

Figure 4. Upstream and downstream flows of materials, information and financial resources within supply chains, logistics and transportation

Even if information flow might not be so obvious at the first glance, its importance cannot be ignored. Murphy and Knemeyer (2018, 22) explain that the management and the movement of information is just as important as that of the physical goods. Asadi (in Farahani et al. 2011, 222) sees information as the “lifeblood of a logistics system”. Information is a key resource, as its transfer determines the effectiveness and accuracy of distribution systems. Murphy and Knemeyer (2018, 40) list the following benefits of effective and efficient use of information in logistics: greater visibility throughout the supply chain, more accurate awareness of customer demand, better coordination of manufacturing, marketing and distribution, and streamlined order processing accompanied by reduced lead times. They perceive that having the right information technologies in logistics is critical to remain competitive, reduce costs and improve customer satisfaction. Asadi (in Farahani et al. 2011, 222) goes beyond this assumption by predicting that the importance of information flow will just increase in the future. This last statement is fundamental in relation to the topic of this report, as blockchain technology has evident potential in the field of secure, reliable and effective information management. (DuPont 2019, 187-188.)

2.2.2 Latest trends and challenges in supply chains

Many agree that supply chain management and logistics have been receiving more and more attention throughout the past decades. These fields have been considered increasingly important amongst the different operations within companies and their value-creating capabilities have become recognized. (Asadi in Farahani et al. 2011, 221; Christopher 2016; Sadjady in Farahani et al. 2011, 23; Christopher in Waters et al. 2007, 32; Murphy

& Knemeyer 2018, 23; Waters et al. 2007, 4.) In fact, many now suggest that it is no longer companies but supply chains that compete. A company can no longer build itself in an isolated way, but it has to work on creating a responsive and resilient supply chain in cooperation with its partners. That is considered to be crucial in order to remain competitive. (Christopher in Waters et al. 2007, 24; Mangan & Lalwani 2016, 329.) Christopher (2016) even claims that survival requires logistics-oriented organizations. Zakery (in Farahani et al. 2011, 100) adds that efficient supply chains rely on fast, responsive and dependable transportation systems. This subchapter introduces the latest trends and challenges shaping supply chains, logistics systems and transportation in the 21st century.

Globalization is one of the major trends affecting all aspects of our lives, supply chains alike. In fact, one of the enablers of globalization has been the rapid development of logistics (Murphy & Knemeyer 2018, 26). While on the other hand globalization makes supply chains more complex and global also (Christopher 2016). Notwithstanding cost savings, it results in longer and geographically more sparse supply chains that are subject to an increased level of risk. Furthermore, longer chains are opposing the contemporary trends of time-based competition, just-in-time production and short product lifecycles (Christopher 2016; Zakery in Farahani et al. 2011, 94-95). (Waters et al. 2007, 17.) Globalization also contributes to increasing competition. There is a constant urge of cost reduction. In such a competitive environment, the practice of outsourcing different activities became common. By outsourcing, companies can focus their resources on their core activities, and commission specialist third party providers with performing peripheral tasks. (Christopher 2016; Waters et al. 2007, 4; Zakery in Farahani et al. 2011, 103.) Logistics is one of the most popular fields for outsourcing (Waters et al. 2007, 16). At the same time there is also an increasing interest amongst companies in coopetition, a horizontal cooperation, when competitors work together for commonly beneficial purposes (Christopher 2016).

Christopher and Holweg (2011 in DuPont 2019, 174) highlight that the first thirty years of supply chain management has been characterized by stability, but it is no longer the case. Companies have been experiencing a dramatic increase in volatility and uncertainty from the fields of demand and supply. Supply chains have to adapt to fast changing markets and unforeseeable events, need to embrace risk and develop structural flexibility and responsiveness. In such a turbulent setting, Christopher (2016) reminds that it is crucial for companies to have real-time visibility over the supply chains from-end-to-end and to utilize state-of-the-art tools for sharing information. (Lyall, Mercier & Gstettner 2018; Mangan & Lalwani 2016, 332.)

There is a growing pressure from the direction of customer expectations: customers are becoming more demanding than ever (Waters et al. 2007, 12-13). Shortening product life cycles require that materials move faster through the supply chains (Christopher 2016). Widespreading practices of mass-customization call for more flexible logistics systems. E-commerce brings different speed, sizes and volumes in shipments, and technology enables that intermediaries are removed from between consumers and producers. (Murphy & Knemeyer 2018, 24-25, 50-52; Waters et al. 2007, 4, 17; Zakery in Farahani et al. 2011, 95-96.) Currently the lack of adaptability to shifts in demand is one of the major challenges in supply chains. Christopher (2016) emphasizes that supply chain management and logistics need to move from forecast-driven approach towards demand-driven approach. A shift is needed from “production-push” philosophies towards “demand-pull” ones. Consumers are increasingly conscious about their choices and have a growing interest in the provenance and the integrity of the products they buy (Christopher 2016). There is special awareness about environmental implications, and concerns need to be addressed (Mangan & Lalwani 2016, 332; Waters et al. 2007, 4, 17; Zakery in Farahani et al. 2011, 101-102). Supply chain visibility helps with fighting counterfeiting and other compliance issues (Murphy 2020).

Another major trend affecting countless aspects of life is the penetration of new technologies, supply chain management not being an exception. DuPont (2019, 171, 187) points out that logistics has always been a technology and information industry. In subchapter 2.2.1 “Supply chain management, logistics and transportation” the importance and essential nature of information flow has already been emphasized. Information technology supports the desired flexibility and responsiveness in supply chains (Zakery in Farahani et al. 2011, 95-96) and is an important enabler of effectiveness and efficiency (Xinping & Simon in Waters et al. 2007, 178). Adaptive information systems are needed to manage the complexities of current logistics systems as well. The automation of processes reduces the number of errors, costs and improves cycle times. (Mangan & Lalwani 2016, 208, 210; Waters et al. 2007, 4.)

Electronic Data Interchange (EDI) systems and bar-coding technology have been used for decades now for enhancing data transfer. Currently the global positioning systems (GPS) and radio frequency identification (RDIF) technologies accompanied by wireless and mobile technologies (Internet of Things included) are widely and further increasingly utilized with the purpose of collecting data (Kshetri 2018; Murphy & Knemeyer 2018, 25, 45, 53; Zakery in Farahani et al. 2011, 95-96). The challenge for the future is how industries will manage and analyse this vast amount of data collected through these different sensors. It

is calling for big data, analytics, artificial intelligence and cloud computing to provide an answer to these challenges (Christopher 2016; Murphy & Knemeyer 2018, 41, 52). (Liotine & Ginocchio 2019, 11-12.) Blockchain technology can support these tools by being the platform, where such information is stored, shared and automated algorithms can execute smart contracts. Technology can provide a solution for several long-running but ignored problems in supply chain management: improving traceability, promoting sustainability and increasing the efficiency of trade documentation and dispute resolution (MIT Center for Transportation and Logistics 2018, 20).

Within 5-10 years' time Lyall, Mercier and Gstettner (2018) envision a smoothly running, self-regulating supply chain, where automated workflows optimized by a "digital control tower" are replacing most of the workers currently executing repetitive tasks. It will fundamentally reshape the workforce as well: a small number, but highly skilled and specialized workers will operate such digital tools. Zakery (in Farahani et al. 2011, 103) cites IBM's vision about the future logistics provider: "more global, concentrated, segmented around customer type and universally better at execution. Furthermore, it will offer end-to-end supply-chain integration and business process capabilities from the supplier management side up to the customer services side." Currently, logistics information system is still very fragmented and human intervention is the norm in executing transactions (SmartLog 2021). Lammi (2017, 38) points out an instant issue: however cargo moves efficiently, the information related to it does not. There is a severe need for efficient communication and information sharing systems between logistics companies. It is an attribute in which blockchain technology excels. According to Murphy and Knemeyer (2018, 54), the most important technology issue currently regards information security. A prevalent demand from logistics is also concerning increased security. Blockchain has the capabilities to address these common issues as well. (McDermott 2017 in Dupont 2019, 176.)

Lastly, this paragraph introduces some specifically transportation related challenges. A typical issue in transportation is the capacity problem. There are heightened security measures applied due to the terrorist-threat. (Zakery in Farahani et al. 2011, 100.) Carrier decision making problems are regarding crew and traffic assignment, vehicle allocation, scheduling and network design (Khooban in Farahani et al. 2011, 119). Shipper decision making problems are transportation mode selection, shipment consolidation and load planning and packing problems (Khooban in Farahani et al. 2011, 122). The previously listed decision problems can all be addressed at least to some extent by utilizing information technology tools. The usage of blockchain technology can also be considered, when there is a need for enhanced security, authenticity and data sharing.

Table 3 below summarizes the major trends and challenges introduced in this subchapter. Even though technology imposes some challenges to supply chains as well, all in all it is rather an enabler in addressing the rest of the challenges prevalent in 21st century supply chains.

Table 3. Major trends and related challenges prevalent in current supply chains

Trends	Challenges
Recognition of importance	
Globalization Outsourcing Coopetition	Longer and more complex supply chains Maintain short cycle times Higher level of risk Increased competition Keep costs at a low level
Fast changing, turbulent markets	Volatility in supply and demand Unforeseeable events Higher level of risk
More demanding customers Shortening product lifecycles Mass customization E-commerce Sustainability becomes a must	Move materials fast Add flexibility to systems Prove product integrity Provide information on provenance Comply with environmental standards
Emerging technologies Vast amounts of data can be collected	Manage available data and benefit from it Share data efficiently between companies Data security Need for rightly skilled employees

The following chapter introduces how one of the emerging technologies, blockchain can help supply chain management overcome these challenges and go beyond its present limits.

2.3 Using blockchain technology in supply chains

It has been introduced in chapter 2.1.6 “Blockchain 2.0” what diverse capabilities blockchain technology might have in different industries. In this chapter a closer look is taken on the implementations in supply chain management field. Different authors have ambitious visions about the potential of blockchain based solutions in supply chains. Views range from considering blockchain as a tool for innovation in supply chains (Liotine & Ginocchio 2019), through seeing it as a substantial (Kshetri 2018 in Schmidt & Wagner 2019), ground-breaking solution (Pilkington 2016), to even expecting from it to transform (Kshetri 2018), or even revolutionize (Lyall et al. 2018) supply networks. Liotine and Ginocchio (2019, 87-88) highlight that blockchain’s abilities in reducing costs are particularly applicable in supply chain and logistics operations. Others emphasize that it will bring about transparent (Van Hoek et al. 2020), lean and just-in-time supply chains (DuPont

2019, 183). Calatayud (2017 in DuPont 2019, 180) even envision a self-thinking or autonomous supply chain enabled by this emerging technology, especially through the use of smart contracts.

2.3.1 Blockchain's features for supply chains

There are some factors which make blockchain technology specifically suitable for supply chain management field. One of those is the complex nature of the processes: there is a myriad of parties involved, operations are hugely documentation heavy, and these documents are principally still handled manually (DHL Trend Research 2018, 3, 12; Liotine & Ginocchio 2019, 75; Owyang & Szymanski 2017, 13-14). Furthermore, tracking shipments from origin to destination has been a major challenge to the industry throughout the last 50 years (Liotine & Ginocchio 2019, 75). Blockchain has the potential to provide a solution to those challenges.

Another characteristic of a supply chain is that it traditionally lacks trust (Cottrill 2018; Owyang & Szymanski 2017, 13-14). It has been discussed in the previous chapters that blockchain had an answer to the trust-problem as well. And when confidentiality is required, permissioned solutions can be the right choice (Salviotti et al. 2018, 3475).

DuPont (2019, 184) cites Frohlich and Westbrook (2001), who have found that those companies can achieve the highest performance that have integrated their complete arch of supply chain into one system: suppliers, the manufacturer and customers. Blockchain has the capabilities to do so, and even to extend a firm's view over processes as well, which traditionally are out of that particular firm's reach - but make part of their supply chain (Deloitte Ireland LLP 2020, 8). With current trends of products getting more integrated into supply chains and the spread of Internet of Things (IoT) technology, enterprises will require more advanced management techniques (DuPont 2019, 183). Blockchain can be one of those.

Liotine and Ginocchio (2019, 60) remind of a fundamental change blockchain technology can bring to supply chains. It is related to how information flows through the supply network. Traditionally it follows the material flow. This route is linear, there might be several obstacles, information can be siloed in different databases. This results in delayed and restricted availability of information. Through its distributed characteristics, blockchain can enable data sharing in a decentralized manner. In this case all members have same visibility over the same data at the same time. Figure 5 illustrates the difference between the

two approaches. Such a transformation in the practice of information flow enables new ways of cooperation and operational models in supply chains.

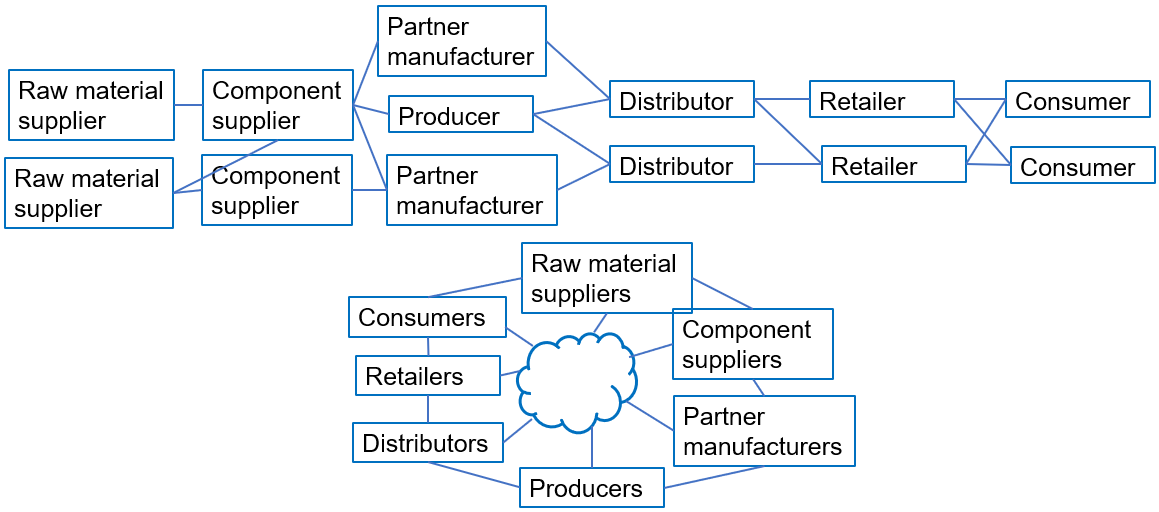

Figure 5. The difference between the traditional (top) and the blockchain-based (bottom) supply chain information network (adapted from Liotine & Ginocchio 2019, 60.)

It is no surprise that Deloitte Ireland's (2020, 6) survey measured particular interest from this field in 2019. According to Kshetri (2018) this sector is among the ones that are most likely to be transformed by blockchain. The same Deloitte survey expected to see further increasing interest from supply chain field towards blockchain based solutions (Deloitte Ireland LLP 2020, 8). The following subchapters will introduce the specific use cases for blockchain in supply chains.

2.3.2 Use cases in supply chain management

Some industries match with blockchain's supply chain capabilities better than others. Tech, auto or garment industry can offer promising opportunities for blockchain, as these are characterized by a restricted, small number of suppliers. Those can be more easily brough together to a common platform. On the other hand, oil industry is also a potential target sector. Even if there are numerous layers of suppliers, only a few big players dominate the market. If any of them engage with blockchain, chances are high that the rest of the sector will follow, in order to remain competitive. (Kshetri 2018.) Furthermore, such areas have remarkable potential, where the question of provenance, authenticity and compliance is of great importance. Examples range from food, pharmaceuticals, medical devices, through automotive or aerospace parts, electronics to diamonds or the mining of different rare metals. In these instances, often human lives are at stake, such as in the case

of food contaminations or counterfeit parts in vehicles. (Kshetri 2018; Schmidt & Wagner 2019; Liotine & Ginocchio 2019, 76-77; MIT Center for Transportation and Logistics 2018, 11-12.)

With no regard to industry sector, the most commonly referred use cases in supply chain management field are track and trace capabilities of the blockchain technology. Shipments are already tracked, and products are traceable to some extent, but blockchain technology could raise these activities to new levels. Furthermore, blockchain would enable the elimination of the extensive manual-based paperwork and replace it with digital, even smart contract-based automated solutions. Blockchain technology can offer solutions in the field of supply chain finance as well. The following paragraphs introduces these opportunities more in detail.

One of the most critical questions in logistics is related to tracking: “where is my shipment”. With the help of blockchain technology, this question can be answered in real-time, not only on shipment level, but on the level of individual parts also (Owyang & Szymanski 2017, 3). Apart from the location of the shipment, several other conditions can be followed throughout the shipping process. Sensors can report about temperature, humidity, possible damages etc. (Pilkington 2016; Hewett et al. 2020; Liotine & Ginocchio 2019, 76-77.) This data can be saved and shared on blockchain directly with other stakeholders. It will decrease information asymmetry and inconsistency (Liotine & Ginocchio 2019, 74). There is no need for exchanging e-mails or waiting for the information to get through several layers of actors. Such reliable and secure data for instance can contribute to eliminate physical inspections upon arrival also (Cottrill 2018). Shipment data can be reported to authorities as well throughout blockchain platform, making border crossings much smoother. (ElMessiry et al. 2019, 163-164.)

Tracing supported by blockchain technology offers a comprehensive visibility over the complete lifecycle of a product. It might span from sourcing through manufacturing until eventual recycling, resale or disposal. (Murphy 2020; Liotine & Ginocchio 2019, 73.) All data related to the origin and any transformation occurred to the product throughout the supply chain can be collected and be made available to stakeholders (Pilkington 2016; Liotine & Ginocchio 2019, 66). It can help during the procurement process with evaluating supplier value and risk (Liotine & Ginocchio 2019, 73-74). It can offer consumers unlimited access to data about the provenance of the product, making purchase decisions more conscious (DuPont 2019, 181-183). It can be better assured that quality, health, ethical or environmental standards are maintained - without needing to trust or rely on any third party. (Owyang & Szymanski 2017, 3; Schmidt & Wagner 2019; Hewett et al. 2020; Cottrill

2018; Liotine & Ginocchio 2019, 76-77.) Such a tool can be extremely powerful in tracing back food contaminations, thus saving lives and enabling faster and more targeted product recalls (Owyang & Szymanski 2017, 15-16; Leonard 2017, 1; Cottrill 2018).

Blockchain has undeniable capabilities in the field of data processing too. IBM and Maersk have conducted a research on how paperwork of a single container is handled in typical supply chains. They have found out that it might go through 30 people or organizations and trigger 200 interactions. (DuPont 2019, 181-183.) It could be drastically reduced, if this substantial paperwork is securely stored and processed on blockchain in a digital manner (Kshetri 2018; Cottrill 2018). It would eliminate the burden of the extensive and time-consuming shipping documentation and promote that information flow is better aligned with the material flow. Customs and border authorities could also be part of this process, which could result in enhanced border safety, shorter processing times and obviously lower costs (DuPont 2019, 181-183).

Smart contracts could bring further improvement to plenty of supply chain relations. It could automate invoicing and the settlements of payments. Furthermore, insurances or dispute resolution could be automatically triggered if certain conditions are met. (Owyang & Szymanski 2017, 3; Liotine & Ginocchio 2019, 78; MIT Center for Transportation and Logistics 2018, 14.)

Last but not least, supply chain finance is another field that blockchain technology can transform (Cottrill 2018). It would enable that the financial flows (payments) within the supply chains are more closely connected to the physical (material) and digital (information) flows (Hewett et al. 2020). Smart contracts could further facilitate that these flows are better aligned with each other (Liotine & Ginocchio 2019, 74-75). Some even consider that payments could be made in cryptocurrencies (ElMessiry et al. 2019, 163-164). However, that would require that cryptocurrencies are stabilized beforehand (MIT Center for Transportation and Logistics 2018, 15).

Table 4 below summarizes the main capabilities of blockchain technology in different supply chain application fields that were introduced in the previous paragraphs.

Table 4. Capabilities of blockchain technology in different supply chain applications

Supply chain application fields	Capabilities of blockchain technology
Track shipments	On item level, supported by sensor data
Trace products	Through lifecycle (from end to end)
Shipping documentation	Digitalized
Invoicing, insurances, disputes, payments	Smart contracts
Supply chain finance	Synchronize financial flows with material flows

2.3.3 Benefits and challenges of blockchain's implementation in supply chains

The benefits and obstacles associated with blockchain technology's implementation in supply chain field are mostly corresponding to the ones identified in general for all industries in subchapters 2.1.2 "Definition, attributes and advantages" and 2.1.3 "Critics and limitations". However, it still makes sense to observe them from supply chain viewpoint also, as there might be different emphases compared to other industries. This subchapter aims to focus on supply chain specific advantages and disadvantages.

According to the survey of the American Productivity and Quality Center (APQC) and Supply Chain Management Review, supply chain professionals see the biggest advantage of blockchain technology in cost savings (Partida 2018; ElMessiry et al. 2019, 163-164). There are plenty of different costs concerned, such as search and information costs related to supplier selection. Furthermore transactional, operational, administrative, documentation, (re-)negotiation, agreement and post-contract control costs are eliminated by smart contracts. (Liotine & Ginocchio 2019, 86-88; Schmidt & Wagner 2019; Kshetri 2018.) In addition, overall cost of moving goods can be reduced by using blockchain technology. (Owyang & Szymanski 2017, 13-14.)

Cottrill (2018) argues that from supply chain perspective, trust is one of blockchain's biggest benefits. The elimination of central intermediaries and third parties contribute to cost reductions and trust facilitate further business. (Liotine & Ginocchio 2019, 87-88; Owyang & Szymanski 2017, 13-14; Van Hoek et al. 2020; Kshetri 2018.) It is particularly beneficial for small producers that can directly connect to other companies and do not need to rely on additional middlemen (MIT Center for Transportation and Logistics 2018, 20).

Blockchain serves as a highly efficient tool for synchronizing data across multiple parties (Liotine & Ginocchio 2019, 86). Apart from that it brings further efficiencies to supply chain as well. It accelerates the administrative processes, the flow of goods and supply chain

processes in general. It even shortens the supply chain by eliminating insufficient intermediaries. The reduction of paperwork, automations and shortened tracing times further contribute to increased efficiency. (Owyang & Szymanski 2017, 13-14; Van Hoek et al. 2020; ElMessiry et al. 2019, 163-164; Liotine & Ginocchio 2019, 76-77; MIT Center for Transportation and Logistics 2018, 13-14, 19; Kshetri 2018.)

Enhanced visibility brought by blockchain technology result in transparent supply chains. It is capable of giving a 360-degree view to business stakeholders (Leonard 2017, 1), reaching from multitier supply channels to distribution channels also (Partida 2018). It has plenty of benefits to businesses. It supports information symmetry and reduces the risk of delays, disputes and prevent goods from being lost or getting stuck in supply chains. (ElMessiry et al. 2019, 163-164; Liotine & Ginocchio 2019, 87-88; Van Hoek et al. 2020; MIT Center for Transportation and Logistics 2018, 14.)

Transparency makes actors of the supply chain more accountable for how they operate, and it contributes to making supply chains more sustainable (MIT Center for Transportation and Logistics 2018, 14; Kshetri 2018). It makes it possible to more efficiently verify if goods are ethically produced or comply with environmental standards. It makes it easier to assess and ensure quality and improve product safety. It helps to tackle the problem of counterfeit goods (Partida 2018; ElMessiry et al. 2019, 163-164; Kshetri 2018), reduce corruption and fight tax evasion (MIT Center for Transportation and Logistics 2018, 20). (Van Hoek et al. 2020; Kshetri 2018.)

On the whole, using blockchain technology in supply chains can result in having better-quality data and better processes. Through tracking products end-to-end in real time, fragmented supply chains will become more integrated (Partida 2018). Better availability of accurate data will help with measuring outcomes and key performance metrics more precisely (Kshetri 2018), matching demand and exceptions better (Partida 2018; MIT Center for Transportation and Logistics 2018, 20), identifying bottlenecks, supporting audits or allocating just the right amount of resources to different activities (Liotine & Ginocchio 2019, 76-77; Kshetri 2018). In a Roundtable Report by MIT Center for Transportation and Logistics (2018, 20) it is stated that even if blockchain is not solving supply chains' current problems right away, it can still be an incentive for companies to start thinking about and investing in resolving many long-time ignored problems of supply chains.

Obstacles related to the implementation of blockchain based solutions in supply chains are almost identical to the ones typical of all industries. Companies are cautious about making investments in it as long as the return on investment is unclear. The adoption of

any new, emerging technology requires time and money, and it may take several years that benefits materialize. The above-mentioned savings are expected to be realized when the technology is widely used among industry partners (Kshetri 2018; Partida 2018). (MIT Center for Transportation and Logistics 2018, 19.) However, the coopetition-paradox is hindering the widespread of such distributed solutions. (Deloitte Ireland LLP 2020, 11; Kshetri 2018.) The most commonly raised question is: is blockchain really needed? In fact, if processes work well for a company, there is no need for investing in new technologies (MIT Center for Transportation and Logistics 2018, 13). The Roundtable Report by MIT Center for Transportation and Logistics (2018, 20) defines the current status of blockchain technology as “a hammer in search of a nail”. As long as there is not a clear business case for it, companies will rather take a wait and see attitude towards it. The lack of skilled workforce is an obstacle to implementation in supply chain field also (Partida 2018).

Another common concern is regarding the complexity and fragmentation of supply chains. In contrast to expecting blockchain to make supply chains more integrated and connected, some are worried that the use of potentially different blockchains will create further information silos. Moreover, there is the risk of increasing complexity by adding a further system on the top of the existing ones (MIT Center for Transportation and Logistics 2018, 13). DuPont (2019, 177) also states that “blockchain is not to replace existing systems, rather to facilitate transactions through ERP platforms.” The high complexity of global supply chains, with a myriad of different regulations and standards in place can render the implementation of blockchain solutions particularly challenging. The question of interoperability is crucial. (Murphy 2020; Casey & Wong 2017 in Kshetri 2018) Blockchain creators need to build bridges, not islands (MIT Center for Transportation and Logistics 2018, 16).

There are such practical obstacles as well that blockchain based solutions require high level of computerization and excessive data processing capabilities (Liotine & Ginocchio 2019, 82-85). Many supply chain actors however are located in developing countries, where the necessary infrastructure might not be available. (Kshetri 2018.) Cybersecurity risks are also often considered. It is highly important that the data inserted to the chain is correct (Liotine & Ginocchio 2019, 82-85; MIT Center for Transportation and Logistics 2018, 16). However, it is challenging to make sure that for instance sensors are not manipulated, which provide data about the product throughout the shipping process (Carson et al. 2018).

Table 5 below summarizes the benefits and challenges related to the implementation of blockchain based solutions in supply chains. Single companies need to evaluate their own

situation in order to be able to decide, which side of the balance scale is weighing more for them. (Carson et al. 2018; Cottrill 2018.)

Table 5. Balance scale of benefits and challenges related to the implementation of blockchain based solutions in supply chains

Benefits:	Challenges:
• cost savings • trust facilitate business • elimination of middlemen • accelerated flow of goods • shortened supply chains • reduction of paperwork • automations • transparent supply chains • information symmetry • reduced delays, lost products • less disputes • sustainable supply chains • product quality and authenticity ensured • reduced corruption and tax evasion • less fragmented supply chains • more accurate performance metrics • more resilient supply chains	• ROI unclear • benefits require industry-wide adoption • coopetition-paradox • clear business case is missing • lack of skilled workforce • creation of information silos • increasing supply chain complexity • implementation in international supply chains is challenging • interoperability issues • require infrastructure and computing capabilities • cybersecurity • tampered input data

2.3.4 Using blockchain in logistics and transportation

Further narrowing down the scope, this subchapter takes a closer look at blockchain's application in logistics and transportation in particular. Many agree that blockchain is a good match with the current demands of the logistics industry (DuPont 2019, 176). The survey of the American Productivity and Quality Center (APQC) and Supply Chain Management Review revealed that 26% of the surveyed supply chain professionals consider using blockchain in logistics field. This area has received the most responses and was followed by another key area of procurement at 20%. (Partida 2018.) DuPont (2019, 170-172) states that logistics has always been a technology and information industry. He identifies a strong market demand in logistics for blockchain and recognizes the business case for blockchain in logistics as "modest, yet influential". He furthermore sees high chances that blockchain will "significantly alter the logistics industry". Blockchain has risen as a top priority in transportation also, as digital technology is reshaping the sector (Leonard 2017, 1).

Blockchain is seen as the means of bringing the long-awaited digital shift to logistics (DuPont 2019, 176). Many emphasize that it will enable the digitalization of the excessive paperwork and give full visibility to shipments' documentation along its whole journey.

(DuPont 2019, 176; MIT Center for Transportation and Logistics 2018, 13.) It is capable of ensuring the completeness and accuracy of the documentation in question and prevent tampering with the papers.

Furthermore, it can simplify the shipping process, reduce processing times and the costs of intermediaries (for example associated with freight brokers). (Liotine & Ginocchio 2019, 76; DuPont 2019, 175.) Freight forwarders and carriers are actually expected to play a crucial role in blockchain's implementation in this sector. Shippers outsource the transportation to them and are only interested if shipments are safely and timely delivered in a cost-effective manner. They are not paying attention to the tools forwarders and carriers are using to provide their service. Consequently, it will be freight forwarders' and carriers' attitude to blockchain to decide how this sector embraces this new technology in the near future. (MIT Center for Transportation and Logistics 2018, 13.)

Throughout the above-mentioned improvements blockchain is expected to contribute to more effective resource allocation, reduction of losses and prevention of planning errors originating from the bullwhip effect. Business decisions are supported by immediately available reports (DuPont 2019, 181). With such comprehensive and real-time data on capacity, costs and delivery times companies are capable of improving the planning of shipments and the dynamic adjustment of pricing. (Liotine & Ginocchio 2019, 76.)

Blockchain can be particularly beneficial at the crucial point, when a container is handed over from one party to another. With the help of the tracking data provided by IoT-based devices, blockchain has the potential to automate the process with smart contracts. (DuPont 2019, 181.) Further transportation specific use-cases are enhancing tracking to meet the current expectations of businesses in detail and speed, or helping with making proactive decisions. Blockchain can make processes smoother in fields of carrier onboarding, driver record authentication, payments etc. (Leonard 2017, 5-10.) The usage of smart pallets would make it easier to locate pallets and could contribute to more flexible and optimized pallet utilization. (Liotine & Ginocchio 2019, 78.)

There are different views on how blockchain will interact with currently used systems in logistics. Some expect that it will be integrated with the widely used Electronic Data Interchange (EDI) systems that companies utilize for internal and interfirm communication. DuPont (2019, 176, 191) sees that it will add a "tamper-proof security-layer" to those existing systems or even replace them. According to different views, blockchain is the answer to the information sharing deficiencies that EDI-users are struggling with. Levine (2017 in

Kshetri 2018) argues also that blockchain is capable of resolving the communication problem in shipping. He highlights that while in finance central databases already exist that might already serve businesses' needs sufficiently, currently there are not such databases and trusted central intermediaries in the field of shipping. In this sector blockchain could create those means that facilitate transparent information flow. Enterprises expect blockchain to provide the one version on truth to the businesses (DuPont 2019, 180). (Xinping & Simon in Waters et al. 2007, 182.)

Figure 6 provides a synthesis of the previous paragraphs. It introduces the complex relations between the different improvements and benefits blockchain is about to bring to logistics and specifically to transportation sector. The focal points of improvement are framed in rectangles: digital shift, the simplification of the shipping process, more effective resource allocation and some use-cases that are already under experimentation. In the heart of the image, highlighted with thick borders, can be found the most promising implementations for the future: the digitalization of the paperwork, the automation of container handovers and payments and more comprehensive tracking. The rest of the image is showcasing the specific benefits described in detail in the previous paragraphs, and their linkages to the focal improvement points.

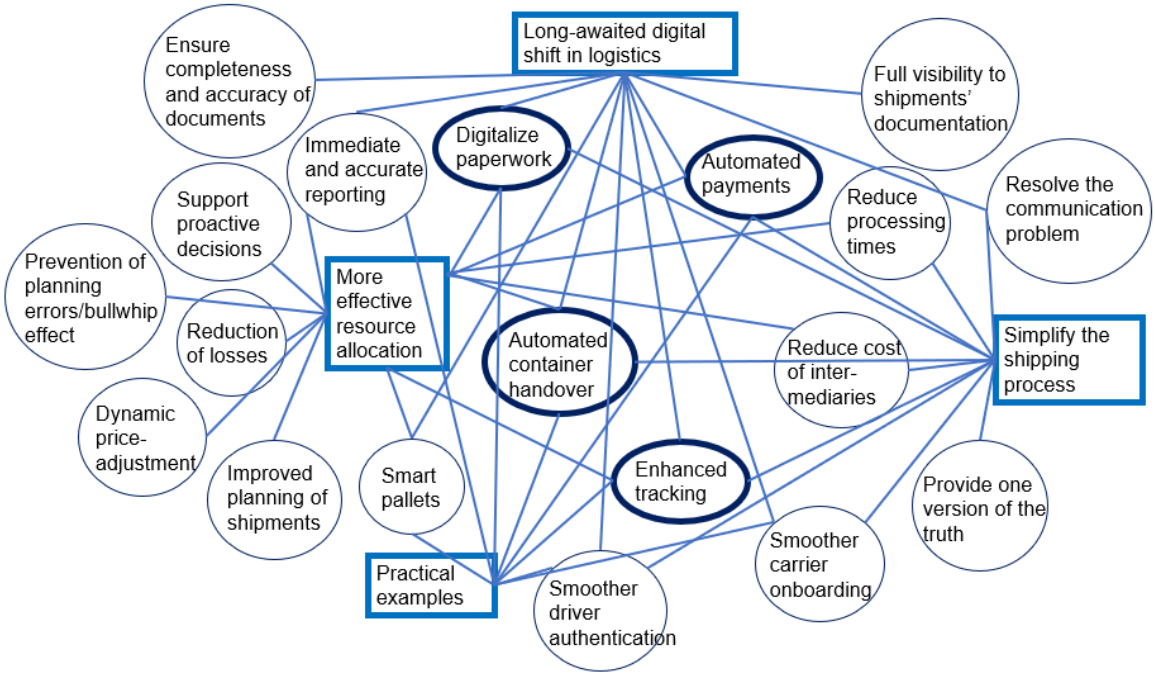

Figure 6. Improvements and benefits blockchain is about to bring to the logistics industry

Many highlight the synergies obtainable when combining blockchain and Internet of Things (IoT) technologies (Kshetri 2018). DuPont (2019, 178) even defines the integration of blockchain with IoT for logistics as the "future of supply chain". Internet of Things

means a network of sensor- and software-equipped devices that communicate and coordinate through the internet. In the recent years, the usage of such connected devices has already become a reality in the transportation industry. The widespread availability of low-cost sensors made IoT devices indispensable elements in robust supply chains. Having those sensors mounted to shipping containers and transportation vehicles lately brought the most significant change in logistics technology. (DuPont 2019, 170, 172.) However, these systems rely on centralized communication models and currently are connected through cloud servers. Salviotti and colleagues (2018, 3471) expect that blockchain can resolve the scalability, privacy and reliability issues experienced in the field of IoT and bring about a more resilient ecosystem.

In an ideal setting, sensors would collect the data, IoT devices would enable that the data is transmitted to other devices on the same network, and blockchain would add the necessary security and authenticity features to the system. Furthermore, blockchain has the potential to track and coordinate billions of connected devices and connect multiple IoT platforms. As a straight outcome, tracking becomes more prompt, accurate and cost-effective (Kshetri 2018). By adding smart contracts to the system, the data arriving directly from the sensors could automatically trigger transactions and result in process automations. (DuPont 2019, 172-178.) When further combined with other technologies, such as artificial intelligence (AI) or big data, even more significant impacts are attainable.

2.3.5 Proofs of concept from the field of supply chain

Even though blockchain is an emerging technology, it has already reached the maturity that such prominent companies started experimenting with it as IBM, Microsoft, Walmart, Maersk, Unilever, Nestle, FedEx, UPS, DB Schenker etc (DuPont 2019, 41). To extend the scope further, Dennis Gerson, an engineer and technical adviser at IBM, estimated that 75% of Fortune 400 companies had tested blockchain by 2018. This number has just definitely increased since. But we must note that 90% of those tests have not reached the pilot phase. (Van Hoek et al. 2020.) Nevertheless, it is worth taking a look at the rest. Some already implemented proofs of concept (PoCs) provided remarkable results. Van Hoek and colleagues (2020) synthesize the value of blockchain for supply networks to a matrix of four quadrants, which are differentiated based on the levels of adoption. The elements are defined by the axes of scope and depth of impact. Applications of blockchain technology in supply chain – PoCs included – can be categorized in one of the quadrants, introduced in figure 7 below.

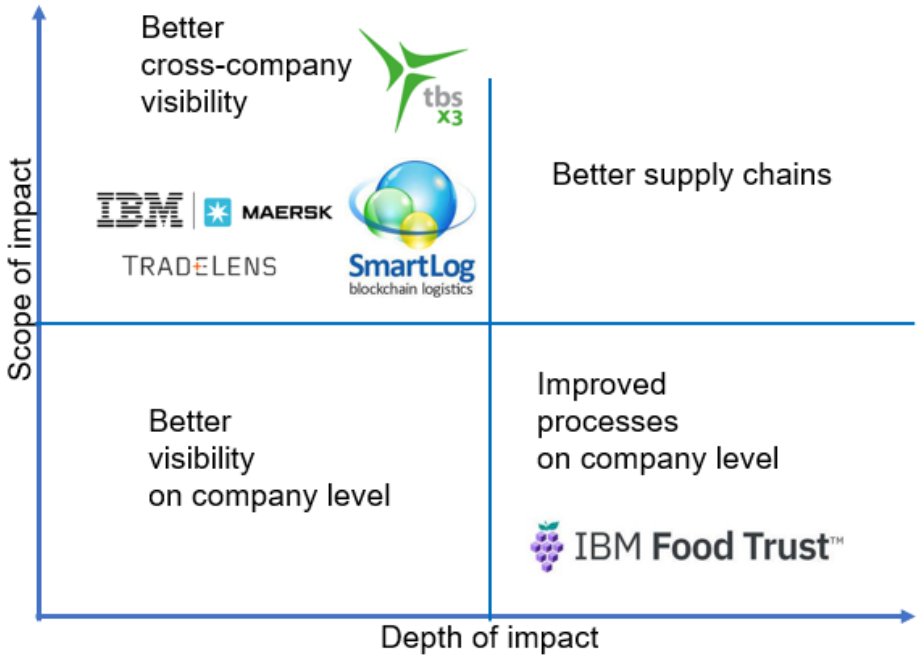

Figure 7. Value of blockchain for supply chain solutions (adapted from Van Hoek et al. 2020.)

Recently most applications are stuck in the bottom left corner, as single companies use the technology to see more. Very often it means that they see more of their current data and processes that might eventually even be faulty. For example, blockchain can reduce radically how quick a single product can be traced back to the origin. It does not change anything fundamentally about the supply chain and does not resolve any problem. It adds speed to existing processes. Remarkable improvements can be achieved when companies start reaching out to the other quadrants of the matrix. Moving upwards further improves visibility, but blockchain becomes transformative, when we reach the right side of the matrix and process improvements are made. On the one hand, the scope of impact is extended if numerous companies start using the same blockchain for sharing information or executing transactions. This cross-company cooperation is located in the top left corner. On the other hand, the depth of impact is being enhanced when a company is not only using the technology to gain a better visibility of the supply chain but uses it to improve its own processes. This option is represented in the bottom right corner. For instance, with the help of blockchain, time-consuming manual paperwork can be exchanged by digitally managed smart contracts. It can result in longer shelf-life for the products, as those can move faster through the supply chain. Most benefits can be gained, if a solution is correspondent to the top right quadrant. In case companies making part of the same supply chain are using blockchain to improve their cooperation that will result in building better supply chains. It could be the upmost advantage blockchain can offer to supply chain management. (Van Hoek et al. 2020.)

The following paragraphs give some specific examples of already implemented proofs of concept. Due to the fact that logistics partners are already known to each other and has legal ties in place, DuPont (2019, 171, 180) identifies permissioned and private blockchains suitable for logistics' applications. The following use-cases affirm his statement. One of the most impressive PoCs is IBM's Food Trust established in 2019. Its profile is tracing goods, mostly food products for its giant partners, such as Walmart, Carrefour or Nestle. (Deloitte Ireland LLP 2020, 8.) In one of the best-known cases, Food Trust was tracing mangoes from the farms in Mexico up until the stores of Walmart in the United States. Its major achievement has been that the utilization of blockchain technology reduced the tracing time from almost 7 days to 2,2 minutes. (Van Hoek et al. 2020; Cottrill 2018.) The application has also traced pork products from China and later from Latin-America. (DuPont 2019, 178.) However, these experiments fall in the bottom left quadrant of the Van Hoek (2020) matrix, as they only accelerate existing processes within a company. Now Walmart has 1,1 million items on the blockchain that enable them to make product recalls much more efficient (Schmidt & Wagner 2019). We can say that they have now reached the right bottom quadrant through improving their internal processes.

Another notable PoC is coming from the field of logistics. TradeLens is a joint endeavour of the Danish shipping giant, Maersk and the technology pioneer IBM. (Carson et al. 2018.) An early adopter programme started in 2018 and a fully working version became available in 2019. Its novelty stood in the fact that throughout time TradeLens has involved hundreds of actors form the logistics field to be part of the common platform; ports, terminal operators, carriers, freight forwarders, other logistics companies and even customs offices included. TradeLens focuses on tracking shipping containers and making customs processes significantly faster and more secure. (Van Hoek et al. 2020; Schmidt & Wagner 2019.) Practical use-cases involved tracking a container of perishable flowers from Kenya to the Netherlands, or pineapples from Columbia and oranges from California (DuPont 2019, 175). By operating industry-wide and bringing together various participants from the whole shipping industry, it places this application to the upper left quadrant of the Van Hoek (2020) matrix.

A similar project has been implemented through the Baltic Sea in 2016-2019. Kouvola Innovations, the economic development firm of the city of Kouvola, a transportation hub in Finland, led a project funded by the European Union's Interreg Central Baltic program. Together with other participants from Sweden, Estonia and Latvia they have created SmartLog, a proof of concept project for IoT blockchain solution in the logistics industry.

Similarly to TradeLens, numerous operators and port management systems were involved. The scope of the project included the development of a software, the creation of a prototype, generation of a measurement framework and the testing of the prototype in 2 EU transportation corridors reaching over the Baltic Sea. All three elements of the project brought a successful outcome. Blockchain facilitated the flow of information between parties, which resulted in reduced cargo transport times. (Lammi 2017, 36-38; SmartLog 2021.) The project also involved smart contracts directly built into the containers. It has given the cargo containers a limited decision-making authority regarding route-planning. By tendering transport contracts, containers were capable of dynamically organizing their routes. (Castillo 2016.) SmartLog was also an industry-wide initiative, which increased the scope of visibility for several companies, thus making part of the upper left quadrant of the Van Hoek (2020) matrix.

Further notable trial has been a consortium created by DP World Australia (the fifth largest container port operator globally) and the Australian branch of DB Schenker, with the help of the blockchain start-up TBSx3 in May 2017. They have used a blockchain architecture to track the distribution of wines from South Australia to Northeast-China. The initiative was aimed at protecting global supply chains from counterfeiting and improving consumer trust. (Burnson 2018.) Due to the fact that it involved several parties by creating a consortium for the supply chain of wines, this project can also be placed in the upper left quadrant of the Van Hoek (2020) matrix.

Van Hoek and colleagues (2020) state indeed that no blockchain implementation has reached the upper right quadrant so far. However, in case the above introduced applications can further increase the scope and the depth of their impact, they can contribute to building better supply chains.

As this thesis focused on the transportation industry, it is important to introduce the Blockchain in Transport Alliance (BiTA) initiative, founded in August 2017. Even though it is not a proof of concept, still it is an important element for enabling future implementations of blockchain technology in the transportation industry. BiTA is the biggest commercial blockchain alliance globally. It has nearly 500 members in over 25 countries from the freight, transportation, logistics and its related industries. Of all its activities, the development of freight industry blockchain standards is the most significant one for the future of the technology in the concerned industries. By developing common standards, freight industry is taking a major step towards the upper right corner of the Van Hoek (2020) matrix. Besides its standard-creating activities, BiTA provides education to its members and others on blockchain technology and supports the usage of new solutions. BiTA organizes

conferences for its members twice a year and networking meetups all year around. Members are eligible to participate in the activities of Think Tanks, Working Groups and Technical Committees. It is headquartered in the United States. (BiTAa 2021.) The Board of directors is compiled from companies like FedEx, UPS, Freight Waves, Daimler or Salesforce.com (BiTAb 2021).

2.3.6 Future trends for blockchain technology

The first blockchain transaction has been executed a bit more than a decade ago. Eleven years after that, a Deloitte Ireland report (2020, 2) stated that “2020 is the start of blockchain’s decade”. However, in between there are various views with different levels of optimism and enthusiasm for the future of blockchain. This subchapter introduces some of those visions, with special regard to expectations in the supply chain and logistics sector.

Mika Lammi (2017, 36), project leader of the SmartLog application has identified 2016 as the blockchain year of peak hype, the very same year that the SmartLog project was launched. By 2018 the ecosystem has been cleaned up, as overhyped projects failed and gave more ground to pragmatic initiatives (Deloitte Ireland LLP 2020, 4). Some have seen 2019 as the year on “blockchain fatigue” (Tapscott 2020), as the hype has further faded away. In fact, that was the year when a shift from hype to quality happened (Warren 2020). As a sign of that, some notable companies became part of the blockchain community (like Facebook) and for example two major competitors of Maersk have joined the TradeLens platform. (Tapscott 2020; Warren 2020.) It is also an indicator that the coopetition paradox started getting less impactful. It was also the year, when the diversification of industries accelerated. Fintech still remained in leading position, but supply chain management was one of the sectors that particularly became effected by this penetration (Deloitte 2019; Deloitte Ireland LLP 2020, 4). While in 2019 only 66% of the surveyed supply chain professionals were familiar with blockchain technology, this number has risen to 80% by 2020 according to data collected by American Productivity and Quality Center and Supply Chain Management Review (APQC & SCMR 2020). Blockchain is now seen as an integral element to organizational innovation in supply chains (Pawczuk et al. 2020, 2). This year brought the opportunity for blockchain to move on from proof of concept implementations towards robust enterprise ready solutions (Deloitte Ireland LLP 2020, 2-3). The quick progress of oracles reduced the switching costs (Nazarov 2020) and consortia became even more accepted. Question is no longer about joining consortia or not. Discussions evolve around how to run consortia in a way that it is equally beneficial for all participants. (Pawczuk et al. 2020, 20.) According to McKinsey’s evaluation, blockchain might become feasible at scale in about 3-5 years (Deloitte Ireland LLP 2020, 9). The Covid-19

pandemic interestingly caused blockchain maturing at an accelerated pace. On a general level digital identity became a priority for coronavirus-related needs. (Warren & Deshmukh 2021.) From supply chain point of view, the pandemic has disrupted traditional supply chains. Sales channels has irreversibly been shifted to digital ways of operation, which has set new requirements for supply chains too. Trust and supply chains have to be re-built. It is a great opportunity for blockchain that can bring the desired visibility and transparency to supply chains. (Hewett et al. 2020.) Kotecha and Muma (2020) affirm that "blockchain technology will play a critical role in the digital transformation of supply chains emerging in a post-Covid-19 world".

So far blockchain-scene has been about learning and exploring the potential of the technology. Future will be more focused on building practical applications. (Deloitte 2018.) In the short term we can most probably expect cost reductions from the technology. Transformative business models can evolve only in the long term. (Carson et al. 2018.) However, there are different views on how fast these novelties might arrive. Pawczuk and colleagues (2020, 24) expect that blockchain will gain greater traction in the coming 1-2 years. Van Hoek and colleagues (2020) also anticipate that it will take years that blockchain mature into something widely accepted and used. They continue by mentioning decades, when changes in the economic and social infrastructure might happen. While DuPont (2019, 10) warns to remain "cautiously optimistic" about the potential of blockchain, as it has not transformed any industry so far. Michael J Casey, a senior advisor for blockchain research at MIT's Digital Currency Initiative agrees by defining blockchain as the "technology of tomorrow, not today" (Van Hoek et al. 2020).

Van Hoek and colleagues (2020) reveal also that however leaders are interested, many do not have the strategy, roadmap or resources allocated, when it comes to practicalities. The Roundtable Report by MIT Center for Transportation and Logistics (2018, 22) argues that blockchain technology is still in its infancy and different outcomes are likely to develop. An expert from the Massachusetts Institute of Technology (MIT) agrees by giving three possible scenarios: blockchain will alter to some relatively minor extent the ways of doing business; it will transform the complete infrastructure; or some other combination of the previous two will occur. (MIT Center for Transportation and Logistics 2018, 22.) Salviotti and colleagues (2018, 3475) raise attention that the most affected industries can no longer postpone embracing blockchain technology, while for the less impacted industries it offers the opportunity for innovation. The Roundtable Report by MIT Center for Transportation and Logistics (2018, 22) concludes that regardless of what standpoint a

company takes, the ones, which are now engaged in creating the rules for the new playground, will create those for the ones as well, who are watching it from the sidelines at the moment.

3 Research and analysis framework

The research element of this thesis aimed to investigate to what extent the findings available from the literature review were prevalent in real business settings of three case companies in the transportation business. The following subchapters introduce how the research has been conducted. Conclusions drawn from the research are explained in chapter 4, “Suitability of blockchain technology for the case companies”. Furthermore, a scheme set up by the World Economic Forum is introduced. It can be used to determine if any kind of blockchain solution is suitable for a business or not. This framework was applied to the companies participating in the research and recommendations were given to those companies at the end of each interview analysis.

3.1.1 Research design and methods

Qualitative research methodology has been used in this thesis, due to its suitability to collect and analyse rich and detailed sets of data. Qualitative research works with non-numerical data and focuses on interpretation and understanding. It puts emphasis on meanings, relationships and description, rather than quantification. (Eriksson & Kovalainen 2008; Ng & Coakes 2014; Saunders, Lewis & Thornhill 2019, 175-179; Weathington, Cunningham & Pittenger, 2012, 399.) Such an approach helped with examining the situation of the case companies in detail, getting rich insight into their motivations and draw conclusions from those.

The research was a combination of evaluative, exploratory and descriptive components. It aimed to evaluate to what extent blockchain technology was suitable for supply chain use cases at the case companies. It intended to explore this relatively new and current topic and get an insight to the case companies’ approaches to this technology. The descriptive element was designated to give an accurate introduction to the case companies’ relationship to blockchain technology and the potential use cases available for each of the companies. The research used a deductive approach: it applied the existing theory to the cases, to test its validity. (Saunders et al. 2019, 186-187, 652; Weathington et al. 2012, 399.)

Three case companies were examined. These companies are all operating in the transportation business however, they are quite different in size, scope of activities and relationship to technology. It enabled that a cross-case analysis was conducted, revealing how different contexts affected the potential of blockchain technology in the transportation industry. Case study analysis has been chosen as the method of research because it is

suitable for studying a topic in great depth within real-life settings. It provides an intensive and detailed analysis of a case. It is especially appropriate for investigating complex, contemporary issues. (Saunders et al. 2019, 196-198.) However, it is important to highlight the weaknesses of such a method as well: case study analysis cannot provide a solid ground for generalization. It enabled that this thesis was challenging the existing theory against real cases. Another limitation of this research was that case study analysis usually incorporates data collected from various sources, to enrich the whole picture. (Eriksson & Kovalainen 2008; Ng & Coakes 2014.) This research has only used one method for the collection of data: interviews.

Primary data for the research has been collected through three semi-structured interviews with managers from the case companies. The interviews have been conducted during April 2021, through video conferencing tools due to the Covid-19 pandemic. Such a setting is not the most appropriate for interviewing however, camera has been used to help with building rapport with the interviewees (Bajpai 2018; Saunders et al. 2019, 473). Interview is a purposeful conversation between various parties. In semi-structured interviews a list of predetermined topics and a set of questions give the framework for the interview. The interviewee is free to speak about themes that are of particular interest to him, while the interviewer still guides the flow of the conversation by the predetermined topics and questions. Semi-structured interview is especially suitable when attitudes and opinions are researched. (Bajpai 2018; Hesse-Biber & Leavy 2011; Saunders et al. 2019, 434-444.) It made an important part of this report to find out the case companies' approach towards blockchain technology, its advantages and limitations. It has been agreed with the interviewees that their real names and company names are not revealed, only their positions at the case companies. It also contributed that interviewees could share their opinions and sentiments more openly. Companies and interviewees were referred to in the same order, as interviews at the case companies took place: Company/Interviewee X, Company/Interviewee Y and Company/Interviewee Z.

3.1.2 The process of data collection

The interview framework is available from Appendix 1. The main topics covered were aligned with the investigative questions of this thesis (available from subchapter 1.2 "Thesis topic"): current challenges for the case companies, their responses to those, looking into improvement possibilities and examining the possible obstacles related to blockchain technology's implementation. The framework including the planned interview questions has been shared with the interviewees well before the interviews took place. It was ac-

companied by a short introduction to the literature review of the thesis. The latter was necessary, because as also literature highlights, many supply chain professionals have limited understanding of the topic (Blanchard, 2018; Partida 2018; Seth 2019; Van Hoek et al. 2020). Consequently, basic terms and concepts have been introduced to the interviewees throughout the interviews as well, when it was necessary. As the interviewees had the chance to get acquainted with the interview questions beforehand, all interviews followed a similar scenario. First the interviewees' attitude to blockchain technology and the case companies' relationship to technology in general have been mapped. Afterwards the interviewees were given a chance to freely share what was on their mind about the topic. However, they were guided to some extent by the interviewer's questions along the way, to keep the conversation within the scope of interest of the thesis. Finally, those themes and interview questions have also been covered that were not raised up throughout the initial conversation. The interview transcripts were not made available either due to confidentiality reasons.

3.1.3 The process of data analysis

Content or thematic analysis have been used for analysing the data. By establishing codes, data with similar meanings can be categorized together. Throughout the use of codes content analysis identifies themes and patterns in the data sets. It produces valuable data from the interview transcripts for further analysis and for drawing conclusions. (Eriksson & Kovalainen 2008; Gillham 2005; Kvale & Brinkmann 2009; Saunders et al. 2019, 641-643, 651-653.) Due to the deductive nature of this research, codes have been established based on the literature review and those codes were looked for in the interviews. However, a very small portion of the codes has also been identified in an inductive manner from the interviews, when interviewees have brought up interesting aspects not considered in the literature review. (Saunders et al. 2019, 652.) The codes used for this research can be found in Appendix 2. Themes for codes and the codes themselves were also aligned with the investigative questions of this thesis, defined in subchapter 1.2 "Thesis topic".

3.1.4 Toolkit for determining the suitability of blockchain technology for a case

The World Economic Forum (WEF), according to its mission, is the International Organization for Public-Private Cooperation. It brings together "the foremost political, business, cultural and other leaders of society to shape global, regional and industry agendas… with the aim of driving positive change". One of its key areas of focus is mastering the Fourth Industrial Revolution. (WEFa, 2021.) Blockchain technology receives particular attention

from the 274 topics followed by WEF's transformation maps (WEFb 2021): it is one of those 18 topics that have a separate platform dedicated to (WEFc, 2021). This report was using a white paper released by this organization for determining the suitability of blockchain technology for the case companies. Furthermore, this framework also suggests which type of blockchain would be the most appropriate for a certain firm. (See chapter 2.1.4 "Types of blockchain" of this thesis about the different types available.) As there are different approaches in the literature to the classification of blockchain, typology used by the framework is summarized up in the following. The white paper differentiates between permissionless-public systems; permissioned-public and permissioned-private systems. Permissionless has no restriction either on access or on reading or writing rights. Permissioned ones restrict the pool of participants to whitelisted ones. In the public version transactions are openly readable, as it gives reading rights to all participants. On the other hand, only a limited number of members have writing rights. The private version gives reading and writing rights to all participants and often consortia is established to manage the ownership. (Mulligan et al. 2018, 5.) This above-mentioned framework introduces a decision tree of 11 yes-no questions. With the help of those, business leaders can execute an initial assessment, whether their company should invest in exploring blockchain technology or not. It is highly important, because blockchain technology has the potential to resolve a wide range of problems, but it is crucial to find the correct use case for it. Otherwise, it is just a waste of resources, as Mulligan and colleagues (2018, 4) state it in this white paper as well. Table 6 below introduces the questions and the decision-route from the toolkit.

Table 6. Blockchain implementation decision tree (adapted from Mulligan et al. 2018, 6.)

	Questions	Answer		Outcome
A.	Are you trying to remove intermediaries or brokers?	YES	NO →	
B.	Are you working with digital assets (versus physical assets)?	YES	NO →	Do not use blockchain.
C.	Can you create a permanent authoritative record of the digital asset in question?	YES	NO →	
D.	Do you require high performance, rapid (~millisecond) transactions?	NO	YES →	Blockchain can't do this efficiently yet, but solutions are in development.
E.	Do you intend to store large amounts of non-transactional data as part of your solution?	NO	YES →	
F.	Do you want/need to rely on a trusted party? (e.g., for compliance or liability reasons)	NO	YES →	Blockchain may work – further research is needed
G.	Are you managing contractual relationships or value exchange?	YES	NO →	
H.	Do you require shared write access?	YES	-	
I.	Do contributors know and trust each other?	YES	NO	
	Are contributors' interests unified or well-aligned?	NO	YES →	
J.	Do you need to be able to control functionality?	NO	YES →	Strong case for blockchain (private/permissioned ledger)
K.	Should transactions be public?	NO	YES →	Strong case for blockchain (public ledger)

Some of the above questions might require further explanation. Question A points out blockchain's incompatibility with intermediaries: it is one of the major features of blockchain technology to make the use of brokers unnecessary. Question B highlights the importance to have digital replications of the physical assets, so that those could be handled on the blockchain. Question C refers to the fact that companies need to be able to create a permanent record of the transactions as well that can be later on stored and shared through the blockchain platform. Questions D and E are related to computation limitations of current blockchain solutions. There are industries, where the speed of the transactions is crucial. Most probably supply chain management does not belong to those, at least to the extent of milliseconds. It must be also noted that the more centralized (private) a blockchain is, the faster solution is achievable (Mulligan et al. 2018, 5). Question F emphasizes that if a trusted party needs to be involved into the transactions for compliance or reliability reasons, it is crucial to involve the regulator in the blockchain project as well. This way conformity to the regulations can be ensured. Otherwise, some other solution needs to be sought than blockchain. Question G points out that blockchain is a powerful solution when contractual relationships and value exchange are executed. In other cases, different solutions might be a better choice. As question H highlights, blockchain can be a great tool to manage shared writing rights. If such feature is not needed, another technology can prove to be a better solution. Question I investigates trust issues, as blockchain technology is a promising solution to those. On the one hand if parties trust each other and their interests are aligned, further research is needed to determine, if blockchain is still necessary to enhance trust between them. However, on the other hand, if parties are unknown to each other or their interests might be opposing despite they trust each other, further questions need to be answered from the decision tree to identify the appropriate form of blockchain to use. Control of functionality referred to in question J means: do single parties need to take decisions on issues like node distribution, permissioning, engagement rules, etc. or is it the distributed network taking care of that. If the former, then a private/permissioned network might be suitable. If the latter, then transactions' publicity examined in question K will determine the desired form of blockchain to be used. If transactions are public, it is advisable that blockchain platform is also public, permissionless. Following the same logic, if transactions need to be kept private, blockchain platform is likely to be private, permissioned. (Mulligan et al. 2018, 6-9.) Case companies were assessed based on this decision-tree, and recommendations were given to those companies at the end of each interview analysis.

4 Suitability of blockchain technology for the case companies

This chapter introduces the analysis and interpretation of the conducted interviews. Firstly, each of the interviews is presented in separate subchapters, in a manner that follows the interview framework. After that, potential use cases for blockchain implementation are identified for the case companies. Furthermore, toolkit described in subchapter 3.1.4 "Toolkit for determining the suitability of blockchain technology for a case" is applied to the case companies. Lastly, in subchapter 4.4 "General overview of the cases" conclusions are synthetized and put in parallel with the literature review available from chapter 2 "The potential of blockchain technology in supply chains".

4.1 Company X: prepared for blockchain implementation

Company X is an innovative company with eagerness to discover new technologies and find such use cases where those technologies can serve their interests the best.

4.1.1 Interview with Company X

The Chief Information Technology Officer (CIO) of Company X had the most knowledge about blockchain technology, compared to the rest of the interviewees. He appreciates that his company is innovative and give space for new ideas, despite it is operating in a traditional business. Company X benefits broadly from technology: automation and digitalization are extensively utilized due to the small number of employees; artificial intelligence is supporting activities to eliminate human error in critical tasks. Furthermore, the company examined the suitability of blockchain technology for its operations years ago, when blockchain's hype was at its highest. Interviewee X has found that blockchain "fits very well to supply chains" and "blockchain would give us really good benefits". However, the company is taking a waiting position, saying that "we cannot do anything right now with blockchain". As the company just represents an element in other companies' supply chains, there is no point in using this technology as long as other players are not joining. The company has also considered if they build a blockchain themselves, but as it is a global business, they rather expect some central actor, an authority or a global company for example, to engage in setting up a blockchain for the whole industry. In fact, one of the service-station chains that Company X is supplying with fuel has already started experimenting with the technology. As Interviewee X has summarized their approach: "from the technology point of view: we are ready for it. Technologies are there, already, to be able to join a blockchain…we don't have this part of work when someone is proposing something".

The challenges of company X are mostly related to the bio movement in the oil industry. They need to be able to trace down the components of the fuel that the company supplies to the service stations. Another trend is the increasing demand for sustainable fuels. Company X also has to be able to prove to the authorities by submitting certificates that they have the requested percentage of bio component in their products. The company has put enormous resources and effort in building digitalized solutions to comply with the above requirements. Now it is working “nicely and efficiently” with the help of the business intelligence the company has set up in recent years. A related challenge is, how the company can acquire enough bio components in the future. Standards are expected to be increasing, while there is a limited capacity available from these materials worldwide. Furthermore, biggest resources of bio components are located in Asia, at a great distance from the Nordic markets.

There were numerous obstacles to blockchain’s implementation identified throughout the interview. Company X’s major reasons for not using blockchain yet has already been discussed: there is not a suitable platform in the industry available yet that other companies would be using also. Another challenge is finding rightly skilled people to develop against blockchain. Related to that Interviewee X has pointed out that same things can be done with traditional databases as well using the current skill set: “we might not have the resources and know-how to make the big blockchain, even though it would give us some benefits, but we cannot keep up developing it because we don't have resources. Then why don't use that solution that we have resources to”. As for coopetition, Interviewee X did not see issue in that. According to his view “more business-related and secret data are not shared via the blockchain”. He acknowledges blockchains benefits in term of the immutability of the data however, he also has concerns if correct and authentic data is added to the blockchain originally or not. He also sees an obstacle in the companies’ willingness of investing into this new technology. In case they have systems running that they are satisfied with, what would convince them to make the change? He is assuming that it might be a similar process as companies went online: there was a point reached when companies could no longer afford not using e-mail and websites to maintain their competitiveness.

As it has been introduced above, Company X has already identified two use-cases of blockchain for themselves. One is tracing the fuel components that they have to be able to report to the service stations. Interviewee X has ambitious visions about future implementations: “what I'm expecting is that…in the future, when you go to a service station… there are screens and when you fill your car, you can see at the same time the supply chain of

those litres that you are filling up your car with". Company X can trace it down itself efficiently but showing it to customers requires a further giant leap ahead. Another possible use case is the submission of certificates on bio content of the fuels to the authorities. Currently PDF files are used in that process. "If there was a blockchain having that data in it that would be fantastic…But of course this can be handled without blockchain." – Interviewee X shared his opinion on that. Throughout the interview a third potential use case has also been identified. Authorities demand that Company X has a real time visibility about the location and physical attributes (temperature, amount and quality) of the fuel they control. The technology background has been built up for that tracking capability some years ago and by the usage of GPS technology and sensors "it works really well". So far Company X had to have its own database on that. In the future this will have to be reported to authorities as well, as the EU Commission has passed a legislation on it recently. According to the opinion of Interviewee X, if the European Union sets up a blockchain for this purpose, the uploading and updating of the data could happen securely and on real time basis through blockchain.

4.1.2 Blockchain implementation decision tree applied to Company X

As the interview has already shown, Company X has strong potential use cases for blockchain implementation, and they have already taken steps to prepare their internal tools and processes to be able to connect to a blockchain. When applying the blockchain implementation decision tree to Company X the following path was taken. (Capital letters are indicating the different questions of the decision tree available from table 6.) A: In one (tracing down fuel components) of the three use cases intermediaries can obviously be eliminated. By using blockchain, data could directly be available to service stations or customers, it should not flow through all the actors of the supply chain. Based on the interview it seems that the company is in direct contact with the authorities for the reporting purposes. In case such data does not have to flow through different actors, there might not be a need for blockchain for the other two use cases (reporting on bio content and tracking of fuels). However, if Company X is also receiving certificates through their supply chains and forwarding those to the authorities (Company X being the intermediary in this instance), blockchain could improve the reporting process. Same applies to the tracking information of the fuels. B and C: Company X has already reached a high level of digitalization and it has permanent digital replications of its products. D and E: Company X does not need rapid transactions and not planning to store large amount of non-transactional data on blockchain. F: For the two use cases related to reporting (on bio content and tracking of fuels) Company X needs to rely on a trusted party for compliance reasons, thus the outcome of the decision tree is "Blockchain may work – further research is

needed". Other than that, in those cases the involvement of the authorities to the process in inevitable. As for the tracing use case, there is no need for a trusted party. G: Company X is most probably having contractual obligations towards service stations to provide data on the fuel components. H: As Company X also receives information on fuel components from down of its own supply chain, shared writing rights would serve the purpose that this data is added to the blockchain already at the origin. I: Contributors might know each other to some extent, but trust might be missing, as Interviewee X was also suspicious if he can trust the data. J and K: Service stations need to decide if they need to control functionality or publicity of the data – examining the standpoint of service stations is out of scope of this thesis. Those decisions taken by the service stations can determine if a private permissioned or a public solution would be suitable.

Company X in some way is dependent from other actors in terms of blockchain implementation. In two use cases authorities need to be involved due to compliance requirements, and in the third case seems that service stations need to determine what sort of blockchain could be used. Those are also global companies, so are in a better position to propose a blockchain solution for the industry. Would any of the above-mentioned options be taken, or any other solution than blockchain, Interviewee X believes that "technology is really the solution in the future" of Company X.

4.2 Company Y: discovering the benefits of new technologies

Company Y has an extensive international network of partners and customers, and it has to manage versatile data flows within this network related to its shipments.

4.2.1 Interview with Company Y

Company Y and the Chief Executive Officer (CEO) of Company Y can be regarded relatively newcomers to the field of information technology, blockchain not being an exception. According to Interviewee Y's self-assessment: "it is a very new thing for me" and regarding company-level involvement: "we are very much at the starting point at the moment". However, Company Y is conscious about the relevance and timeliness of the digital solutions. As Interviewee Y has put it: "You cannot survive only to transport goods from A to B. You really have to understand more around, and the main thing is this data and IT technology. So, in that way you can save cost, be more effective and cost effective, and also you will have a better position in competition against the other companies then". The company has just recently launched a new project that is focused on data analytics. First, they are about to collect and store huge amounts of data. Later on, they will use it to generate

different reports that support decision making and improve operations. At some point in the future, they might start sharing relevant information from it to other companies. But for now, focus is on internal data sharing.

One of the current trends making major impact on Company Y is the expansion of e-commerce. Now the main focus of the company's operations' is on business-to-business (B2B) deliveries between factories. Interviewee Y expects that this focus will be shifted towards business-to-customer (B2C) deliveries related to e-commerce in the future. A major difference here is that business customers can receive shipments throughout working hours, while with individuals the scheduling of the shipments will be more important. They might have specific requirements about timing, and it is important to inform them before a shipment is about to arrive to ensure successful delivery. With these kinds of shipments, the sharing of shipment data will become much more significant. Even though adverse trends are also recognized. Due to Covid19 pandemic's impact, more manufacturing activity is returning to Europe from Asia, which increases the B2B sector's volumes. Another major trend is the growing importance of last-mile deliveries (LMD). Effectivity requisites related to LMDs "puts a lot of pressure on IT-system and for data". The current data analytics project is a tool Company Y uses to respond to the above listed challenges. Interviewee Y perceives anyhow that the IT-development and the related technical skills represent a difficulty for his company. Furthermore, in his opinion it is also crucial to build a reliable partner network outside their core operational region: "if you like to improve your business and expand, the ways to do it that you find very good partners to do it".

Numerous areas have been identified throughout the interview, where digital technologies (blockchain included) might bring improvements. Even if Company Y has successfully built a reliable partner network, they are often struggling with the flow of information within their network. Company Y has EDI-integration with only a small number of partners, mainly telephone and e-mail are used for information exchanging purposes. It is time-consuming, often reminders are needed to obtain the necessary information, and information might also be missing due to human error. Automation has not yet been utilized either in the warehouse for sorting or in routine administrative office activities. In fact, with the help of artificial intelligence the shipments' sorting for optimal deliveries will be improved: "Now we have people who are playing cards. That is something that we will do in the future, but not now". Another field where digitalization could bring benefits is abandoning paper-based shipment documentation. As Interviewee Y has also stated: "my target is that someday we can use only electrical waybills…because that this really waste of environment and waste of time, and it is not clever because you can really easily handle ship-

ments without any paper." Another interesting initiative has also been discussed in the interview. Interviewee Y has mentioned a platform from Poland (Timocom), where truckers share information about not-full load shipments, and aim to consolidate those between each other. If there are two smaller shipments for the same route, those can be carried by only one truck, which is beneficial for both parties. It contributes to better utilization of resources and elimination of (partially) empty runs. Such a model has also been tried in Finland, but it did not prove to be successful. Small truckers have rather seen a threat in it to their businesses. Revealing such information on shipments to competitors bears the risk that their customers are contacted directly by other companies next time and they lose orders. However, as Interviewee Y highlighted "this is not an issue for bigger companies, because they have a lot of shipments, they do not have time or interest, or they will play different rules".

Possible obstacles to blockchain technology's implementation have also been discussed. Company Y is also facing such issues as there is not yet any operational blockchain application in their field of activities that they might consider using. Broad adoption in this sector would also be a prerequisite of successful blockchain adoption. In fact, Company Y reported that they are satisfied with EDI-integration that they are using. According to Interviewee Y's perception building the EDI-connection is "complicated", but once it is up and running, "it is not so complicated" anymore. The fact, that the company and the CEO is not "digital native" could also hinder the adoption of blockchain technology. Compared to Company X, Company Y misses a clear business case for blockchain technology's implementation. Interviewee Y has not mentioned any trust issues with their partners. Actually, it is rather the other way around: "Luckily, we have found partners who are trustable". Even though he has experienced that some foreign partners have difficulties in trusting them due to cultural reasons. Interviewee Y has accepted the idea of coopetition with no negative feelings either. He has shared the Timocom freight exchange system from Poland, as a positive example for that.

Based on the current challenges of Company Y and obstacles to blockchain implementation introduced in the previous paragraphs, the following use cases for blockchain technology were considered for Company Y. There are various possibilities for sharing data that the company collects and processes through its data analytics tool: location data for last-mile deliveries, working hours of the drivers to the concerned authorities, different reports requested by its customers on CO2-footprint or on keeping to timetable-promise. Blockchain might provide benefits with the optimalization of routing and loads, if additional information would we added from other parties as well to enhance decision making. The reduction of manual work and paper-heavy documentation could also be supported by

blockchain technology: smart contracts have the capability of replacing routine administrative tasks and digitalized documents can be handled on the blockchain between partners. Trust with foreign partners could be improved by blockchain based tools. Furthermore, the exchange of shipment information with domestic and foreign business partners could happen securely and fast through a blockchain platform, if such a tool is made available in this sector.

4.2.2 Blockchain implementation decision tree applied to Company Y

There is not such a clear business case for Company Y as it existed for Company X. Consequently, the toolkit for determining blockchain's suitability for use cases was utilized in a slightly different way for this company. It was examined question by question if any of the above identified use cases is making through the decision tree or not. (Capital letters are indicating the different questions of the decision tree available from table 6.) A: The elimination of intermediaries is a crucial point when considering blockchain implementations. In most of the cases Company Y is in direct contact with its end customers, there are no intermediaries concerned. Company Y delivers shipments that are part of other companies' supply chains – in this case Company Y itself might be considered an intermediary, which forwards information for example on the location of a shipment to the next party in the supply chain. In these cases, Company Y could contribute to a blockchain of some other company, rather than just passing the information ahead. But it is then the other company's interest to set up a blockchain. It is indifferent for Company Y, where it submits the requested information. Same applies to the different reporting obligations. If there is no intermediary concerned, some other solution than blockchain can better do the job. As it has already been said in relation to the optimalization of routing and load, gaining benefits from blockchain requires that other parties' information also contributes to the decision-making process. The reduction of manual work and paper-heavy documentation and data exchange with business partners can also only happen through blockchain efficiently if there is a platform used by other parties as well and intermediaries need to be eliminated. Otherwise, other tools might serve this purpose better. B and C: In order to Company Y can join any blockchain application it has to carry on with digitalizing its physical assets and creating permanent digital records of them. D does not apply to Company Y. Questions E-K can be considered when a blockchain tool is available to use.

In accordance with what the CEO of Company Y has said at the end of the interview - "at least it's good to know something about it, so then in the future learn more" – this report assessed that Company Y could wait to see if a blockchain application suitable for its profile becomes available in the future. At that point it can consider further the questions of

the decision tree for blockchain implementation again, whether any of the possible use cases makes through it or not. With the currently available information it could not be decided yet.

4.3 Company Z: cautiously looking for the interest to participate

Company Z is the Finnish branch of a globally operating freight forwarder. It is one of the biggest ones in the market worldwide, thus it could be in a position to lead the blockchain implementation in the transportation industry.

4.3.1 Interview with Company Z

Interviewee Z is the Head of Airfreight at Company Z. According to his self-assessment, he has a certain knowledge about blockchain technology, but he is “a bit of lacking the concrete openings of it”. Seemed that he takes a broader approach by referring to rather distributed ledger technologies, of which blockchain is one option. In the focus of Company Z’s new digitalization strategy is “…integrating with various parties and sharing the data”, which might be a strong use case for blockchain technology. But the tools considered for that are EDI and more increasingly API (“a lighter connection, like plug-in version to the different kinds of software”). Even though the parent company at the headquarters examines blockchain technology’s suitability to Company Z’s needs. Blockchain technology is used to some extent already in various countries, but not in Finland. One of the applications is smart invoicing, and the further potential of smart contracts is being validated by the same start-up initiative. As a great example for integration and data sharing Interviewee Z introduced the cargo community from Amsterdam airport (Amsterdam’s Smart Cargo Mainport Programme, SCMP). It was not specified what is the technology behind this initiative, but it connects airlines, freight forwarders and even customs office to enhance the cargo flow through the airport. He has shared that even a similar idea has been raised for Helsinki airport too. By integrating players and benefiting from the efficiencies of such a common platform, the attractiveness of Helsinki airport could be increased, declaring it the fastest cargo entry point to the European Union for example.

The challenges of Company Z are mostly related to digitalization issues. According to Interviewee Z’s assessment, Company Z has been somewhat behind its competitors in terms of digitalization. Currently it receives special attention at the company, to improve in that field. One of the major steps ahead has be the introduction of a new ERP system. Another crucial topic for Company Z is how to make it the easiest possible for its customers to make bookings to them. Even though some prefer using IT-platforms, still the majority

of the customers favours using e-mail and phone for doing business with Company Z. As customer service is at the focus for the company, these traditional ways of interaction cannot be ignored and need to be sustained. Company Z also struggles with building up the integrations with its customers, which engage in closer collaboration with them. As Interviewee Z pointed out: “I see more like a problem that it's not made easy enough to plug in the data change in the various software that parties are using… it takes such a long time that we get that working and that frustrates me”.

Obstacles to blockchain’s implementation has been observed from various angles. Despite the slow speed of setting up connections, Interviewee Z is satisfied with EDI/API solutions Company Z is using with some of its customers and subcontractors. He perceives no security risk that would require the further security features blockchain can add to those connections. Even though unlike the other two interviewees, Interviewee Z sees a prevalent risk in coopetition. In relation to the Helsinki airport cargo community, he has numerous concerns: “who would run that? I mean if that's an individual company it's always in favour of somebody… so there's a conflict of interest and therefore I see that it can be only the government, who's neutral… authorities to get this conflict of interest away.” Furthermore, in his opinion there need to be a strong incentive, so that companies participate: “the company needs to gain something by sharing”. Interviewee Z identifies an additional risk, which is not coming from its direct competitors, but from the airlines. There is an increasing interest from both the sides of companies and airlines to connect directly, bypassing freight forwarders. That might be a real risk to the operating model of freight forwarders in a world, where trade is happening freely and there are no obstacles to that. However, Interviewee Z in the current political environment rather sees “more isolating than combining…in that kind of world where it’s coming more and more complex, every company needs a forwarder who actually filters that pain of the world to the customer”. Notwithstanding the above, airlines might still be willing to integrate directly with the biggest customers, for the most popular destinations. However, airlines would not be able to eliminate freight forwarders from the process. Big customers will always have shipments to difficultly reachable destinations and the number of frequent shippers is very limited. Company Z has approximately 2000-2500 airfreight customers, of which only 40-50 are shipping on a regular basis. There is no point in building up an integration with each and every of them, only with the ones that are shipping frequently and in big volumes. It has also been discussed in the interview, if Company Z could use its market power to be the company that sets up the blockchain platform for the market. In fact, according to the opinion of Interviewee Z, Company Z’s market share of 25% is not sufficient to take through such changes. As it has earlier been discussed, majority of the customers favours phone and e-mail to technology solutions. Interviewee Z predicts, in case those options

are no longer available for making bookings, those customers would just choose competitor companies. When supposing major market share for Company Z, Interviewee Z was doubtful if their competitors would then join. If Company Z sets up the rules of the common platform, according to its own taste, why would its competitors be willing to be part of it and pay for it?

Defining use cases for Company Z was challenging in the sense that principal company tools to be used are decided at the headquarters. Even though Company Z has some power in deciding on integrations and data sharing conditions, as the parent company counts on the business strategies of the local branches. Consequently, Company Z's integrations with its customers and subcontractors could be examined, if a blockchain platform can make those connections easier and smoother. Even though Interviewee Z has not identified any risk from the field of data security in general, he mentioned that one of the major subcontractors is having visibility over the complete ERP of Company Z. It poses a risk to the company in the sense that the subcontractor in question is providing its services to Company Z's competitors as well. If it wants to, it could share sensitive business data (prices, volumes etc) to Company Z's competitors. One of blockchain's features is that it can be set through credentials, who is having access to what. Such an attribute would help in addressing this data security concern. Smart contract use-cases being validated by the headquarters definitely provides a further potential for such a giant concern. The elimination of freight forwarders (as intermediaries in international shipping) does not seem realistic in an increasingly protectionist global trade scene. The Helsinki airport cargo community would certainly be a use case to be examined further if the coopetition paradox can be eased.

4.3.2 Blockchain implementation decision tree applied to Company Z

Company Z does either not have a clear business case for blockchain implementation, as Company Y did not have too. Consequently, the toolkit for determining blockchain's suitability for use cases was utilized in the same manner, as for Company Y. It was examined question by question if any of the above identified use cases is making through the decision tree or not. (Capital letters are indicating the different questions of the decision tree available from table 6.) A: The elimination of intermediaries is a crucial point when considering blockchain implementations. In the case of integrations with customers and subcontractors, there are no intermediaries to be eliminated. Obviously, some other solution than blockchain is sufficient. The Helsinki airport cargo community was another promising option for blockchain if a neutral actor can build a solution for that. It might be out of the

scope of Company Z, and further information should be collected on the initiative. Anyway, the idea offers good opportunities for data sharing and most probably intermediaries can also be eliminated through it. B and C: Permanent digital records of the physical assets need to be created by the participating actors. D and E: millisecond transactions are not necessary in this industry and the storage of large amounts of non-transactional data is not required either. F: Several authorities are concerned with air export and imports, consequently the involvement of such authorities is essential in this case. G-H-I: Most probably the participating actors would be in contractual relationships, many of them would require writing access, and their interests would not be well-aligned – just as the issue of the coopetition paradox has highlighted. The outcome is a strong case for blockchain. J-K: these questions can be answered through further research focused on this airport cargo community to determine the suitable form of blockchain for this use case.

Company Z is certainly open to new technology solutions. As Interviewee Z has also pointed out in the interview: “We don't want to hinder any technology development, we just want to be part of it.” They are definitely embracing the idea of integrating with business partners however, they are cautious about the details of the implementations and blockchain is not necessarily the solution for them. The words of Interviewee Z are affirming this approach: “We would like to have more and more EDI bookings, we would like to connect more and more to the airlines, to truckers. Nobody wants to manually upload data and then we're coming to the discussion that if somebody is having the data, how that this should be shared?”

4.4 General overview of the cases

As an overall assessment it can be said that the interviews reflected what was earlier found in the literature review. Due to the fact that the three cases were so different in many aspects, a wide scope of topics and issues has been raised throughout the discussions with the interviewees. Even though the small number and the dissimilarity of the cases did not make it possible to generalize, certain conclusions could still be drawn.

The low level of trust between business partners has been emphasized a lot throughout the literature review, underlining the use cases for blockchain, by being the source of trust in those instances. Also, the issue of false data received from partners has been frequently mentioned. Actually, none of the interviewees have reported trust issues within their partner network. It might even be a cultural aspect, as Interviewee Y has shared his experience: “we are used to trust to each other in Finland, and we are ready to trust also

foreign people. But … they are not trusting us as much as we are trusting them. That the culture is totally different."

The case companies' approach to EDI was also significantly different to the one suggested by the literature review. The latter introduced it as something old-fashioned, difficult and more and more abandoned by companies. The research part of this thesis found that all companies were satisfied with their EDI solutions. They have reported difficulties related to the set-up of such solutions, but there was no intent about replacing those solutions or enhancing them when once up and running.

The concept of coopetition has been talked through with all the case companies as well. Unlike in theory, only one of the three case companies was concerned about the topic. Interestingly, it was the local branch of the global concern, which might even have the possibility to form a blockchain solution for the industry. Seemingly, this potential made it cautious, as most probably its competitors have the same potential and intent of shaping such a platform to their own taste. As it has been discussed in the literature as well, issues around governance were the most critical for them. The smaller companies were trustful about cooperating with their competitors, if certain security rules are respected. None of those companies have the power to influence the blockchains to their favour, thus they had no concerns about it regarding their competitors either.

The literature has also highlighted that markets have become turbulent and volatile recently, which is a major challenge to companies nowadays. Surprisingly, the case companies were not confirming it at all. They have rather described stable business environments, where they can operate undisturbedly.

What was absolutely common about all three companies that none of them engaged in developing a blockchain itself. Each of them expects bigger, other, neutral, public actors to do that job. Instead of eliminating intermediaries, they rather expect them to create and run this platform. This is somewhat against the initial conception of blockchain, but actually in the majority of the use cases considered for these companies, the involvement of authorities was inevitable for compliance reasons. Further similar points from the interviews are listed in table 7 below.

Table 7. Common points raised by all the interviewees

Themes	Codes
Trends and challenges in 21st century supply chains	Outsourcing
	More demanding customers
	Digitalization
	Manage available data and benefit from it
	Share data efficiently between companies
Advantages of blockchain technology	Creates trust
Supply chain application fields of blockchain technology	Track shipments on item level
	Digitalized (shipping) documents, reduced paperwork
Benefits of blockchain technology in supply chains	-
Improvements and benefits to the logistics industry	-
Limitations related to blockchain technology	Traditional databases are sufficient
	No single platform emerged so far
	Low adoption rate
	Benefits require broad adoption
Challenges related to the implementation of blockchain technology in supply chains	-

All of them are benefitting from the fact that other companies are outsourcing transportation tasks to them, and similarly all of them are using own subcontractors to execute some tasks not making part of their core activities. Digitalization is amongst the most current issues they are focusing to and managing their data the right way is also crucial to them. Tracking shipments and the handling paperwork digitally were the common blockchain use cases that all companies might consider. Obstacles to blockchain implementation were also commonly shared: they are satisfied with their current solutions, and as long as there is not a widely used single platform that they can start using, they have no incentive to change their operations.

Another common point was that practical issues about blockchain implementation were not considered by any of the companies yet: such as financial aspects (costs and possible savings), lack of standards, issues of interoperability. Reason to that might be that actual implementation is not considered in the near future. Also, a huge number of possible benefits were not taken into account by the case companies. Reason to that can be that companies are not yet aware of the full capabilities of blockchain technology, and the approximately 60 minutes long interviews could not provide enough depth to the topic to reveal all those benefits. Table 8 below displays the complete list of those aspects from the literature review that were not discussed in either of the interviews.

Table 8. Points not raised in either of the interviews

Themes	Codes
Trends and challenges in 21st century supply chains	Maintain short cycle times
	Higher level of risk
	Increased competition
	Keep costs at a low level
	Fast changing, turbulent markets
	Volatility in supply and demand
	Unforeseeable events
	Shortening product lifecycles
	Mass customization
Advantages of blockchain technology	Visibility over data
	Minimize risk of failure
	Eliminate the need for intermediary
	Reduce complexity
	Reduce cost
Supply chain application fields of blockchain technology	Supply chain finance
Benefits of blockchain technology in supply chains	Shortened supply chains
	Transparent supply chains
	Information symmetry
	Reduction of delays and lost products
	Less disputes
	Reduced corruption and tax evasion
	Less fragmented supply chains
	More resilient supply chains
Improvements and benefits blockchain is about to bring to the logistics industry	Automated container handover
	Full visibility to shipments' documentation
	Reduce processing times
	Reduce cost of intermediaries
	Smoother carrier onboarding
	Smoother driver authentication
	Smart pallets
	Dynamic price adjustment
	Reduction of losses
Limitations related to blockchain technology	Only a few successful applications
	Common standard are missing
	Switching costs
	Data-processing constraints
	Environmental concerns
Challenges related to the implementation of blockchain technology in supply chains	ROI (return on investment) unclear
	Creation of information silos
	Increasing supply chain complexity
	International implementation is challenging
	Require infrastructure and computing capabilities
	Cybersecurity

What made these interviews very different was not the size of the companies, rather the fact that they are at very different stages of embracing technology. It was determining their approach to blockchain technology the most. An overall impression about all of the interviews were that case companies in their real business settings are perceiving much more the limitations and obstacles, than it is expressed in the literature. The latter is characterized mostly by enthusiasm and optimism.

5 Conclusions

This final chapter summarizes the key findings of the report, highlights the recommendations to the case companies and discusses about the reliability, relevance and limitations of the research. Furthermore, suggestions for further research are given. The chapter is concluded by the author's reflections on her own learning process.

5.1 Key findings

This thesis aimed to investigate what opportunities the application of blockchain technology brings to international supply chains and especially to transportation industry. Through review of latest theory, the study explored the potential blockchain technology has in international supply chains. Three different business cases from the transportation industry have been used to test theory against real business settings. The research has found that the cases in general reflected what was discussed in the literature regarding the challenges transportation companies are facing and their responses to those. Especially the collection, management and sharing of data received particular attention from all three companies. However, some differences have also been identified. The case companies have not reported major trust issues from within their partner networks, which was otherwise a prevalent issue in supply chains according to literature. Cultural reasons might have led to such differences. Case companies were also satisfied with their EDI solutions, even though literature suggests that common difficulties related to EDI are pushing companies towards blockchain-based solutions. Literature emphasized the issue of coopetition as well. However, only one of the three case companies was concerned about cooperating with its competitors on a common platform.

Based on the literature review the following blockchain-enabled use cases have been identified as best matches for the transportation industry: the digitalization of the paperwork, the automation of container handovers and payments, and more comprehensive tracking. The use cases identified for the case companies ranged from tracing product components, tracking the location and attributes of the goods, reporting to authorities in relation to compliance requirements, digitizing paperwork, or sharing shipment related data within the partner network to enhance the flow of goods. The validity of those use cases was verified through a decision tree released by the World Economic Forum for determining the suitability of blockchain technology for a case. As none of the case companies has yet started implementing blockchain based solutions, obstacles related to that have been also identified. Commonly, all three case companies were expecting other parties to set up a platform they can start using at some point.

Compared to the literature, real business cases have emphasized rather the limitations and obstacles of blockchain implementations in the transportation industry than the benefits of it. The general optimism and enthusiasm of researchers was not confirmed by the case company examples investigated by this thesis.

5.2 Recommendations

As result of the evaluation, the following re-commendations were given to the case companies. Company X is dependent from other actors in terms of blockchain implementation: authorities need to be involved due to compliance requirements, or its clients are in the position of developing a blockchain solution and determining what sort of blockchain (public or private) will be used. Thus, research has confirmed that the waiting position of Company X is serving the interest of the company the best. However, its blockchain use cases are very strong and worth keeping at sight: tracing down fuel components, reporting to authorities on the origin and on the location of their products.

This report assessed that Company Y could also wait to see if a blockchain application suitable for its profile becomes available in the future. At that point it can consider again the questions of the decision tree for blockchain implementation, whether any of the possible use cases makes through it or not. Company Y's blockchain use cases were not that strong (there were no intermediaries to be eliminated), some other solution might prove to be more suitable for them.

Similar outcome has been reached in the case of Company Z as well. Taken into consideration its challenges related to business integrations, blockchain is not necessarily the best solution for them. New blockchain-based solutions might become available in their field of operations (airport cargo community), which can prove to be a strong case for blockchain implementation. However, Company Z is not in a position of developing this solution itself, it is also dependent from other actors.

5.3 Reliability, relevance and limitations

This research studied three relatively different case companies located in Finland. The number of the cases was very limited. The fact that all of them were from the same cultural environment definitely affected the interviewees' attitudes to some of the topics and has not given a valid picture of international supply chains in general. Case companies were relatively different compared to each other, which made generalizations even more

unfounded. These circumstances were emphasized when some cautious general conclusions were drawn. However, the variety of the cases made it possible to cover a relatively wide scope of topics from the literature by real life examples as well.

Due to the anonymity of the interviewees, they could openly speak about their opinions and attitudes. It certainly bore an added value to the report and contributed to the reliability of the collected data. All interviewees were rated in the beginning of the interviews based on their knowledge of blockchain technology. This step helped with judging how comprehensive understanding that interviewee had about the thesis topic, and how his responses could be interpreted.

This report investigated a relatively new and current topic, which has not yet been researched thoroughly. Consequently, in spite of the limitations of it, this thesis provided relevant addition to the existing knowledge base. It revealed some companies' real attitudes towards the topic. Furthermore, it confirmed most of the common findings of other resources and challenged some of the arguments stated in other reports.

5.4 Suggestions for further research

The above introduced limitations imply that the business and the geographical scope of this study could be broadened. That way by gaining additional data, generalization of the findings will be possible and more accurate. On the other hand, the scope of the research could also be focused down to more specific subtopics, such as the benefits of blockchain in relation to customs clearance processes or examining more in detail the oil industry or the case of the Helsinki airport cargo community and its match with blockchain technology. Even the vast potential of smart contracts has not been discussed in the interviews, due to the lack of time. Further discussions with the case companies could provide enough depth to be able to evaluate use cases related to that as well.

5.5 Reflection on learning

The preparation of this thesis report has provided plenty of value to the author. She gained knowledge on the different trends and technologies shaping the present and the future of international supply chains. She has also achieved a deeper understanding about how companies approach challenges in general and new technologies in particular. She has gained insight to the different considerations companies need to take, when deciding on changes to their operations, and making major investments towards some target. It was a pleasure and honour to speak to C-suite leaders about this technology and to

find out their approaches from a strategic level. The author also learned a lot by doing: conducting interviews and writing an academic report in a foreign language.

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Appendices

Appendix 1. Interview framework

Theme	Investigative Questions (IQs)	Interview Questions
Background		Please tell me/introduce briefly about your company You are CEO/Head of AFR/CIO…please tell me about your career at the company.
Warm-up: Blockchain		On a scale 1 to 5, how would you assess yourself: are you familiar with BC tech? What is your company's approach/attitude towards BC? Do you have questions regarding ppt material? All clear?
Challenges Challenges of 21st century SCs Challenges BC can help with	IQ 1: What are the major challenges Company X is facing?	What are the most instant-burning-current challenges shaping your company's present and future? What is the most time-consuming/costly process you have? Is there any field you want to see improvement? Where? What kind of plans do you have for future development of the company? What other companies in your industry are struggling with? How does your company relate to those challenges - is it a challenge for you also? Why not? What will make the biggest impact on the future of your company/industry?
Responses to own challenges to current SC-issues	IQ 2: What tools Company X is currently using to address these challenges?	How do you respond to/tackle your current challenges? Are you satisfied with your company's current answers/tools/solutions? Why? Why not? How do you cope with the common challenges of your industry? How do you prepare for the unforeseen?
Improvement fit of BC-benefits with company needs	IQ 3: How could Company X's operations be improved by the usage of blockchain technology?	Do you need to share data with other parties? (Do you use EDI? Else? Satisfied?) How would you evaluate information flow within your org and partner network? Satisfied? Why? Do you have good-quality data on your shipments to support your decision making? Do you have issues with data quality, security, false, faulty, missing data? What issues? Why not? Do you track your shipments? What tool you use for that? Satisfied? Why? Why not? Do you have complete transparency/visibility over your activities? Would it help you succeed? How do you handle and hand over documentation? Any digital? Satisfied? Why? Why not? Do you have time consuming repetitive processes involving other parties (to be automated)? Do you rely on any third party intermediary (authorities, mediators between you & cust/partner)? Do you have trust-issues with partners?
Obstacles fit of BC-pitfalls/disadvantages with company constraints	IQ 4: What obstacles would hinder Company X from introducing a blockchain based solution?	Do you have financial resources for new technology? What is your company's relationship with digitalization like? To what extent you embrace tech? Is any partner from your network uses BC? How do you feel about cooperating in the same platform with your competitors?
Recommendations	IQ 5: What recommendations can be given to Company X regarding block-chain implementation?	Do you have any expectation towards my report? Do you have any question you would like that I find an answer to regarding BC?
Cool off		(Has this discussion changed your view of BC in any sense?)
		Would you add anything else to the discussion?
		Do you have any questions?

Appendix 2. List of codes for data analysis

Investigative questions	Themes	Codes	Company X fuel supplying company	Company Y express road carrier	Company Z global freight forwarder
IQ 1: What are the major challenges Company X/YZ is facing? IQ 2: What tools Company X/Y/Z is currently using to address these challenges?	Trends and challenges in 21st century supply chains	Globalization			
		Outsourcing	x	x	x
		Longer and more complex supply chains	x		
		Maintain short cycle times			
		Higher level of risk			
		Increased competition			
		Keep costs at a low level			
		Fast changing, turbulent markets			
		Volatility in supply and demand			
		Unforeseeable events			
		More demanding customers	x	x	x
		Shortening product lifecycles			
		Mass customization			
		E-commerce		x	
		Move materials fast		x	
		Add flexibility to systems		x	
		Prove product integrity	x		
		Provide information on provenance	x		
		Comply with environmental standards	x		
		Digitalization	x	x	x
		Manage available data and benefit from it	x	x	x
		Share data efficiently between companies	x	x	x
		Data security		x	x
		Need for rightly skilled employees	x		
	Additional aspects from the interviews	Last-mile deliveries		x	
		IT-integration with business partners		x	x
		Automation of processes	x	x	
IQ 3: How could Company X/Y/Z's operations be improved by the usage of blockchain technology?	Advantages of blockchain technology	Secure	x		
		Immutable	x		
		Transparent	x		
		Visibility over data			
		Tamper-proof, prevents fraud	x		
		Minimize risk of failure			
		Authentic, accountable, credible data	x		
		Creates trust	x	x	x
		Eliminate the need for intermediary			
		Automation (smart contracts)	x		x
		Efficiency		x	
		Reduce complexity			
		Reduce cost			
	Supply chain application fields of blockchain technology	Track shipments on item level	x	x	x
		Trace products end-to-end	x		
		Digitalized (shipping) documents, reduced paperwork	x	x	x
		Smart contract application fields: invoicing, insurances, disputes, payments			x
		Supply chain finance			
	Benefits of blockchain technology in supply chains	Trust facilitates business		x	
		Accelerated flow of goods		x	
		Shortened supply chains			
		Transparent supply chains			
		Information symmetry			
		Reduction of delays and lost products			
		Less disputes			
		Sustainable supply chains	x		
		Product quality and authenticity ensured	x		
		Reduced corruption and tax evasion			
		Less fragmented supply chains			
		More accurate performance metrics		x	
		More resilient supply chains			

Investigative questions	Themes	Codes	Company X fuel supplying company	Company Y express road carrier	Company Z global freight forwarder
IQ 3: How could Company X/Y/Z's operations be improved by the usage of blockchain technology?	Improvements and benefits blockchain is about to bring to the logistics industry	Automated container handover			
		Full visibility to shipments' documentation			
		Resolve communication defficiencies		x	
		Reduce processing times			
		Reduce cost of intermediaries			
		Provide one version of truth	x		
		Smoother carrier onboarding			
		Smoother driver authentication			
		Smart pallets			
		Improved planning of shipments, prevent errors		x	
		Dynamic price adjustment			
		Reduction of losses			
		Support proactive decisions		x	
		Immediate and accurate reporting		x	
		Ensure complete and accurate documents		x	
	Additional aspects from the interviews	Reporting on driving hours		x	
IQ 4: What obstacles would hinder Company X/Y/Z from introducing a blockchain based solution?	Limitations related to blockchain technology	Traditional databases are sufficient	x	x	x
		No single platform emerged so far	x	x	x
		Only a few successful applications			
		Low adoption rate	x	x	x
		Risky/is it only hype?	x		
		Management has limited knowledge about it		x	
		Lack of talented staff	x		
		Common standard are missing			
		Integration with current systems			x
		Switching costs			
		Data-processing constraints			
		Concerns that input data is not tampered with	x		
		Data security			x
		Privacy			x
		Coopetition paradox			x
		Benefits require broad adoption	x	x	x
		Environmental concerns			
	Challenges related to the implementation of blockchain technology in supply chains	ROI (return on investment) unclear			
		Clear business case is missing		x	x
		Lack of skilled workforce	x		
		Creation of information silos			
		Increasing supply chain complexity			
		International implementation is challenging			
		Interoperability issues			x
		Require infrastructure and computing capabilities			
		Cybersecurity			
	Additional aspects from the interviews	Need for an explicit interest to join			x

Appendix 3. List of tables

Appendix 4. List of figures