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Bachelor Thesis

Blockchain Technology in Supply Chain and Logistics

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"100 % of transport organisations will adopt blockchain in some guise, either public or private"

Richard Nash,

Intelligent Transport Global Industry Expert, IBM

Abstract

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Content:

With the introduction of the "Bitcoin" back in 2008, the underlying concept of it the so-called blockchain holds the potential to reshape the conventional concept of data transfer especially the hereby involved trust between the parties (Nakamoto, 2008 p. 2). Assumed to be the "next big thing" referring to the internet hype in the 90s and early 2000s the blockchain approach provides numerous adoption possibilities other than only creating cryptocurrencies (Cf. Hernandez, 2017 p. 2; Blockchain in Logistics, 2018 pp. 8-12; Morabito, 2017 pp. 28-34). As a relatively new technology from the IT sector, this technology redefines the conventional flow of information in a highly transparent and decentralised way; broadly speaking, with the method of storing "linked lists" (Cf. Swan, 2015 pp. x-xi; Morabito, 2017 p. 71; Chandrasekhar, 2016).

The blockchain technology shares information transparently visible to all involved parties in an immutable way since each piece of stored information is secured with a mathematical algorithm and is therefore almost impossible to be manipulated without getting detected (Cf. Medium.com, 2018 b; Blockgeeks.com, 2018 a). Although the blockchain initially was primarily considered to have tremendous impacts on the financial sector in which trust plays a crucial role, today it is deemed to provide many innovative opportunities for several business sectors besides the financial one (Blockgeeks.com, 2018 a). Particularly when it comes to transferring confidential data between several parties as it is the case in the logistics sector which lacks in an efficient and secure flow of information concept since data is often re-entered in different systems of the involved parties (Cf. Prümm and Kauschke, 2017; Blockchain in Logistics, 2018 pp.12-13).

Regarding the supply chain and logistics, the blockchain technology is currently still in the development phase and lacks coherent studies and widely utilised applications. Hence, the potential is yet to be identified in order to make the technology widely known and implemented among the globalised supply chain (Cf. Prümm and Kauschke, 2017; Petersen and Hackius, 2018 p. 1). However, there is progress as more and more companies in the logistics sector are becoming aware of the innovative potential of the blockchain and are already developing blockchain-based applications, e.g. the shipping giant Maersk collaborates with IBM to develop a blockchain based application in order to optimise supply chain processes (Maersk.com, 2018). Especially the start-up scene is curious about this technology as many businesses are currently working on potential blockchain-based applications, as it is the case for the company "CargoX" which plans to revolutionise the transfer of the Bill of Lading by implementing "Smart Contracts" (Cargox.io, 2018).

Hence, this thesis aims to reflect the current state of research around the blockchain technology in the logistics sector and supply chain. To this end, the general state of development on the topic of the blockchain technology will be systematically examined. Subsequently, various blockchain-based concepts, especially for the exchange of valuable information in the logistics sector and the supply chain, are to be critically analysed and compared with already existing approaches. Finally, based on the analysis, the potential benefits, as well as the limitations and challenges of the blockchain impact on the logistics industry, are to be examined and constructively discussed.

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List of Abbreviations

BL	Bill of Lading
DAO	Decentralised Autonomous Organisation
DDBMS	Distributed Database Management System
DLT	Distributed Ledger Technology
DSC	Digital Supply Chain
EDIFACT	Electronic Data Interchange for Administration, Trade and Commerce
FF	Freight Forwarder
GDP	Gross Domestic Product
IMO	International Maritime Organization
IoT	Internet of Things
PDF	Portable Document Format
PoA	Proof of Authority
PoS	Proof of Stake
PoW	Proof of Work
SHA 256	Secured Hash Algorithm 256
SMS	Short Message Service
SWOT	Strength Weakness Opportunity Threat
USD	United States Dollar
VGM	Verified Gross Mass

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1 Introduction

The purpose of the first chapter is to introduce the reader to the thesis and to provide a first impression of the structure. At the beginning of this section a short overview of the blockchain technology and why it is relevant to the logistics sector will be given. This is followed by emphasising the problem statement, the purpose and objective as well as the scope and limitation of the thesis. The chapter concludes with the overall structure of the thesis.

1.1 Motivation

Within the last years, the term digitalisation seems to be omnipresent in the media landscape, justified by the fact that our world is getting even more and more globalised and connected. There are consistently new innovative technologies emerging, such as the current blockchain technology which has sparked an enormous hype around its potential for reshaping the concept of exchanging valuable data (Blockgeeks.com, 2018 a).

Almost ten years after its inception in 2008, the blockchain technology which was initially introduced as a tool for exchanging cryptocurrencies (Bitcoin), is today considered as a cutting-edge technological innovation with countless application possibilities in a plethora of industries (Cf. Blockchain in Logistics, 2018 pp.8-12; Morabito, 2017 pp. 28-34). Just as the internet was introduced as the digital tool for exchanging information, the blockchain technology is considered as the tool which gives this information a substantial value (Blockgeeks.com, 2018 a).

A blockchain is a peer to peer immutable shared ledger which is able to store different kinds of data sets among its network. It stores the data in a distributed environment without the need of involving an intermediary who secures the process. That means that the rules of the blockchain application are not governed by a central authority but instead by the consensus of the whole community (Nakamoto, 2008 p. 8).

Although the technology is still in its development stage and not yet fully recognised as a new approach for exchanging data, the blockchain is considered as a disruptive and sustainable solution for transacting valuable information in an unconventional way (C.R., 2018). For instance, referring to the hype cycle of the IT market research firm Gartner (appendix 2), expectations for blockchain technologies have increased dramatically. In the long run, Gartner expects entire industries to be affected by the blockchain technology (Levy, 2018).

According to CoinDesk, alone in the first three quarters of 2018, about USD 3.9 billion of venture capital has been invested in blockchain start-ups which indicates that the blockchain is a credible innovative technology (Palmer, 2018).

Furthermore, according to Gartner's hype cycle, within the next five to ten years, widespread applications of the blockchain will probably be available in several industries as the financial, pharma and especially in logistics and supply chain processes (Cf. Levy, 2018; Panetta, 2018). The IMO estimates that over 90 % of the world trade is conducted by the transportation via the sea in which the logistics sector plays a crucial role as it organises and manages the process of transporting the respective consignments between two parties, commonly the buyer and the seller (Cf. Business.un.org, n.d.; Manaadiar, 2018).

Discrepancies and errors related to the information exchange among the transportation processes occur frequently. Therefore, the World Economic Forum estimates that by reducing errors in the supply chain caused by inefficient business processes, the globally traded volume has the potential to increase by about 15 % (Lieber, 2017).

The blockchain technology has the potential to provide an appropriate solution to optimise these processes across the logistics sector especially the overall supply chain visibility (How Blockchain Can Reshape Trade Finance, n.d. pp. 1-2).

Moreover, the World Economic Forum estimates that the blockchain technology holds the potential to raise the global GDP by 5 % (Lieber, 2017). However, there are currently no sophisticated studies regarding the blockchain approach in the logistics sector since at the current stage it is not a fully developed technology. Further, adopting new technologies in the logistics sector can be very time intensive and costly due to the numerous involved interests. Therefore, implementing as well as maintaining a new technology within a complex business sector as it is the case in logistics industry can be very challenging (Morley, 2017).

Thus, this thesis not only aims to provide an overview of the blockchain technology and possible applications, but also puts emphasis on the challenges the technology will probably face in the future.

1.2 Problem Statement and Research Questions

Several parties are involved when it comes to the transportation of a consignment, including the shipper, carrier and freight forwarder to name a few. The logistics industry comprises a complex process involving many IT systems, thousands of different transactions and business rules which can differ enormously from country to country.

Additionally, most of the involved actors in the logistics industry are utilising their own inter-firm information tracking systems which are often outdated and involve most of the time inefficient manual processes conducted by the employees. This unnecessarily results in re-entries; hence frequent errors are common which result in higher costs for all parties involved in the transportation processes. Furthermore, the lack of coordination and collaboration among the participants results in higher complexity and therefore increases the workload (Cf. Lehmacher, 2017; Jensen, Bjorn-Andersen and Vatrapu, 2014 pp. 7-10).

As the logistics sector engages numerous processes which involve the exchange of different data updated by multiple parties in the respective inter-firm tracking systems, a blockchain as a single information source has the potential to reduce the complexity and therefore increase the efficiency of supply chain processes. The technology enables real-time updates and quicker processing time for exchanging vital documents within the community. Moreover, the blockchain automates tasks and diminishes the need for manual data entries which leads to higher accuracy and enormous time savings (Cf. Marr, 2018; Columbus, 2019).

The central problem statement can be split as follows into two sub-questions:

1. What is the blockchain technology, how does it work and what are the potential key advantages of adopting it into logistical processes?

The first question addresses what the blockchain technology is and how it works which is examined in the literature review and the analysis of the specific characteristics of the technology.

After examining the concept of the blockchain technology with all its characteristics, the first research question also includes the examination of the potential benefits of the blockchain technology and why logistics providers should adopt it into their supply chain processes.

2. What are the risks and key challenges facing a potential blockchain adoption and how likely is its integration into the logistics sector?

The second research question is based on the first sub-questions which provide a general understanding of the technology and its potentials. Accordingly, the second sub-question is addressed to analyse the risks and challenges related to a sophisticated adoption of the blockchain technology in the logistics sector.

Furthermore, the overall likelihood of the blockchain adoption will be analysed with a focus on the thereby occurring obstacles. Due to the fact that the blockchain enables every participant to obtain the same immutable copy of the data transmitted through the network, the blockchain approach could therefore also improve trust, transparency and traceability among the actors of the supply chain (Pratap, 2018). Thus, additionally to answering the research questions, the thesis also aims to analyse to what extent the blockchain approach could impact these supply chain properties.

1.3 Research Objective

The objective of this research is to determine the potentials of the blockchain technology on the supply chain and logistics. Moreover, the organisational and technical obstacles that come with the blockchain technology will be analysed and put into relation with the probability of the overall recognition in the logistics sector. Furthermore, different characteristics of the blockchain technology such as the concept of smart contracts will also be examined. Additionally, the thesis aims to identify and analyse the advantages but also the challenges and limitations coming with such an innovative technology.

1.4 Research Scope and Limitations

Although this thesis focuses on the essential technical characteristics of the blockchain technology, it is not a technological paper. Instead, the blockchain technology is studied from an economically relevant perspective hence the technicalities of the blockchain technology are kept to a minimum. In order to delve into the technological characteristics of the blockchain concept, the books “Blockchain: Blueprint for a New Economy” by Melanie Swan (2015) and “Business Innovation Through Blockchain: The B3 Perspective” by Vincenzo Morabito (2017) are recommended as introductory literature.

Moreover, although the blockchain technology also holds the potential to disrupt other industries, this thesis aims at reflecting the logistical aspect. The scope of the research is therefore limited to the economic impact of the blockchain technology and how it could optimise the logistics sector especially the traditional supply chains processes.

Nevertheless, even though the thesis is referring to logistics and supply chains as a whole, the emphasis is rather on adopting possible solutions in the communication processes between supply chain actors. All conclusions and results developed in the thesis, remain on a theoretical basis as the majority of the acquired sources are based on test-approaches or early concepts since the potentials, as well as the challenges of the blockchain technology still require comprehensive real-life applications.

1.5 Thesis Structure

The thesis consists of six main parts which are continuously built on each other. The first chapter provides the introduction of the thesis. More specifically it determines the motivation, problem statement and the objective of the thesis as well as the scope and limitation. The second chapter contains an extensive literature overview and provides definitions of all relevant characteristics of the blockchain technology in order to understand the main features of possible blockchain-based applications.

Continuing with the third chapter in which the methodology of the thesis will be introduced with the particular choice of the research methods utilised to obtain the information for the thesis. This is followed by the fourth chapter which contains the analysing part. In this part, the results of the conducted interviews are to be presented as well as the analysis of different blockchain-based applications for specific supply chain processes.

Subsequently, the fifth chapter contains the assessment of the analysis with the advantages and challenges facing possible blockchain adoption in the logistics sector. In this chapter, the legal aspect of the blockchain application in the context of supply chain and logistics will also be discussed. The final chapter aims at answering the research questions and contains the conclusion of the thesis.

2 Literature Review

The following chapter aims to provide a comprehensive literature overview related to logistics and supply chain as well as to explain what the blockchain technology is and how its characteristics are defined. The first part contains a general overview of the logistics industry and the supply chain in the context of the digitalisation followed by the definition of the key characteristic of the blockchain technology. This chapter ends with a short overview of current blockchain-based approaches in the logistics sector.

2.1 Logistics and Supply Chain

Logistics is considered the lifeblood of the world economy with an estimated 90% of the world trade transported via the international shipping industry every year (Lieber, 2017). The logistics sector in its beginnings up to the current situation developed to a significant economic sector which connects the world. With the invention of the container back in the year 1955 by Malcolm Mclean (Priceandspeed.com.au, n.d.), the international transportation of goods grew more critical than ever before.

However, the supply chains as we know them today are getting even more and more complex and globalised (Cf. Lehmacher, 2017; Jensen, et al. 2014 p. 2). It is quite common that products which are sold in the U.S. have been prior manufactured in Europe and assembled in China.

Business processes are essentially underlying by globalised processes which involve an enormous number of transactions from parties with various backgrounds. Conventional supply chains comprise many geographies, industries and pass through several stages in which information is transferred both downstream and upstream commonly starting with the suppliers, manufacturers, distributors, carriers, retailers and ending with the customers. This process requires that the supply chains operate more efficient than ever before to accommodate the complexity of today's movement of goods. The smooth flow of information is vital for crucial business decisions that potentially impact the costs of a product and the share of the market (Cf. Pereira, 2009 pp. 373-376; Jensen, et al. 2014 pp. 7-10).

The logistics sector is an international industry with several stakeholders involving a supply chain which consists of five essential stages. These phases consist of planning, developing, manufacturing, delivering and returns. The first stage of the supply chain process, planning, is about analysing and focusing on fulfilling customer demands and deciding on a suitable operations strategy. The second stage focuses on creating a development plan for the specific product which also includes, besides the pricing, how to commercialise the product (Cf. Hyatt, 2016; Itinfo.am, n.d.).

The product lifecycle management is the third stage of a supply chain in which the whole lifecycle of a product from its inception to the engineering design and the manufacturing processes is structured and analysed. The fourth phase is concerned with the transportation of the products which typically encompasses several parties who are assigned to customer processing inquiries to select optimal delivery options. The freight forwarder and the carrier are the key parties of the delivery phase since they typically conduct the significant part of the transportation processes. The purpose of the fifth step is to manage all returns associated with defect products which include identifying the condition of the respective products and managing customer feedback (Cf. Buxton, 2017; Bouhaddou, 2018; Hyatt, 2016; Itinfo.am, n.d.).

Additionally, to the flow of the materials which is concerned with the shipment of the physical products from the seller to the buyer, the supply chain comprises two other main flows. One of them is the flow of data in which the documentation of the transfer of the goods is communicated with the respective parties involving the order and shipment information. The third main-flow is the capital flow in which the payment and transfer of the ownership of the respective asset are conducted (Cf. Aluko, 2016; Logistiikanmaailma.fi, n.d.; Rajgopal, 2016 p. 14).

2.2 Issues Related to Conventional Supply Chain Visibility

Although the digital revolution is in full progress, the logistics industry compared to other industries is hardly transforming into the digital age (Weinelt, 2016 p. 4). That has many reasons, one of them being the fact that transporting goods remains a traditional business which is predominantly conducted via manual processes (Opensea.pro, n.d.). According to the interviews with Company XY (see p. 33), it is not unusual that the necessary paperwork and approvals throughout the transportation of, e.g. a container, are so prolonged and time-consuming that the vessel arrives at the discharge port before vital documents like the bill of lading or the verified gross mass (Company XY, personal communication, November 21, 2018).

Moreover, the current supply chains and the inherent underlying information technology systems are no longer able to support the complexity of the supply chains, which have become highly scattered across multiple stakeholders. One fundamental problem of the traditional supply chain is its lack of a timely and complete information transfer between the involved parties which leads to unnecessary expenses and wasted time. The outdated process of data transactions in the logistics industry is significantly inefficient which results in unnecessary complexity and increases the overall transportation costs (Company XY, personal communication, November 21, 2018).

The vast amounts of paper processes incurred in the logistics industry, as well as the fact that the movement of goods is an international business, involves a variety of different cultures, languages, laws, procedural requirements, regulations and organisations. This diversity of international trade further contributes to the lack of a standardised process which is one of the reasons why the logistics sector lags behind other industries when it comes to digitalisation (Cf. Blockchain in Logistics, 2018 p. 4; Ganne, 2018 pp. 17-19; Digital, 2018).

Hence, according to IBM, the processing and administrating costs of the flow of physical documents tend to be disproportionally high and is estimated to cause a staggering one-fifth of the total transportation costs (Haziot, 2018). The complexity of international trade is highlighted by a research project conducted by Maersk and IBM in 2017 in which they collaborated to analyse the process of transporting roses and avocados from east Africa to Europe (IBM, 2017). The research concluded that the shipment involved more than 200 interactions by 30 different organisations. The journey lasted for about 34 days of which ten days were delays caused by waiting for document approvals. That simple example proves that even the most common products are involved in a time-consuming and documentation intensive process (Ganne, 2018 pp. 17-18).

Besides the high costs related to the documentation of goods and additional time added to the shipping process caused by the complexity of the nature of international trade, the supply chain is also vulnerable to fraud (like submitting inaccurate invoices to reduce taxation and customs duties) which is a serious issue especially in developing nations (Yermo and Schröder, 2014 pp. 1-4).

The blockchain technology has the potential to optimise the following three crucial components of a supply chain (Cf. Company XY, personal communication, November 30, 2018; Deloitte 2017 Goldmansachs.com, n.d.).

2.2.1 Trust

Trust is a central pillar of business interactions throughout every step of the supply chain. The success of an organisation depends upon establishing and maintaining trust within the structure of the company. The external partnership of a company is highly dependent on a mutual degree of trust which is the starting point of successfully conducting a business (Company XY, personal communication, November 30, 2018).

Trust between the involved parties within the logistics sector is a precondition for sharing valuable data and assets which is the framework for the success of a longstanding partnership. A third party is usually required to act as the trustee between a buyer and a seller until the deal is completed. It is common that companies are sceptical towards sharing confidential information and details about the deal with other actors of the supply chain. As long as the trust between the parties is not self-evident, a third party as a freight forwarder or a bank is necessary to strengthen the whole business process (Cf. Francisco and Swanson, 2017 p. 5; Uca, Çemberci and Civelek, 2017 pp. 217-221; Notland, 2017).

In fact, though, a third party does not actually remove the trust issues between supply chain actors; instead, it shifts the trust to an additional party which eventually further complicates the logistical processes (Company XY, personal communication, November 30, 2018).

2.2.2 Transparency

Supply chains in today's economy are highly globalised and getting more and more complicated thanks to the numerous involved actors located around the world with different interests regarding the supply chain processes. Before reaching the customer, goods have to go through several shipment processes with an extensive amount of documentation and transactions.

Naturally, customers wish to know where their products come from and how they were produced while other stakeholders of the supply chain want to know what happens throughout the supply chain as they are more or less part of it (Cf. Company XY, personal communication, November 30, 2018; New, 2010; Francisco and Swanson, 2017 pp. 1-2).

However, companies are often struggling when it comes to the transparency of the shipment process, as there is often only limited information available throughout the supply chains (Cf. Francisco and Swanson, 2017 pp. 1-2; Deloitte, 2017). Moreover, there is still little knowledge of when, where and how products have been created.

This is particularly problematic for products like diamonds, drugs, food and fashion as there is a high demand for transparency and knowledge about the origin and/ or production of these products since there are recurring ethical issues involved (Cf. New, 2010; Francisco and Swanson, 2017 pp. 1-2;).

2.2.3 Traceability

As the international transportation of goods involves a network of different interests, which result in an enormous amount of physical paperwork, it becomes increasingly harder to effectively trace relevant data of the respective consignment within the supply chain processes.

Furthermore, the stakeholders of the supply chains are commonly utilising individual company-specific-information-technology systems to track and keep the information flow of the transportation processes, making overall traceability even more complicated (Company XY, personal communication, November 30, 2018). The situation is aggravated by the fact that the low degree of collaboration between the supply chain actors leads to a lack of visibility and traceability which ultimately causes (among other things) unexpected delays of the shipment process, therefore partially increasing the transportation costs (Cf. Ganne, 2018 pp. 28, 77-80; Notland, 2019; Ghosh, 2016).

To put it in a nutshell, the blockchain technology could dramatically optimise the overall supply chain visibility with its critical characteristics of trust, transparency and traceability. This would decrease risks and costs related to supply chain processes (Cf. Company XY, personal communication, November 30, 2018; Ganne, 2018 pp. 106-107; Notland, 2017).

2.3 Logistics 4.0

Obviously, there is an inevitable need for optimising the current predominantly manually-conducted supply chain processes towards a more digitalised and autonomous one in order to take part in the ongoing industrial revolution, the Industry 4.0 (Schrauf and Berttram, 2016 p. 4).

The unstoppable process of the Industry 4.0 is the next step of the technological evolution which started with the first industrial revolution in which automation was introduced thanks to the invention of steam and water power in the 17th century. That was followed by the second industrial revolution which introduced the electrically-operated mass production with the assembly line manufacturing. The advanced use of electronic devices and the invention of the computer with the introduction of information technology triggered the third industrial revolution in the past century. The current and fourth industrial revolution is about adopting innovations such as the internet of things (IoT), big data, robotics and artificial intelligence. Machines are learning to optimise themselves and communicate with each other without the need for manual interferences which also affects the logistics industry on a whole scale (Cf. Schrauf and Berttram, 2016 p. 8; Rojko, 2017 pp.78-82).

The fourth industrial revolution referring to the logistics sector describes the digitalisation and interconnection of production and logistics systems with “things” as machines, facilities, vehicles and so on. The focus lies in digitisation, in which enterprises are seeking to orient themselves to the increasing complexity of customer demands through digital marketing, social media and, of course, the intensive e-commerce sector. Therefore, the vision of Logistics 4.0 which is the analogy to the Industry 4.0 describes a digitalised logistics sector to create an ecosystem in which several digital technologies as the big data, internet of things and blockchain will be implemented to optimise the transportation processes (Cf. Schrauf and Berttram, 2016 pp. 5-12; Rojko, 2017 pp.78-82).

In contemporary times, due to the lack of collaboration, high complexity of supply chains and the increasing customer demands, even the most significant logistics companies are not able to accommodate an end-to-end information integration throughout their supply chains. Therefore, companies have to collaborate to increase the integration under to concept of the “Digital Supply Chain” (DSC) to optimise their processes (Cf. Korpela, Hallikas and Dahlberg, 2017 pp. 3-6; Schrauf and Berttram, 2016 pp. 7- 12).

The DSC sits at the heart of Logistics 4.0 and is considered as an integral component of every stakeholder of a supply chain especially those who manufacture and distribute products in which the transaction of data represents a major aspect of their processes. The key factors driving the transformation of the conventional supply chain into a more digitised one are the new emerging technologies which are affecting the global economy and pushing the logistics companies to adjust their supply chain processes to stay competitive.

In addition, the increasing expectations and demands of customers and business partners require a more reliable and transparent supply chain. Companies in the logistics sector are currently realising the need for more digitalised processes and are already investing heavily in optimising their businesses towards a more digitised supply chain (Cf. Korpela, Hallikas and Dahlberg, 2017 pp. 3-6; Schrauf and Berttram, 2016 p. 7).

Driven by the ongoing Logistics 4.0, recently PwC surveyed more than 2000 logistics companies regarding their stance towards the digitisation of their supply chains. One-third of these companies responded that they are already working on digitising their supply chain processes and 72 % are expecting to create a digital supply chain in the next five years. This survey illustrates that the logistics industry is about to reshape its current partially outdated supply chain processes, justified by the fact that companies are expecting the digitalisation to lead to economic gains in which companies who adopted a digitised supply chain are expecting efficiency gains of 4.1 % a year and a yield of 2.9 % in revenues annually (Schrauf and Berttram, 2016 p. 11).

2.4 Idea Behind the Blockchain Technology

The blockchain technology could be utilised as a crucial feature of a digital supply chain and is currently one of the most discussed technological innovations due to its unique and often as "revolutionary" considered concept. Although the blockchain technology was developed in the 1990s, the first implemented application of the technology is dated back to the whitepaper of the cryptocurrency “Bitcoin” which was introduced by the pseudonym “Satoshi Nakamoto” in 2008 (Cf. Nakamoto, 2008; Narayanan, Bonneau and Felten, 2016 pp. 15-17).

There is no official description of the technology, commonly the blockchain is described as ledger which can be private or public (or a combination of both) and contains data about all transactions made within an agreed upon peer-to-peer network. The most important characteristic of the blockchain is that its database (ledger) can be distributed among all nodes which are basically the participants of the blockchain network. This data structure is distributed throughout several computers (nodes), so if one computer is shot down or gets hacked, there is no single point of failure. Therefore, the blockchain technology highly secures the transfer of the data among its peer-to-peer network. The database of the blockchain is not centrally governed but instead governed by the whole community (Cf. Ganne, 2018 pp. 5-7; Morabito, 2017 pp. 3-8; Goldmansachs.com, n.d.).

Moreover, it consists of a linked list of “blocks” which is secured with cryptography and consistently verified throughout the network. The blockchain is an immutable ledger which means that once a transaction is added to the blockchain, it cannot be altered. The main components of a transaction within the blockchain are the sender, the transaction and the receiver. Furthermore, each transaction contains a time-stamp which is also shared with all participants of the blockchain network.

To guarantee the secured network of the blockchain and to prove the validity of the transactions, processes in the blockchain involve on the one hand cryptography or more specifically the hashing algorithm and on the other hand the user verification process (Cf. Ganne, 2018 pp. 5-7; Morabito, 2017 pp. 3-8; Goldmansachs.com, n.d.).

As defined by the blockchains source code, a block can contain a certain amount of data (transactions) and as soon as the respective data is bundled, the block can be approved and verified by the network in order to be added as a new block to the blockchain. A block also stores transactions of previously verified blocks, hence the blockchain is considered as a “linked list”. A blockchain is tamper-evident since newly created blocks are added in a “append only” manner making any unauthorised attempts of changing previous blocks easily detected by the blockchain community.

The blockchain is therefore a highly attractive technology for recording and tracing valuable data, processing transactions and managing records in a decentralised and simultaneously highly secured approach with many application scenarios (Cf. Ganne, 2018 pp. 5-7; Morabito, 2017 pp. 3-8; Goldmansachs.com, n.d.).

The currently immense market capitalisation of the Bitcoin and other cryptocurrencies (as of February 2019 over USD 100 billion), as well as the media outreach, has led to an increasing awareness throughout all sectors of the global economy towards the blockchain technology (Coinmarketcap.com, 2019). Rahul Kapoor, an analyst at Bloomberg Intelligence, stated referring to the blockchain that: *“This would be the biggest innovation in the industry since the containerisation”* (Park, 2018). Individuals, businesses as well as governments are currently considering approaches to adopt the blockchain technology into various sectors (Goldmansachs.com, n.d.).

The following figure illustrates the general idea behind the Blockchain technology.

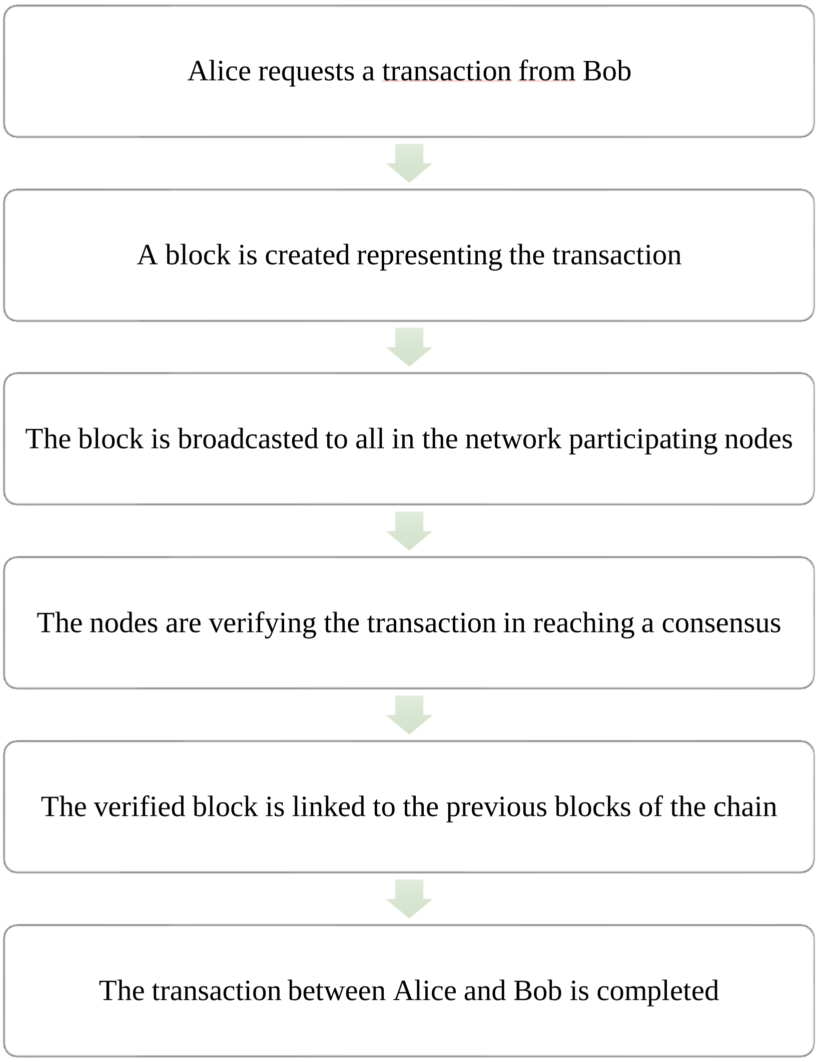


Figure 1: *Idea Behind the Blockchain Technology (own illustration based on Antonopoulos, 2014 pp. 10-13)*

2.5 Technical Aspects

In the following section, the technical aspects of the blockchain technology are to be defined, in order to be able to better understand the potential impacts of the technology on supply chain processes. Due to the fact that the Bitcoin was the first successfully implemented blockchain application and its sophisticated spectrum of documentation, in the following, the Bitcoin blockchain will be used as an example to facilitate the understanding of the technology.

2.5.1 Distributed Ledger Technology

The terms blockchain and distributed ledger technology in short DLT are often used almost interchangeably, although properly speaking the DLT is an umbrella term which is used to describe the technologies which distribute data among all of its participants. The blockchain is an application of the DLT and a subcategory of a broader definition. In fact, the blockchain was the first DLT which had a sophisticated and fully functional concept, and the only one which gained a wide range of recognition by the public.

A DLT is a database which distributes information across several nodes. Each node, on the other hand, replicates and saves an identical copy of the database (ledger). Every single node of the network updates itself independently if new data is transferred. The disruptive feature of the DLT is that the ledger is not maintained by a central authority but instead by the whole network. Since each record in the ledger is executed independently from a central authority, the participating nodes are able to "vote" on these records in order to ensure that the majority of the network agrees with the conclusion (Cf. Ray, 2018 b; bbva.com, 2018; Ganne, 2018 p. 7).

The concept of voting and agreeing to the ledger is referred to as reaching a consensus which is conducted automatically by a consensus mechanism. As soon as a consensus is reached, the DLT updates itself and the latest version of it is saved and distributed among all nodes in the respective network. This unprecedented technology presents a new idea for how crucial data is handled and distributed. It can alter the traditional approach of how individuals, companies and even governments transact information with each other. As aforementioned, blockchains are just one form of the DLT in which particularly "chains of blocks" are used to provide a secured and distributed consensus (Cf. Ray, 2018 b; bbva.com, 2018; Ganne, 2018 p. 7).

Nevertheless, the architecture of the blockchain differs from other kinds of distributed ledgers. The uniqueness of the blockchain is that data is collected and organised in blocks which are linked to each other with cryptography. Hence, a blockchain is actually a continuously growing chain of immutably linked blocks containing records. Shaan Ray an author at the data science online-journal "Towards data Science" stated that: "*Every blockchain is a distributed ledger, but not every distributed ledger is a blockchain"* (Ray, 2018 b).

Although each of these concepts requires a consensus among the involved nodes, the blockchain specifically organises and manages the data transfer with linked blocks whereas the distributed ledger can also provide other possibilities in organising the data transfer with a decentralised consensus mechanism (Cf. Ray, 2018 b; bbva.com, 2018; Ganne, 2018 p. 7).

2.5.2 Cryptography

One key aspect of the blockchain technology is the utilisation of cryptography which is a vital security mechanism. Since the blockchain disintermediates third parties as, e.g. banks, it is essential to provide an adequate substitute to those institutions which were fulfilling the purpose of providing security to the transaction process.

The cryptography can optimally replace the security gap caused by avoiding intermediaries. The cryptographical process in the blockchain technology is mainly implemented via hashing which is basically an algorithm that takes any size of information which someone requests to hash and converts it with the help of a mathematical mechanism into a secured hash with a fixed size. The hashed value can be regarded as a "digital fingerprint" of the input value (Cf. Perboli, Musso and Rosano, 2018 p. 3; Walder, 2002; Chirstidis and Devetsikiotis, 2016 pp. 2293-2294; Narayanan et al. 2016 pp. 23-24).

The blockchain technology is based on two cryptographical components, the hash functionality and the digital key infrastructure. The former ensures the security and structure of the transactions and the latter enables the trusted exchange of information between the blockchain participants (Walder, 2002; Narayanan et al. 2016 pp. 23-25; Chirstidis and Devetsikiotis, 2016 pp. 2293-2297).

2.5.2.1 Hashing

As the cryptography is essential for the fundamentals of the blockchain, in turn, the hash function is crucial for the cryptography. A hash function is basically a mathematical operation which essentially takes any input (data/ record) and converts it through a mathematical algorithm to a specific output. A hash can be considered as a fingerprint for a specific quantity of data but without the risk that the data will be exposed.

To avoid that data stored in a blockchain does not unnecessarily increase, larger documents are usually not stored directly on the blockchain, but only a reference with the respective hash value of the document. The hash value is used to verify the authenticity of the respective data and even the slightest change to the original document would result in a completely different hash output (Cf. Sarkar, 2011; Swan, 2015 pp. 37-40; Narayanan et al. 2016 pp. 23-25; Nakamoto, 2008 pp. 1-3).

The hash algorithm has to have the following requirements in order to fulfil its primary purpose of providing security:

- The input value is an arbitrary string with an arbitrary length
- The function is deterministic which means that identical inputs result in the same outputs
- The output value has a firmly defined length, regardless of the inputs formatting
- Even the merest alteration of the input value changes the whole hash

In order to be successfully utilised as a cryptographical function, a hash function has to contain three additional characteristics. One of them is that a hash function has to be a one-way function which is an indispensable component. The one-way functionality of a hash means that it is not possible to draw inferences about the input value when the output value of a hash function is known. As a result, it is necessary that the range of possible inputs be sufficiently broad and distributed. Therefore, it is not possible to calculate the original information from the hash value (Cf. Sarkar, 2011; Swan, 2015 pp. 37-40; Narayanan et al. 2016 pp. 23-25).

The second indispensable component of a cryptographical hash function is the necessity of being puzzle friendly. Referring to the blockchain technology that means that the mathematical algorithm of the hash requires an extensive range of values to find a solution.

The result can only be found by trying a myriad of random values. The third requirement of a hash function is that it has to be collision resistant. The cryptographical definition of collision means that two different input values result in the same output value. A hash is collision resistant when the possibility that two different values resulting in the same hash is implausible (Cf. Sarkar, 2011; Swan, 2015 pp. 37-40; Narayanan et al. 2016 pp. 23-25).

2.5.2.2 SHA 256

One of the most adopted hash functions in cryptography which is also adopted for the Bitcoin ecosystem is the secure hash algorithm (SHA) 256 which consists of 256 bits. A hash is a mathematical computer algorithm that takes in information and converts it into a string of numbers and letters of a certain length. The primary purpose of these processes is to provide a high degree of security to the respective input data.

The “hashed” value is confident and secured since the hash algorithm makes the input data unreadable as illustrated as follows:

Figure 2: *SHA 256 Hashing Algorithm (KeyCDN, 2018)*

The input message gets converted with the hash algorithm into a specific hash value, considered as a unique fingerprint. The initial input data can be of any length whether it is just a number or an entire book. The hash function will always output the same hash for the same input. It is almost impossible to manipulate hash algorithms since if even one character of the input value is changed, it will consequently alter the whole structure of the hash value, hence the immutability of such a hash algorithm.

Due to the fact that hash algorithms are one-way functions, the hash value of the original message cannot be reversed therefore it is commonly used to verify and sign valuable digital documents and transactions (Cf. KeyCDN, 2018; Sarkar, 2011; Narayanan et al. 2016 pp. 30-31).

2.5.2.3 Signatures

Digital signatures are another vital cryptographical tool required to create a secure and tamper-evident blockchain network. The access to the data stored on the blockchain is based on a double key system; hence every node is provided with a private and a public key.

The cryptographical signatures are derived from the public key infrastructure (PKI) in which a key pair is necessary to sign the respective data (transaction). The first digital key is always kept secret and is commonly referred to as the private or secret key (SK) while the other key referred to as the public key (PK) is open to the whole blockchain network. These keys are the digital counterpart to a signature on a document and must contain comparable characteristics. Only one person can sign physical documents with his or her own individual signature, but everyone can read and confirm it. The same is true for the digital signature, which is an individual identification in which everyone in the blockchain network can read and verify it for its authenticity (Cf. Antonopoulos, 2014 pp. 62-69; Walder, 2002; CGI Group Inc., 2004; Narayanan et al. 2016 pp. 79-83).

The digital signature is linked to the signed data and cannot be copied to another one. Therefore, each transaction must be signed personally which is similar to the analogue counterpart in which the signature cannot simply be cut out and pasted onto a new document without getting detected.

The public key is used as an address to receive transactions and is derived from the private key while the cryptographical security mechanism makes it almost impossible to derive the private key from the public key. The authenticity of the public key infrastructure is verified by the fact that the private key is necessary to digitally sign any transaction in which the receiver of the transaction uses the public key to verify that the respective data was initially signed with the private key of the sender. It is also worth mentioning that the private key is never revealed in the whole transaction and verification process. This security approach of the blockchain ensures and prove the nodes identity as well as data security (Cf. Antonopoulos, 2014 pp. 62-69; Walder, 2002; CGI Group Inc., 2004; Narayanan et al. 2016 pp. 79-83).

It helps to protect identities and simultaneously, prevents hackers from tampering data which reduces the risk of fraud immensely. For the sake of security, it is essential that the key pairs are generated randomly and from a broad value range which allows a high number of possibilities to generate key pairs and is correspondingly more difficult to tamper with than a key pair from a small range of values (Cf. Antonopoulos, 2014 pp. 62-69; Narayanan et al. 2016 pp. 79-83; Walder, 2002).

2.5.2.4 Timestamping

The basic purpose of timestamping is to ensure the exact chronological sequence of when the block was created and added to the blockchain. The verifying node compares the timestamp of the generated block with the previous block in order to approve it as a valid one and to avoid double spending. The blockchain network will only agree to transactions with the first-time stamp. Hence, if a node creates for the same bitcoin a transaction with two timestamps, only the previous one would be accepted as valid by the network.

Each created block contains the timestamp of the previous and the current block in the block header. Thus, the timestamps together with the respective hash pointers (basically a cryptographical reference pointing to a particular data block) serving as a link chaining all created blocks chronologically together, hence establishing a “chain” of blocks (Cf. Swan, 2015 pp. 37-40; Narayanan et al. 2016 pp. 15-17; Nakamoto, 2008 p. 2).

2.5.3 Network Design

One of the most disruptive features of the blockchain is its distributed network. Other than the centralised and decentralised application networks, a distributed network is a system in which information is spread throughout various hardware nodes which are connected to each other. Every transaction which was transferred throughout the network of these nodes is maintained in a database which is copied and saved on the full nodes. As a blockchain is a continually growing database, it requires high storing capacity.

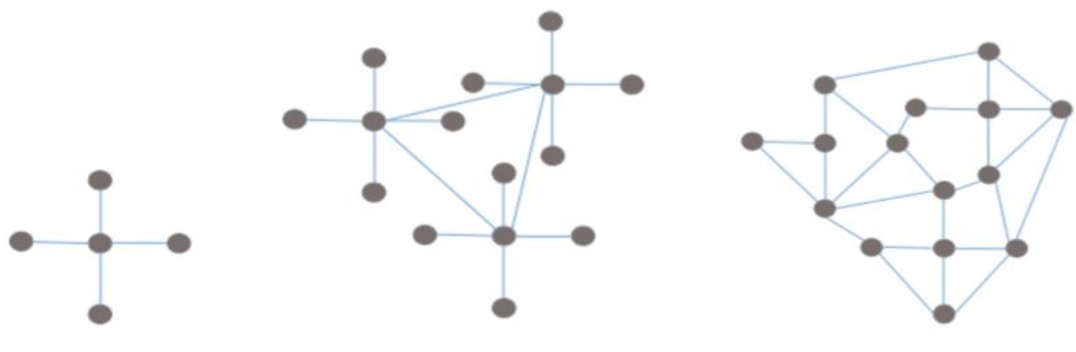
The full nodes are responsible for storing the whole blockchain database with all transactions that ever took place in the blockchain network, from the first genesis block which was the first block ever created to the most present blocks (Cf. Swan, 2015 pp. x-xi; Antonopoulos, 2014 pp. 139-145; Morabito, 2017 pp. 61-64).

The light nodes are just storing parts of the blockchain that they need in order to keep operating in the network as sending and receiving transactions. The full nodes keep track of the whole database and history of all valid transactions, while they ensure that the blockchain is continuously verified. Although each participant of the blockchain is able to obtain the same copy of the whole ledger, only those with the private key are able to transfer the ownership of the asset within the specific block. The blocks can be described as sealed containers in which information is stored and which are only accessible by authorised individuals with the respective permission.

The nodes in a blockchain are able to identify each other by their IP address, but transactions between the nodes are made through their public key (Cf. Swan, 2015 pp. x-xi; Antonopoulos, 2014 pp. 139-145; Morabito, 2017 pp. 61-64).

An essential feature of the (public) blockchain is that all participating nodes are considered to be equal with the same rights of participating with the network, as each node can take part in the consensus algorithm to create and verify the blocks. Other than in the centralised network, there is not a centralised structure as a central authority (Antonopoulos, 2014 p. 113; Narayanan et al. 2016 p. 90).

A distributed blockchain system which is among other things used as a platform for many cryptocurrencies as the Bitcoin (Nakamoto, 2008 p. 1) with the equality of all participating nodes is illustrated in the following figure:



(a) Centralised (b) Decentralised (c) Distributed

Figure 3: *Centralised, Decentralised and Distributed Networks (Morabito, 2017 p. 63)*

As illustrated, the centralised, as well as decentralised systems, are containing a certain degree of control exerted by designated nodes. The difference hereby is that in a centralised system the control is performed by one single entity whereas in a decentralised system the control is shared between several designated nodes.

However, in a distributed system the control is not only shared by designated nodes, but by all in the network involved nodes who are all processing as well managing the network with equal rights (Morabito, 2017 pp. 62-64).

Nevertheless, it always refers to the design of the blockchain network in deciding whether it is centralised, decentralised or distributed which will be discussed in the upcoming section; types of the blockchain (pp. 24-26).

2.5.4 Consensus Algorithms

The consensus algorithm of the blockchain is the verification procedure of the transactions, which instead of trusting in a third party, the blockchains network verifies the authenticity of information based on the cryptographical algorithms. The term consensus refers to the fact that only when at least the majority of the blockchain participants confirming the authenticity of the data it gets validated and added to the blockchain. Therefore, the terminology of "reaching a consensus" is a decisive feature in a distributed system which omits a centralised authority. Since it is not unusual that in distributed system blocks can be created almost at the same time, it is crucial to determine which one is to be added next to the chain.

The consensus algorithm also prevents the problem of "double spending", since without a central authority which monitors the ledger, digital assets could be theoretically copied infinitely, which means that in the case of the cryptocurrency's transaction could be copied and spent several times, hence double spending problem. The consensus algorithm eliminates the need for a third party monitoring the ledgers. Instead, the monitoring is carried out by the whole network. Due to the diversity of the blockchain and its numerous application possibilities, there is a myriad of consensus algorithms, and there are consistently new ones in development (Cf. Nakamoto, 2008 pp. 1-2; Swan, 2015 pp. 95-96; Narayanan et al. 2016 pp. 52-61).

In the following, the "Proof of Work" and the "Proof of Stake" consensus mechanisms are to be further discussed as these two consensus algorithms are the most utilised ones among current blockchain-based applications (Cf. Nguyen and Kim, 2018 p.2; Beyer, 2018). Additionally, the "Proof of Authority" algorithm will also be analysed as this consensus mechanism is a likely choice for blockchain-based applications in the logistics sector (Schwanke and Malzahn, personal communication, January 24, 2019). However, it is important to note that it always highly depends on the specific business case in choosing which consensus algorithm should be utilised (Company XY, personal communication, November 30, 2018).

2.5.4.1 Proof of Work

The consensus mechanism utilised for the Bitcoin ecosystem to solve the issue of double spending and simultaneously preventing the need for an intermediary is called "Proof of Work" (PoW) (Nakamoto, 2008 p. 3). PoW is a network security protocol used as a consensus mechanism to validate transactions and adding new blocks to the blockchain. The validators of the blocks are called "miners" since they try to "mine" the new blocks being added to the blockchain. The miners are trying to generate a specific hash code to validate the new block in which it is required to solve a puzzle or more specifically a mathematical problem. That ensures that a certain amount of work has been contributed to mine (generate) the specific block which is based on the computing power the miners provide to solve the puzzle (Cf. Nguyen and Kim, 2018 pp.2-10; Morabito, 2017 pp.10-11; Blockgeeks.com, n.d. b).

Generally, the higher the computing power, the higher the hash rate is and the more likely it is for the miners to create the new block. The difficulty to solve the mathematical problem is automatically adjusted so that it is guaranteed that the creation of a new block takes more or less about 10 minutes which enhances the security purpose of the blockchain.

The nonce is a value that must be generated so that the searched hash starts with a predetermined number of zeros. Finding the nonce is achieved by randomly computing different nonce values until the right nonce is found. Once a solution to the puzzle is found and the block is generated, the block gets shared with the whole blockchain participants who are therefore able to verify the correctness of the newly created block.

The validation of the block and the agreement on the order of the respective block is carried out by a consensus of the blockchain participants, thus reaching a consensus. The mathematical problem that a miner is trying to solve depends on the previous blocks of the blockchain. Therefore, if someone tried to tamper the block, it would be required for the attacker to recreate that specific block and additionally all subsequent blocks that have been created since. Furthermore, the network accepts only the longest chain of blocks as the valid one. That makes the blockchain practically tamper-evident and immutable due to the limit of computing power a miner or a group of miners could provide (Cf. Nguyen and Kim, 2018 pp. 2-10; Morabito, 2017 pp. 10-11; Blockgeeks.com, n.d. b).

To "incentives" the miners to validate the transactions, each time when the miners solve the mathematical puzzle and adding a new block to the blockchain, they receive a pre-defined amount of the specific cryptocurrency as a reward, called the "block reward". Moreover, the miners receive transaction fees which are included in the transaction (Cf. Schumann, 2018; Frankenfield, 2018).

In the Bitcoin network, the PoW mechanism requires an extreme amount of computational power. According to Swan (2015), the total mining costs of the Bitcoin network in 2013 accounted for about USD 15 million each day (Swan 2015, p. 54). To illustrate this enormous energy consumption of the PoW concept, in its peak phase in the last quarter of 2017 the Bitcoin network consumed more energy than the Republic of Ireland in November that year (Cf. Powercompare.co.uk, 2017; Digiconomist.com, 2017). These are considered as more or less wasted resources; hence many blockchain enthusiasts are exploring and developing alternative consensus mechanisms to optimise the blockchain network (Swan, 2015 p. 83).

However, it should also be mentioned that the majority of the Bitcoin mining process takes place in regions as in rural China due to the low local energy prices. These regions are in need of any business settlement as they lack in a sophisticated infrastructure. Therefore, the "mining process" could be regarded as a reasonable business in these areas which even generate jobs and thus boosts the local economy (Aljazeera.com, 2018).

2.5.4.2 Proof of Stake

The "Proof of Stake" (PoS) mechanism is a common alternative to the PoW concept. Compared to the PoW concept, this consensus algorithm does not rely on the enormous use of computational power. Instead, the PoS follows the approach in who possesses the highest stake in the network to be permissioned of validating new blocks. More specifically, in the PoS mechanism, the decision-making power of approving the block is proportionally distributed to the stakes the participant holds in the blockchain. That means that the participants with the highest stake in the network probably obtain the permission for validating the block.

The validator of the block is chosen deterministically, based on the stake which the participant has contributed to the blockchain network rather than competing with hashing power for generating the next block. This consensus mechanism provides no reward system for adding a new block to the blockchain.

Instead, the validator gets the transaction fees for generating the specific block. The PoS consensus mechanism processes transactions faster than the PoW concept (Cf. Nguyen and Kim, 2018 pp. 10-13; Morabito, 2017 pp. 11-12; Blockgeeks.com, n.d. b).

Moreover, it consumes a smaller amount of computing power and is therefore a cheaper alternative of reaching a distributed consensus. To encounter the issues of the possibility of creating a kind of centralisation in the PoS network, as the validators with the highest stake in the network could attempt to abuse their power over the network, there are current developments of creating a hybrid form in combining both the PoW and PoS consensus mechanisms (Cf. Morabito, 2017 pp. 11-12; Blockgeeks.com, n.d. b).

2.5.4.3 Proof of Authority

According to online blogging platform "Medium", the "Proof of Authority" (PoA) consensus mechanism *is "a modified form of Proof of Stake"* concept in which only approved participants are selected as validators permitted to verify transactions of the blockchain network (Medium.com, 2017 a). This procedure is based on the reputation of the respective validator instead of the stake he or she has as a monetary value. The PoA is therefore considered as on the identity-based reputation consensus mechanism (Cf. Medium.com, 2017 a; Curran, 2018).

Every participating identity of the PoA network needs to be verified by pre-selected validators. The primary function of those validators is to approve transactions made in the network and therefore to generate the respective blocks. In order to ensure efficiency and to provide a certain degree of security, the group of validators is supposed to remain small with about 25 authorities or even less. The PoA consensus mechanism requires far less computational power compared to the conventional PoW and PoS concepts (Cf. Medium.com, 2017 a; Curran, 2018).

Furthermore, the PoA provides no requirements for node-to-node communications in order to reach a consensus. The consistency of the network is therefore independent of the number of the participating nodes since they are basically pre-selected and approved. The cross verification through the network of the participants makes the PoA concept a self-verifying and trustable consensus mechanism.

The PoA is not only designed to be less energy consumptive than the PoW mechanism, but it also removes the central issue of the PoS consensus in which the participant with the higher stake is more probable to be chosen as the next validator. The validators are the key part of the PoA consensus mechanism as they practically run the whole network by validating the transactions (Cf. Medium.com, 2017 a; Curran, 2018).

This concept has three requirements to be fulfilled in order to be a functional consensus mechanism:

1. The identity of the chosen validator has to be true and formally verified throughout the blockchain network in which other participants are also able to cross-check the authenticity of the respective identity.

2. The eligibility for staking the identity must be challenging to obtain in order to make the right of being a validator earned and valued.

3. The process of determining the authority must be consistently the same for all potential validators to create uniformity in the procedures providing a certain degree of trust in its integrity.

These requirements are necessary to keep the network free of corruption and prevent participants from making any fraudulent transactions.

Any validator who acts fraudulently to the network can easily be removed and replaced from the process. That would instantly damage the reputation of the respective validator as well as lead to financial losses. In contemporary times, the use of reputation through identity is of significant relevance as in the current age of the internet, especially thanks to the social media, the reputation of identities can quickly and easily be damaged.

The awareness of the vulnerability of a reputation in the public domain serves as a specific incentive for identities to act honestly towards the PoA network. However, the most effective use case of PoA is primarily suitable for private blockchains which tends to be a more centralised form of the blockchain (Cf. Medium.com, 2017 a; Curran, 2018).

2.5.5 Types of Blockchain

Since the inception of the blockchain technology, two general types of network structures of the blockchain have been developed. These different kinds of a blockchain network are the private and public blockchains; in both scenarios, the blockchain is based on a consensus mechanism (Varshney, 2017). However, the distinction between the two concepts lies in the access requirements of the respective blockchain.

2.5.5.1 Public Blockchain

Blockchains utilised in the economy of cryptocurrencies are usually designed to be permissionless and completely decentralised throughout the network since there is no central authority involved which rules the blockchain. Hence, everyone is allowed to participate in accessing the whole public blockchain as well as to validate transactions with the appropriate software and hardware to participate in the validation process.

All nodes in the public blockchain network share the same rights in accessing and writing data into the network by following the underlying rules which are agreed upon. All the data in a public blockchain network is freely available to all its participants in a through cryptographical encrypted source (Cf. Varshney, 2017; Ganne, 2018 pp. 9-10).

2.5.5.2 Private Blockchain

In private blockchain networks, potential participants need permission to join the blockchain network, which is issued by the entity or authority who runs and set the rules of the private blockchain. These blockchains are structured in a centralised manner since permission is restricted to access data which compared to the public blockchain adds a higher degree of privacy to the participating nodes in the network. Nevertheless, since the blockchain is not decentralised, not all of its participants share the same rights. The private blockchain is suitable for businesses which are not interested in sharing their sensitive data to the public environment. The transaction speed is generally faster in a private blockchain and, the transactions fees are also lower compared to a public blockchain (Cf. Varshney, 2017; Ganne, 2018 p. 10).

Furthermore, parties in a private blockchain should establish a high degree of trust to each other, especially to the central authority which runs the blockchain.

Consequently, private blockchains can be structured to have permission levels assigned to the participants for contributing specific data to the network as well as issuing different levels of authority to the participants to assess specific data. Hence, unauthorised participants are not able to transact or view data on the private blockchain.

The operator of the private blockchain ultimately controls the whole network which diminishes one of the critical elements of the general purpose of a blockchain which is providing a decentralised ledger (Cf. Varshney, 2017; Ganne, 2018 p. 10).

2.5.5.3 Hybrid Blockchain

The hybrid blockchain is a kind of hybrid network of the public and private blockchain and is also called permissioned blockchain. It contains characteristics of both the public and private blockchain networks.

These blockchains are partially decentralised and, as in the private blockchain, permission is required to get access to the network or at least to specific data stored in the hybrid blockchain. The right to get access to the relevant data typically depends on the identity of the participants and the function they have in the network. As in the private blockchain, the hybrid blockchain also contains an operator who controls who can access the blockchain. This operator can decide whether the data can be accessed by the whole network or should remain confident to a specific group of members. These blockchains ensure that all data is private but simultaneously verifiable through an immutable record as in the public blockchain. Centralised blockchains require permission to participate in the network which makes sharing data across the blockchain more difficult (Cf. Varshney, 2017; Zilavy, 2018; Ganne, 2018 p. 11-12).

On the other hand, decentralised blockchains with no central authority monitoring it with all transaction publicly accessible raise security concerns. The concept of the hybrid blockchain is to connect the benefits of the two blockchain versions which allows network participants to selectively share their data publicly with a reduced security concern about their privacy.

In the hybrid blockchain transaction can be private but still verifiable by an immutable record on the consensus of the blockchain. Each transaction gets approved by the nodes and is still trustworthy. Consequently, the power of the central body is limited, since similar to the public blockchain, any modification of a transaction will undergo an intensive approval process making it almost impossible for any participant to tamper with the transactions. Although the hybrid blockchain is transparent and immutable as in the public analogue, it could restrict the rights of the participants as to who can view or approve transactions to prior selected nodes (Cf. Varshney, 2017; Zilavy, 2018; Ganne, 2018 p. 11-12).

Hence, if the network participants of the hybrid blockchain do not want their transaction data to be exposed to the public, they can define the rights to access their confident data. These three general concepts of a blockchain are all based on the degree of the openness of the network.

To put it in a nutshell, the more decentralised the blockchain network is, the less efficient the performance of such a blockchain is. That is partly justified by the fact that a decentralised system needs more resources and time to reach a consensus on the blockchain which also depends on which consensus algorithm the network utilises (Cf. Varshney, 2017; Zilavy, 2018; Ganne, 2018 p. 11-12).

In order to avoid misunderstandings, going forward, only the term blockchain as a generic term will be used referring to all blockchain types.

2.6 Recent Developments

As the blockchain technology is still in the development phase, there have been some promising developments around the technology. One of the most promising developments in the last years is the concept of smart contracts which could redefine the general purpose of traditional contracts.

Another exciting development aspect lies especially in contraction with other emerging technological innovations as the internet of things, big data and artificial intelligence. Hence, there could be in the future some innovative application possibilities associated with the blockchain technology which are yet to be explored.

2.6.1 Smart Contracts

A traditional contract is defined as an arrangement between two or more parties in which they determine written terms and conditions which are enforceable by law as a legal agreement. A smart contract has the same characteristics with the difference that the terms and conditions of the specific contracts are stored as a code within the blockchain (Company XY, personal communication, November 30, 2018).

Smart contracts are considered to be one of the most promising features of the blockchain technology especially for the logistics sector as they are referred to as a promising solution to optimise data flow and supply chain processes (Cf. Schatsky, n.d.; Swan, 2015 pp. 16-18). The term “Smart Contract” was introduced in 1994 by the computer scientist and cryptographer Nick Szabo which he defines as *“a set of promises, specified in the digital form, including protocols within which the parties perform on these promises"* (Szabo, 1994).

Even though the concept of smart contracts was proposed before the introduction of the blockchain, it became only applicable after 2008 due to the inception of the blockchain technology. The concept of smart contracts can be defined as a software protocol automatically able to perform an action when certain conditions are met; basically, the logic behind smart contracts is “if this happens, then do that”.

That means that smart contracts are digitally signed agreed upon certain business rules between two or more parties, and the terms and condition of the agreement are digitally specified by writing a set of codes. More specifically, the script of a smart contract can be stored in the blockchain which comprises legal clauses of a traditional contract and translates it into a programmable code. These kinds of contracts referred to as “smart” thanks to their ability to automatically self-execute pre-defined conditions of highly complex agreements of several involved parties which is beyond the capability of traditional paper contracts and therefore entail the potential to replace them (Cf. Morabito, 2017 pp. 101-105; Szabo, 1994; Swan, 2015 pp.16-18; Ganne, 2018 pp. 13-14).

Agreements which are based on smart contracts could make settlement processes cheaper, automated and decisively faster. As smart contracts run on a blockchain, they are decentralised, which consequently means that they run on all nodes in the specific blockchain network and therefore prevent a single point of failure. The execution of the written code in smart contracts will tell each involved node exactly what it should do and therefore leaves no room for ambiguity. Moreover, it removes the trust which is needed in business agreements, providing each involved participant equal rights in the respective blockchain environment.

Smart contracts are executed on distributed blockchain ledgers which can provide a tamperproof operating system. All involved participants of this system are provided with the same proof of events run by the smart contract which enables a high degree of transparency for the participants to track and validate the immutable timeline of events in real time from the beginning to the end with all involved steps.

Once the smart contract is created and the rules are set, none of the parties is able to modify the underlying code of it readily. Smart contracts can be further developed in achieving a higher degree of self-sufficiency in order to develop complex organisations which are able to act autonomously. These organisations are called “Decentralised Autonomous Organisations”, in short DAO. A variety of linked and interacting smart contracts establish the procedures, rules and obligations the participants of these organisations have to follow (Cf. Morabito, 2017 pp. 101-105; Szabo, 1994; Swan, 2015 pp.16-18; Ganne, 2018 pp. 13-14).

Data transfer in the DAO network is uploaded to the blockchain, which consequently creates transparency throughout the network since an audit trail is accessible to all parties. These DAO´s are distributed and automated which could provide limitless potential. A DAO would have a computer code that runs the obligations, rules and decisions instead a management team ruling the organisation. The participants of the DAO network would decide the rules, establishing a consensus and create smart contracts (Cf. Swan 2015, pp. 22-25; Longfinance.net, 2016).

However, smart contracts are less flexible compared to the “traditional” contracts as they are autonomously programmed, which means that once a smart contract is put on the blockchain, it cannot be changed since the compliance is predefined with the underlying code (Schwanke, personal communication, January 18, 2019).

2.6.2 Internet of Things

The concept of the Internet of Things (IoT) is, besides the blockchain, also a promising and innovative emerging technology. With an estimated 26 billion connected devices in 2020, there are potentially many application approaches including the logistics sector (Swan 2015, p. xii). However, the IoT suffers from difficulties concerning security and privacy weaknesses which could be solved with a blockchain network enabling operation in a secured and decentralised ecosystem for sharing data.

Hence, the blockchain technology is well-suited to become the underlying technology platform for IoT applications by diminishing security and privacy concerns (Cf. Andrea, Chrysostomou and Hadjichristofi, 2015 p. 8; Chirstidis and Devetsikiotis, 2016 p. 2292; Company XY, personal communication, November 30, 2018).

The two primary characteristics of the (public) blockchain as the high-security standard as well as the distributed nature of the network make the technology a suitable underlying technology to link the IoT devices. Therefore, confidentiality and security are automatically granted to the participants of the IoT to protect themselves against untrusted parties. Moreover, the distributed network applies flexibility circumventing one single point of failure. By adopting smart contracts with the IoT, the process could be automated with no need for manual interferences. These “smart devices” could be integrated into a blockchain system as nodes which communicate with the network through smart contracts. The data provided by the IoT devices could be stored on the blockchain in real time always accessible by all other devices.

That, combined with the characteristics of the blockchain technology, could have a tremendous effect on the entire supply chains. As the blockchain and IoT technologies are still in the development process, the real-world application is still to be defined. Nevertheless, the technologies could highly increase efficiency when it comes to automating the shipment process of goods with reducing manual user interference (Cf. Huckle et al., 2016 pp. 463-465; Chirstidis and Devetsikiotis, 2016 pp. 2292- 2294; Pollock, 2018; Company XY, personal communication, November 30, 2018).

Moreover, the blockchain would eliminate the single point of failure risk and simultaneously ensure transparency and robustness by spreading the data among the participating IoT nodes.

Furthermore, the blockchain could add a certain degree of anonymity to the involved parties by utilising pseudonyms as identities. However, some challenges are facing the utilisation of the blockchain technology for the IoT devices. For example, the scalability issue of the blockchain could be an obstacle for an effective implementation as the IoT network is expected to contain a myriad of nodes (Cf. Schwanke, personal communication, January 18, 2019; Pollock, 2018).

2.7 Possible Applications in the Logistics Sector

In order to understand the potential importance of the blockchain technology for the logistics sector and the supply chain, the following section reviews some current application developments of the technology in the logistics sector.

2.7.1 Developments in the Maritime Industry

The potential benefits of the blockchain technology are already recognised throughout the international transportation industry. In March 2017 the world's biggest shipping company Maersk (Marineinsight.com, 2019) and IBM one of the leading IT solutions provider collaborated to develop a blockchain-based application to digitalise the flow of information processes. According to IBM (2017), the blockchain initiative with Maersk has the potential to reduce the complexity of the global trade and hence reduce the costs (IBM, 2017).

That strengthened the integrity of the blockchain which consequently inspired other industry actors to participate in the blockchain revolution and to develop their own blockchain-based applications for optimising their supply chains. This research further highlighted the obvious need for optimising the transportation process and minimising the manual interfaces between the parties.

Hence, the ambitious Maersk and IBM blockchain approach claim to be able to *"manage and track the paper trail of tens of millions of shipping containers across the world"* (IBM, 2017). The blockchain ledger could distribute the shipping documents among all parties involved in the transportation processes, such as the exporter, freight forwarder, carrier, port authority and the importer. By utilising the blockchain technology, all of the concerned parties should be able to view the same data in real time which provides a high degree of transparency.

As the data stored on the blockchain is practically immutable, the involved parties can also be sure that the data is not tampered and authentic. The high degree of security and transparency provided with the blockchain approach are the key arguments why Maersk and IBM are convinced that implementing the blockchain into their processes could reshape the transportation industry and reduce costs, delays and frauds (Cf. IBM, 2017; Maersk.com, 2018). The IBM-Maersk blockchain solution could be of great importance for developing nations in the global trade. As the costs of global trade can be significantly reduced due to the blockchain technology, developing nations could participate more in the transportation of goods (Ganne, 2018 pp. 80-88).

Similar to the IBM and Maersk blockchain project, there are other developments in the logistics sector regarding blockchain-based solutions. For example, in 2017 the South Korean Busan Port Authority and the shipping company Hyundai Merchant Marine partnered with IBM to optimise the Korean shipping industry with focusing on blockchain-based applications to reduce the number of manual processes and increase the safety aspect of data flow (Kang, 2017).

2.7.2 Developments in Port Logistics

The blockchain technology has also raised awareness towards government agencies especially port authorities. For instance, there are various port authorities across Europe currently collaborating and developing blockchain-based platforms for increasing efficiency of port procedures.

Two of Europe's largest ports, the port of Rotterdam and the port of Antwerp are already working on pilot projects regarding the implementation of the blockchain technology, into their systems (Cf. Angell, 2018; Portofantwerp.com, 2017). The port of Rotterdam, for example, is currently collaborating and developing with the start-up "BlockLab" a blockchain-based application with the goal of "*creating a complete, paperless integration of physical, administrative and financial streams within international distribution chains"* (Portofrotterdam.com, 2018).

The driving factor of the project is the inefficiency of the data flow in handling goods at the port caused by the involvement of numerous parties and documents. The developers are hoping to cut costs and to optimise the supply chain concerning transparency and efficiency. The project is also currently in the pilot stage which involves the shipment of a container originated in a factory in Asia to a destination in the Netherlands (Cf. Angell, 2018; Portofrotterdam.com, 2018).

Another example is the collaboration of the UK port operator "Associated British Ports" which operates 21 ports across the UK and the on digitalisation focused company Maritime Transport International who signed a Memorandum of Understanding to develop a blockchain project. The project aims to digitise and integrate the documentation processes and workflow management to enhance the supply chain visibility (World Cargo News, 2018 p. 24).

3 Methodology

The following chapter comprises the research methodology that has been applied to acquire the relevant information for the thesis. First, the purpose of the literature review is outlined, followed by explaining the choice of the research approach and data collection method. The data acquisition was conducted by both qualitative and quantitative research approaches.

The qualitative research was utilised to acquire the primary data for the thesis provided through blockchain experts from academic institutions and the logistics industry. Secondary data was gathered through the quantitative research in which data was acquired primarily through researching web sources.

3.1 Purpose of the Literature Review

The Literature review in the second chapter of this thesis had the purpose to establish a comprehensive background knowledge about logistics and the supply chain as well as to explore the general concept of the blockchain technology. With this, it was essential to provide a context why specifically the blockchain technology could be an innovative approach for optimising processes in logistics. Simultaneously, the literature review provides hereby an understanding of how the blockchain technology works by explaining its fundamental characteristics.

Moreover, the literature review was crucial in order to look deeper into the available literature of logistics and supply chain in conjunction with the blockchain technology which enabled the development of suitable research questions. Additionally, it helped in developing a frame of references to analyse possible blockchain-based applications and to understand the nature and the potential benefits of the relatively newly emerged technology. Due to the fact that the developments of blockchain applications are still in the early stages (introduced in 2008) and that the technology has anonymously emerged from the open web instead of a scientific environment, it lacks academic literature regarding the blockchain technology, especially for possible applications in other areas than cryptocurrencies and finance.

3.2 Research Method

The fact that the blockchain is a relatively new technology which lacks in coherent studies and real-life results was a significant reason for choosing the qualitative research approach for acquiring the primary data. Qualitative research approaches focus on data provided by reliable sources, whereas quantitative research approaches focus on figures and numbers which are currently difficult to obtain since there are only a few reliable and authentic sources available, hence existing evaluations and statistics are at the present difficult to measure (Greener, 2008 pp. 79-80).

In order to analyse the different impacts of the blockchain technology on logistics and the supply chain, the qualitative research data was primarily provided through blockchain experts. Therefore, the qualitative research provided confident sources which established a vital knowledge foundation about the blockchain technology to develop and analyse several perspectives in the context of logistics and supply chain.

Nevertheless, for gathering secondary data, the quantitative research approach was utilised to filter out the few available internet sources related to the blockchain technology in logistics which were subsequently narrowed down to the most credible ones.

3.3 Data Acquisition

As aforementioned, the data research was conducted with the qualitative approach to acquire primary data and the quantitative approach to acquire secondary data. In the following, the data acquisition processes with the respective approaches are to be more specified.

3.3.1 Primary Data

The primary data was acquired on the one hand by attending the module “Blockchain” held in the “International studies of Shipping and Chartering” course at the City University of Applied Science in Bremen, Germany and, on the other hand by conducting semi-structured expert interviews. The “Blockchain” module was held by two blockchain experts who are currently working for a non-profit research and consulting institute which focuses on maritime transportation solutions.

The module comprises a broad spectrum about the blockchain technology and various possible applications in the transportation sector. More specifically, the course provided an in-depth knowledge base about the blockchain technology beginning with its origin to the more complex topics as smart contracts. Besides discussing the technicalities of the blockchain, the course also focused on how the blockchain technology could impact the logistics industry in which inter alia existing blockchain-based approaches were discussed.

In order to compensate the theoretical part of the primary data acquisition provided by the “Blockchain” module, experts from the logistics sector who are actually developing blockchain-based supply chain applications were interviewed.

For this thesis, the interviews have been conducted in a semi-structured manner since the blockchain technology is a relatively new technology and many companies that are currently researching about possible applications have still not been published their results. Hence, qualitative discussions are an appropriate way to get in-depth information within a specific topic which is yet to be fully explored. By keeping the interview semi-structured, it was possible to ask explorative questions and simultaneously let the interviewees feel confident in reflecting his or her knowledge about the topic. Semi-structured interviews are typically prepared before the interview, but the interviewer can to some extent ask questions that are not prepared beforehand which enables a broader discussion about the topic (Bryman and Bell, 2011 p. 467).

Five interviews were conducted of which the first two interviews were held with two interviewees from the same company which is a globally leading freight forwarder. Both interviewees of this company wished to remain anonymous. Therefore, the freight forwarding company will be referred to as “Company XY”. Company XY is currently developing its own blockchain-based applications to optimise the process within their supply chain. The last three interviews were conducted with two IT logistics experts who are currently employed by the company “DAKOSY”, which is based in Hamburg, Germany.

The first interview was conducted with an export manager of the freight forwarding company who is responsible for full container load shipments. The objective of this interview was to determine current problems related to processes within the supply chain of the company.

One of the major issues hereby was the VGM data sharing process which due to its complexity and involvement of several parties is not only an issue for the company, but also for all the parties involved in the supply chain who have to deal with the VGM data. Subsequently, the second interview was conducted with an IT expert employed by the same freight forwarding company.

The structure of this interview was divided into three parts. The first part includes general matters around blockchain technology as well as the current role of the technology within the company. This was followed by the second part in which specifically a blockchain-based VGM solution was discussed. The third part was about application possibilities of smart contracts to digitise vital shipping documents like the bill of lading. Hereby, also the emerging legal and regulatory issues of blockchain-based applications in the logistics sector were discussed.

The last three interviews were conducted with Mr Schwanke and Mr Malzahn who are currently employed by the company DAKOSY, an IT service provider at the Port of Hamburg. Mr Schwanke and Mr Malzahn are among other things project leaders of the "RObobB" initiative which will be discussed in the upcoming analysis of the thesis.

The first interview was conducted only with Mr Schwanke in which general matters around the blockchain technology, as well as the current processes of the container release, were discussed. The second interview was conducted with both, Mr Schwanke and Mr Malzahn who is more acquainted to the concept of smart contracts. In this part, the "RObobB" approach was discussed, more specificity, how the blockchain-based concept (in conjunction with smart contracts) of releasing containers could optimise current processes in port logistics. The last interview was again conducted with Mr Schwanke in which the differences of the blockchain database and a conventional database were discussed.

All in all, the conducted interviews provided on the one hand valuable insights into some issues related to the inefficient data exchange in the logistics sector and, on the other hand, the interviews helped to understand how blockchain-based approaches could optimise these processes. The interviewees emphasised that the blockchain technology still has some obstacles and weak points which are yet to be solved in order to develop sophisticated blockchain solutions. The findings of the interviews are to be further examined in the next chapter in which the analysing part of the thesis will be conducted. The "Blockchain" module of the "Shipping and Chartering" course and the expert interviews are the foundation of the primary data used for this thesis.

The protocol of the questions of the conducted interviews is available in appendix 1 at the end of the thesis.

3.3.2 Secondary Data

The quantitative approach was conducted to gather secondary data by a comprehensive research based on various books, internet sources, PDF´s and blogs. In order to acquire a broader spectrum of information while exploring the internet, keywords were used while searching different databases. Google Scholar was utilised as the main search engine for the secondary data gathering process due to its diversity of the available documents. With this, specific keywords were used to explore the web related to logistics, supply chain and the blockchain technology respectively.

The main keywords used in the secondary data research process consist predominantly of, "logistics", "supply chain", "transport", "Logistics 4.0", "digital supply chain", "supply chain visibility", "blockchain", "blockchain technology" and "smart contracts". In order to diversify the web research process, the Boolean operator AND was utilised to combine these keywords such as to search for "blockchain in logistics".

The search strings were then connected by utilising the Boolean operator as follows:

- Blockchain AND logistics
- Blockchain AND transportation
- Blockchain AND shipping industry
- Blockchain AND supply chain
- Blockchain AND supply chain visibility

The overall data which was acquired through the research has been used to identify and to explore solutions the blockchain-based applications could provide to current problems within the information sharing processes in current supply chains.

The secondary data research was predominantly restricted to the English language although a few German-language sources were also analysed. Furthermore, the research process focused on academic articles and scientific papers but also on whitepapers of different blockchain start-ups especially those related to logistics and supply chain. The selection of the available data was conducted by the degree of its relevance to the thesis, especially to the research questions. Subsequently, suitable sources were categorised concerning their relevance, which was of tremendous assistance during the research processes.

4 Analysis

The purpose of this chapter is to examine the generated information as well as to analyse blockchain-based concepts. First, the three core values of the supply chain visibility in conjunction with the blockchain technology are to be analysed. Afterwards, in order to comprehend practical blockchain solutions for the logistics sector, three blockchain-based concepts will be presented. Hereby, the general requirements for a successful blockchain implementation are first to be determined.

The first concept deals with transmitting the verified gross mass between supply chain actors. Afterwards, the second concept examines possible applications of smart contracts for the Bill of Lading processes and the third concept is about implementing a blockchain-based solution for optimising the process of releasing containers at the ports.

Subsequently, after examining the concepts of implementing the blockchain technology into logistics processes, this chapter will conclude with comparing the blockchain technology with a conventional database with emphasis on the key differences.

4.1 Improving Overall Supply Chain Visibility

As aforementioned, trust, traceability and transparency are the key elements of an efficient supply chain which are not taken for granted in the current logistics sector. The following examines how and why the blockchain technology could optimise these elements in order to strengthen the overall supply chain visibility.

4.1.1 Trust

By utilising the blockchain technology with the decentralised verification process of transactions, third parties are no longer required in replacing trust issues between parties. The third party or trustee is actually replaced by utilising the particular consensus algorithm of the blockchain network (Antonopoulos, 2014 p. 26, 181).

Involved parties who have different interests in the supply chain can rely on the self-administered approach of the blockchain. By establishing the blockchain technology as the underlying infrastructure of the communication process of transportation movements, the involved parties are able to interact with each other with equal rights and responsibilities. This eventually enhances their relationship in which they do not have to concern to which degree they can or cannot trust each other. Instead of further complicating the shipment process by adding an additional party solving trust issues, the blockchain approach in fact “digitises” the attribute of trust by distributing it among the nodes of the blockchain network (Cf. Notland, 2017; Goldmansachs.com, n.d.).

4.1.2 Transparency

Transparency in the blockchain network is provided by developing a decentralised ledger that monitors and records the movement of the consignments throughout the supply chain process. A copy of the respective blockchain is thereafter provided to every participant.

Therefore, the actors within the network are able to gain full transparency concerning any transaction or event (Company XY, personal communication, November 30, 2018). Since customers have over the years become more curious about where the products they consume come from and also about the environmental footprint of the productions along with the produced emissions, the blockchain technology can enhance the transparency regarding the whole lifecycle of products thus, reducing customer concerns (Cf. Notland, 2017; Goldmansachs.com, n.d.).

Hence, suppliers and manufacturers can adopt the blockchain as a competitive advantage by providing their customers with transparent data about the products and their manufacturing processes. If the blockchain technology gains a widespread adoption throughout the logistics sector, suppliers and manufacturers could be pushed to restructure their business processes in order to fulfil the transparency requirements which have emerged with the technology. That could not only have a positive impact on the transparency but also on the environment as customers may avoid companies that are not providing the blockchain-based transparency (Company XY, personal communication, November 30, 2018).

However, to avoid misunderstandings, it is important to note that the transparency aspect of the blockchain technology should be cautiously regarded since the logistics sector is a highly competing industry in which not all parties are keen to openly share their confidential data. Accordingly, the transparency aspect of the blockchain technology would probably be only applicable within a restricted community (Schwanke and Malzahn, personal communication, January 24, 2019).

For example, the carriers could have an interest to share container information with the concerned parties like the port authorities, the logistics providers and so on. Though, in order to stay competitive, it is vital for the carriers to restrict outside parties (competitors) in getting access to their confidential information. Hence, due to data security concerns, the transparency aspect of the blockchain technology would likely be utilised with private blockchains in the logistics sector (Schwanke and Malzahn, personal communication, January 24, 2019).

4.1.3 Traceability

With the implementation of the blockchain technology in the processes of the supply chain, the participants of the network are able to trace every single step of the transportation process in real time. Potentially everyone can trace the respective product to the raw materials used to produce it. This benefits especially consumers of controversial products with concerns of the respective origin as palm oil or even diamonds.

As the blockchain "chains" all events of the shipment process in a single line from the origin to the destination, all participants obtain equal possibilities to trace the events; which leads to the fact that ambiguity is virtually abolished among the parties. Therefore, time can be drastically saved as disputes can be settled faster based on the seamless and immutable track of events provided by the blockchain approach (Cf. Company XY, personal communication, November 30, 2018; Deloitte, 2017; Ganne, 2018 p. 80; Notland, 2019).

4.2 Basic Requirements for Implementing a Blockchain-based Application

One of the core aspects when planning to implement the blockchain technology for improving supply chain processes, is first to determine the respective requirements which need to be developed beforehand in order to prevent miscalculations. First of all, the parties have to determine the degree of openness the blockchain-based application should provide.

There are several blockchain decision models in which specific questions help to decide which blockchain model should be chosen for the specific requirements. The following illustration was developed by Morgen E Peck in 2017 and describes a suitable scenario for choosing the openness of the blockchain.

As illustrated, in the decision model, there are three general categories related to the openness of the blockchain community: the public, private and permissioned blockchain.

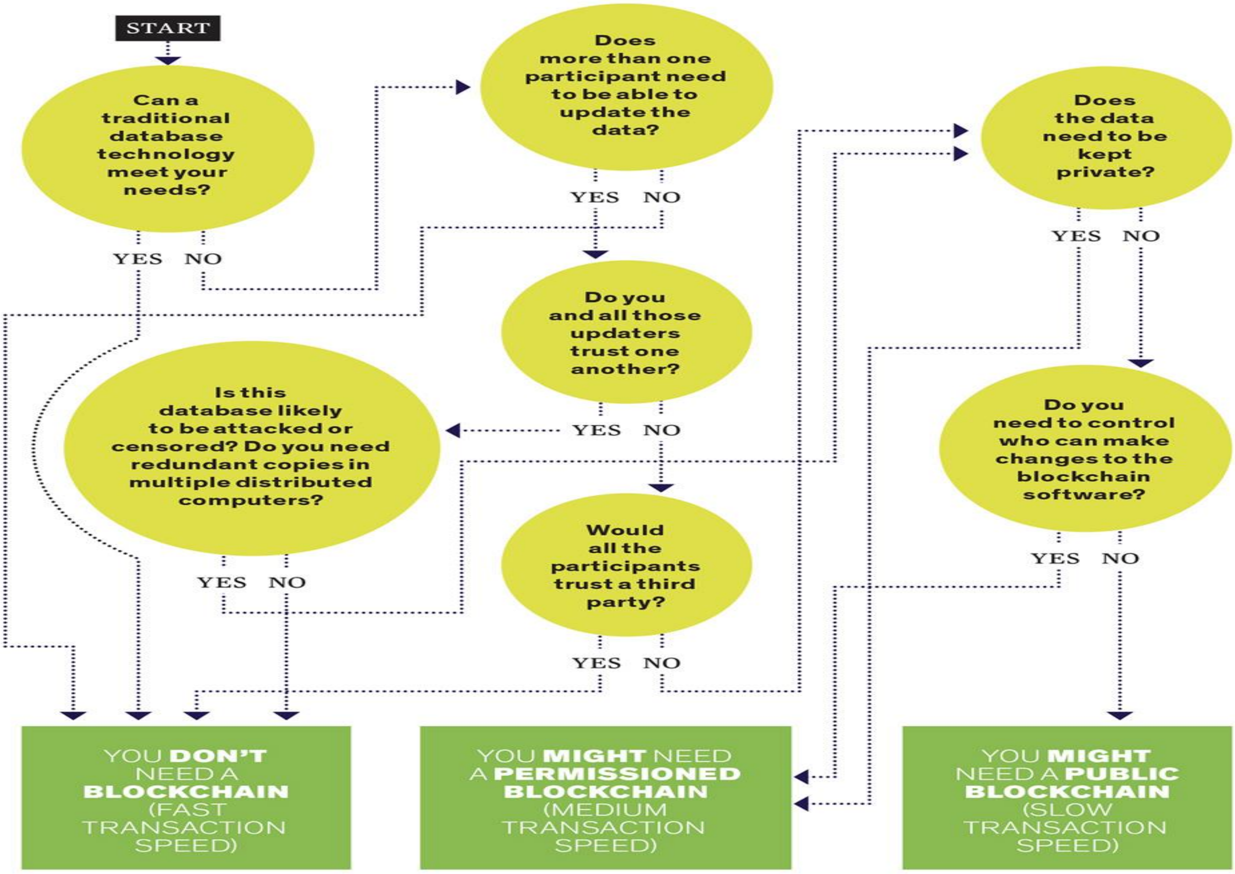


Figure 4: *Blockchain Decision Model (E. Peck, 2017)*

With the questions of the decision model, the interested parties can decide which of the specific blockchain approaches would be the most appropriate one regarding their individual needs (E. Peck, 2017).

After choosing the respective blockchain, the parties have to develop a specific infrastructure regarding the blockchain in which they have to connect their information systems to the blockchain application. More specifically, all participants who wish to implement a blockchain-based application have to collaborate in order to elaborate on a plan in which they have to decide what they want to achieve with the blockchain approach and how to achieve their predeveloped goals. The interested parties have to ask themselves which issues they want to optimise with the blockchain to subsequently analyse if the blockchain could find a remedy (Cf. Company XY, personal communication, November 30, 2018; Schwanke, personal communication, January 18, 2019).

Generally, the parties should share more or less similar issues as, for example, low transparency within their supply chain for which the blockchain could provide mutual benefits to the whole network. Once the parties decide about their mutual goals, they have to adopt the blockchain technology step by step in order to avoid risks since an immediate full-scale implementation would not be technically possible due to the diverse and complex relations of the parties involved in the logistics sector.

Therefore, the blockchain application should also, if possible, be implemented simultaneously to the current information gathering processes the respective community wishes to optimise or replace.

Consequently, they would be able to switch between the approaches in emergency situations to prevent data losses if the blockchain application fails. Moreover, it is common that the parties first have to develop a proof of concept or a pilot project to evaluate the performance of the respective blockchain application and, if necessary, to optimise it (Cf. Company XY, personal communication, November 30, 2018; Schwanke, personal communication, January 18, 2019).

As the blockchain is frequently described as a technology that stores and distributes data in a secured and decentralised way among its participants, close collaboration between the involved parties is of utmost importance (Company XY, personal communication, November 30, 2018; Schwanke, personal communication, February 20, 2019).

4.3 Concepts

In the following, three blockchain-based concepts are to be examined to deepen the understanding of the merits resulting from implementing the blockchain technology for specific processes in the logistics industry. The hereby analysed data is primarily based on the semi-structured interviews which were conducted with the freight forwarding company (which wants to stay anonymous) and with the IT solutions provider DAKOSY.

4.3.1 Blockchain-based VGM Concept

The first concept deals with implementing the blockchain approach for transmitting the VGM data between the parties involved in a transportation process, especially between the shipper, freight forwarder and the carrier. The hereby analysed information is based on the interviews held with the freight forwarding company.

4.3.1.1 Current VGM Concept

The VGM is a "*new requirement to verify the gross mass of a packed container*" (IMO 2018) based under the convention of the Safety of Life at Sea (SOLAS). This new requirement has the purpose of ensuring that the gross mass of a packed container is accurate and valid in order to reduce accidents regarding wrong declarations of the container weight.

As of 1 July 2016, shippers are required to submit the verified gross weight to the carrier prior to the loading process of loading a container onto the respective vessel. All member states of the international maritime organisation are required to comply with the new regulation and to apply the VGM concept considering their national legislation (Cf. Imo.org, n.d.; Company XY, personal communication, November 21, 2018).

According to the semi structured-interview with the freight forwarding company, this process can be very tedious and cost-intensive as there are several parties involved in submitting the VGM data (Company XY, personal communication, November 21, 2018).

The following figure illustrates the complexity of the current process:

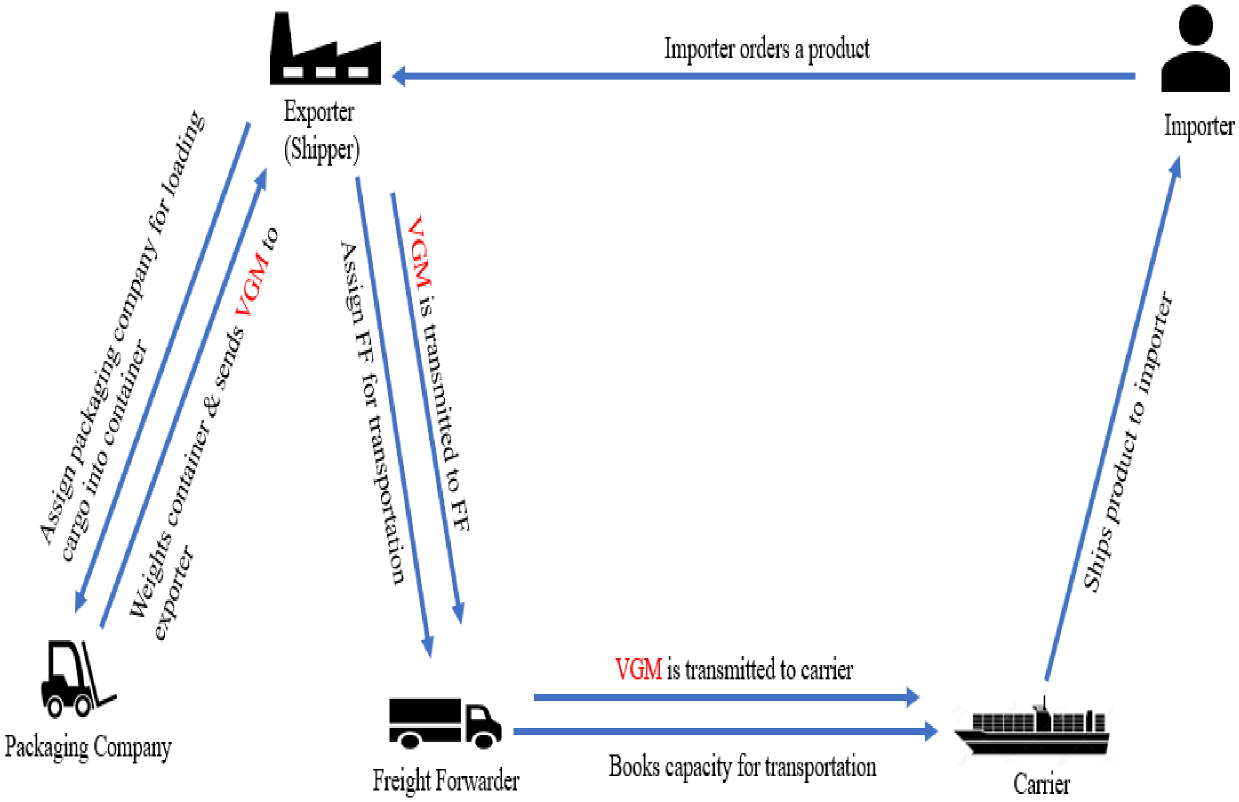


Figure 5: *Current Process of Transmitting the VGM data (own illustration based on the interviews with Company XY)*

According to the interviewee, transmitting the VGM data between the parties involved in transporting a conventional container contains the following steps (from the perspective of a freight forwarding company); first, the shipper has to submit the VGM to the freight forwarder which subsequently forwards this information to the carrier. The carrier can therefore plan the voyages prior to the arrival of the container at the port of loading. Since the VGM is often not accurately known in the stage of the booking process by the freight forwarder or the shipper, the VGM is more or less guessed and submitted to the carrier. This process leads to discrepancies between all parties involved in the transportation process (Company XY, personal communication, November 21, 2018).

4.3.1.2 Issues of the Current Process

Due to the manual conducted processes, it is not uncommon that the wrong VGM is submitted to the carrier or submitted too late which leads to an unnecessary waste of time plus additional costs. In such a scenario it is not directly known who is responsible for submitting the wrong or delayed VGM which is caused by the lack of visibility throughout the supply chain.

Moreover, it occurs quite often that the actual container is delivered to the port before the VGM data, which indicates that the current processes are highly inefficient. Hence, since the obligation of transmitting the VGM was introduced more than two years ago, many actors in the logistics sector especially the freight forwarders are facing newly emerged issues and actually avoidable extra costs related to the current inefficient VGM submitting processes (Company XY, personal communication, November 21, 2018).

According to the freight forwarding company, there are three major challenges related to the current process of submitting the VGM data:

1. The timely and accurate collection of the VGM data through the shipper
2. The timely and accurate transmitting of the VGM data from the shipper to the freight forwarder
3. The timely and accurate transmitting of the VGM data from the freight forwarder to the respective carrier

These three key issues are related to the general issues of the supply chain visibility; especially the transparency lacks enormously throughout the processes resulting in discrepancies and trust issues between the involved parties (Company XY, personal communication, November 21, 2018).

4.3.1.3 Blockchain Solution

As the process of transmitting the VGM data between the parties involved in a shipment can be tedious and time intensive, the blockchain technology seems to provide a solution as illustrated in the following figure:

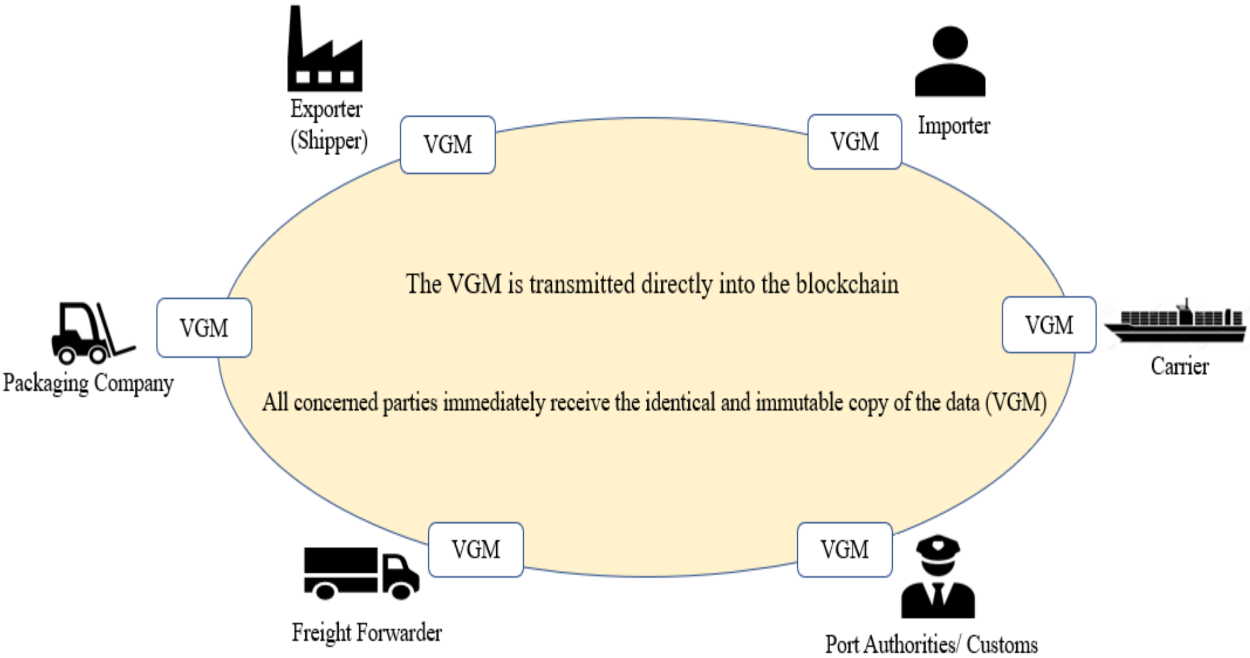


Figure 6: *Blockchain Solution for Transmitting the VGM data (own illustration based on the interviews with Company XY)*

The blockchain-based VGM concept diminishes the bilateral interaction between the involved parties as the responsible party provides the VGM data directly into the blockchain network. Accordingly, all the involved parties receive a copy of the data so that they can precisely trace which party submitted the data with the exact time (timestamp).

Therefore, the blockchain technology acts as a single source of truth from which the VGM data can be received. The blockchain approach could tremendously reduce time issues related to transmitting the VGM data. As soon as the VGM data is uploaded to the blockchain (regardless from which party), every participant would immediately receive the same copy of the data (Company XY, personal communication, November 30, 2018).

4.3.1.4 Potential Benefits

As illustrated in figure 6, the complexity of the VGM process could be tremendously optimised thanks to the single source of truth provide through the blockchain. The main benefit of this blockchain approach is that all VGM related data is submitted to the blockchain portal. That allows the participants to view the exact status of the VGM and remove off-chain communications which could speed up the whole process. Consequently, the degree of transparency is enhanced and improves the ease of doing business.

The interviewee emphasised that by implementing the blockchain approach for transmitting the VGM data, manual interfaces through employees are not required anymore removing one of the key issues of the current process since not all employees immediately forward the VGM information to the counterpart. Delays resulting from the late submission of the VGM data could accordingly be effectively decreased, ultimately benefiting all concerned parties. Furthermore, discrepancies among the parties regarding who is responsible for declaring the wrong VGM data would also diminish since every participant could prove who submitted the VGM to the blockchain. Indeed, there are currently many leading companies collaborating and working on blockchain-based VGM processes (Company XY, personal communication, November 30, 2018).

4.3.2 Blockchain-based Bill of Lading Concept

The second concept focuses on a more complex topic involving the blockchain-based concept of smart contracts which are one of the most promising features of the technology. Especially the process of transmitting the bill of lading is considered to be potentially optimised with utilising smart contracts. The hereby adopted information is also based predominantly on the interviews held with the freight forwarding company.

The company is currently working on a smart contract based solution for optimising processes in logistics. Similar to the VGM concept, first the purpose of the BL is to be explained with the current issues involved. Subsequently, based on the findings of the interviews, the blockchain solution will be presented.

4.3.2.1 Purpose of the BL

According to the freight forwarding company, the BL is a document of title which proves the ownership of the respective consignment. It is one of the most important documents involved in the international carriage of goods for all interested parties, whether the shipper, freight forwarder, carrier or the banks, it is a central document for conducting a transportation. The document confirms that the consignment has been received and loaded on board of the carrier’s vessel which therefore is obliged to deliver the goods to the consignee.

Hence, it also acts as a contract of carriage besides the title of ownership which determines that the owner of the BL is the owner of the respective goods (Company XY, personal communication, November 21, 2018).

The following figure illustrates the simplified process associated with the current process of exchanging the BL in a conventional transportation process.

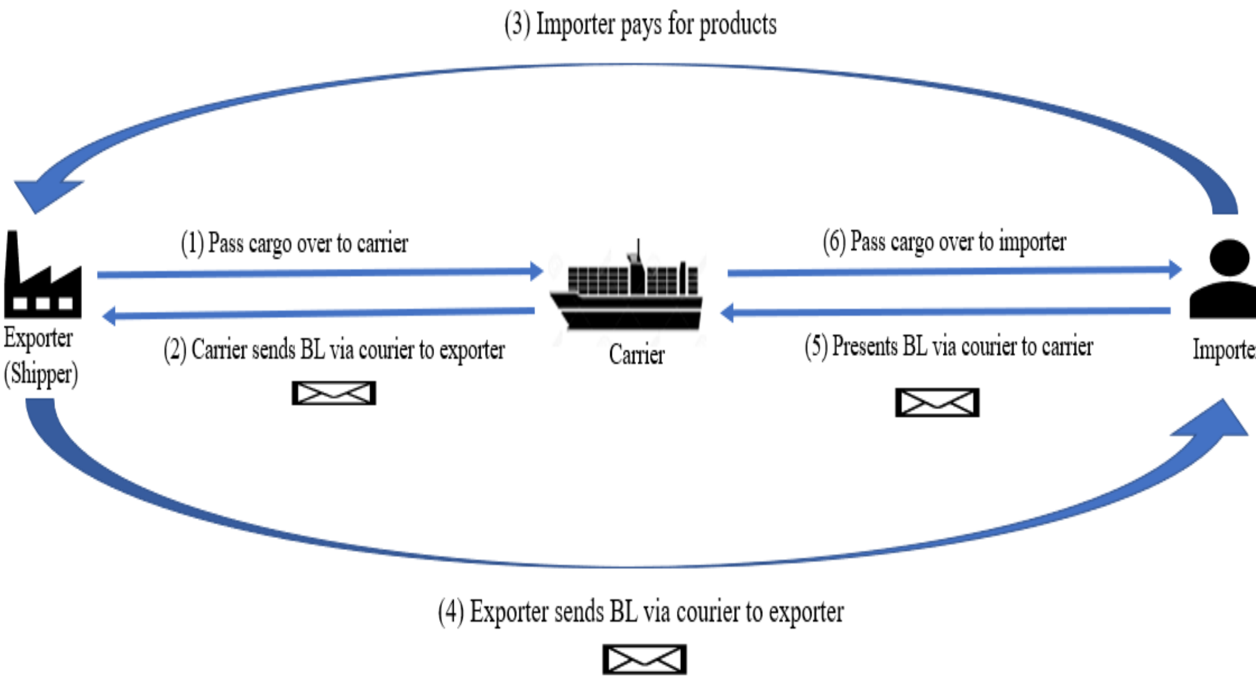


Figure 7: *Current Process of Transmitting the BL (own illustration based on the interviews with Company XY)*

The essential aspect of the BL is that it is not transported with the actual consignment from one port to another. Hence, if a consignment is transported by sea from port to port, the BL is a document that is generally conveyed via a courier to the next port to ensure that if the consignment is lost or damaged in the transportation process, the BL would be preserved as the evidence of the value of the goods. Conveying the BL contains the following steps; first, after receiving the cargo, the carrier has to issue the BL and convey it via an express courier service to the actual shipper (exporter) of the goods.

After receiving the money for the goods, the shipper has to send the BL again with an express courier to the importer of the shipment. In the last step, the importer has to present the BL (usually involving again an express courier service) at the discharge port to the carrier in order to take over the respective consignment at the port of discharge.

This illustration is extremely simplified as in this process usually more actors are involved including the freight forwarders, the banks and the (port) authorities which all have additional interests in the BL processes. The data stored on a BL is crucial as it contains all necessary information about the shipment as among others, the transportation requirements, the quantity of the goods, shipment steps and the parties involved in the transportation. Moreover, the BL contains a description of how the respective goods should be handled and billed (Company XY, personal communication, November 21, 2018).

Furthermore, as the BL is a document of title, it is an important legal document which is also associated with the procedures related to the banking system in which the letter of credit is linked with the BL. Banks have to verify that the data written on the BL complies with the data on the letter of credit which further indicates the importance of the BL (Company XY, personal communication, November 21, 2018).

4.3.2.2 Issues of the Current Process

As transmitting the BL is not processed electronically, it still relies on physical paper processes making it consequently slow and expensive. Currently the average cost of sending a BL from one port to the next costs about USD 100. With over 50 million BL´s created each year, the BL´s is an industry that is worth over USD 5 billion of courier costs each year (Cf. Mele, 2018; Cargox.io, 2018).

Additionally, the average time of exchanging a BL takes about five to ten days; depending on how far the ports are from each other. Since the BL has to be predominantly sent in its paper-form via a courier between the involved parties, the speed inefficiency is one of the most significant issues related to the BL processes which unnecessarily increases the total transportation costs.

Moreover, as the BL is only valid in the original form, it further complicates and slows down the whole transportation process. Thus, according to the freight forwarding company which deals with tens of thousands of BL´s, transmitting the BL is a significant issue related to high costs and long waiting times. What is even more expensive, is if the actual container reaches the port prior to the BL in which it gets detained at the port involving high waiting fees claimed by the carrier. However, the worst scenarios are related to complications of when the BL gets lost as there is only one original copy of the BL (Company XY, personal communication, November 21, 2018).

When the BL is lost, it could take several weeks until a new BL is issued which could lead to enormous costs not only related to demurrage but also to manufacturing downtime of factories which could result in considerable losses. Moreover, a delayed BL could negatively impact time-sensitive products as pharmaceuticals or perishable goods which have to be delivered as fast as possible to the destination. Furthermore, frauds and bribes are still an unsolved problem related to illicit processes related to the BL as under-invoicing the actual value of the consignment on the BL in order to reduce taxation in the respective country.

The logistics industry has recognised these issues related to the paper-based BL, and there is a common objective to overcome them. Therefore, there are some attempts to solve these problems in digitising the BL. However, none of them has gained a widespread adoption through the industry as central problems like transparency and trust issues have still not been solved. Moreover, the problem with the e-BL or digital BL is similar to the double spending problem of the blockchain technology in which there has to be only one original copy acknowledged by the network.

Nevertheless, with the emergence of the blockchain technology and the hereby involvement of the smart contracts, there could be potential solutions to counter these problems (Company XY, personal communication, November 21, 2018).

4.3.2.3 Blockchain Solution

The blockchain based solution of digitising the BL could be implemented in which the BL is uploaded as a smart contract into the blockchain network. As illustrated in figure 8 the smart contract based BL remains accessible through the blockchain to every party at any time. Once the BL is added to the network, it serves as a single source of truth.

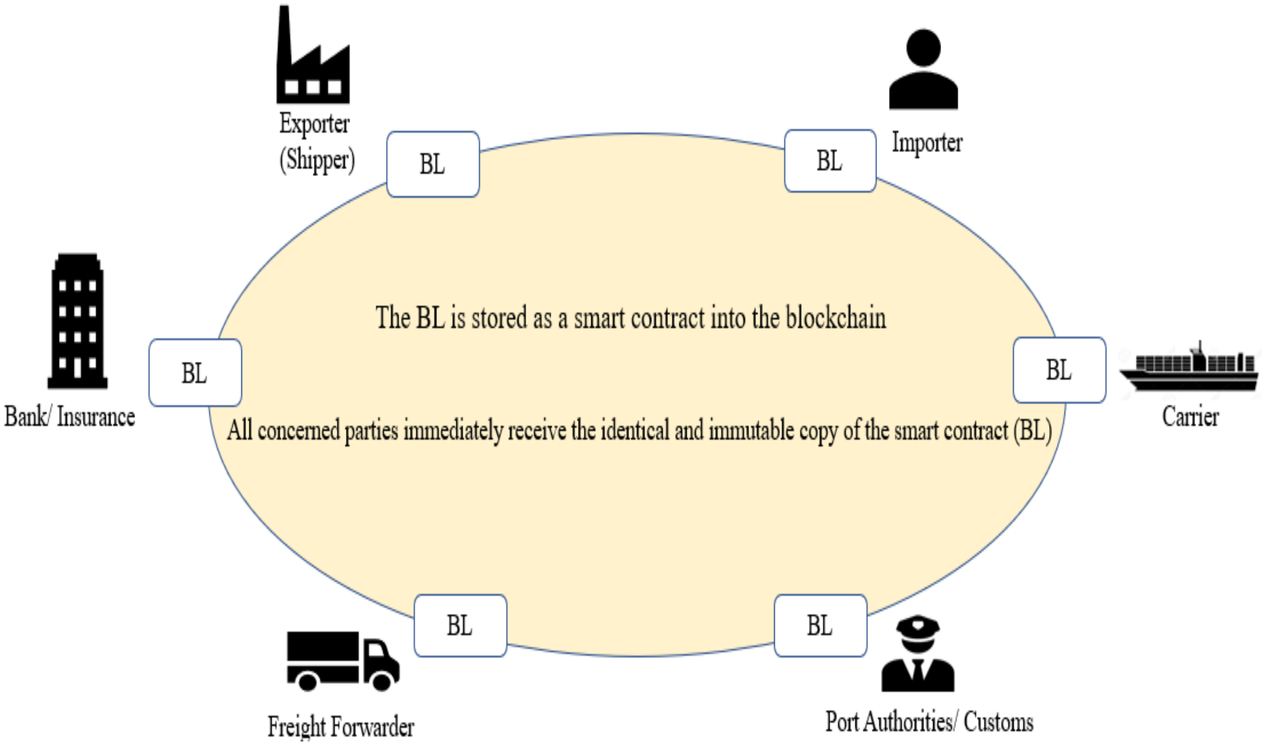


Figure 8: *Blockchain Solution for Transmitting the BL (own illustration based on the interviews with Company XY)*

This kind of a blockchain application could be realised for a permissioned blockchain with restricted access only to the parties required for the transportation process. The parties have to collaborate on setting the rules and conditions of this approach with an appropriate consensus mechanism. As soon as the carrier receives the cargo, he could upload the BL as a smart contract into the blockchain network through a User-Interface. The on the smart contract based BL could contain all the information required like the standard paper-based BL. With this approach, every party would become a participating node with equal transparency in viewing the BL.

Therefore, the BL would remain a single source of truth in the network. The involved nodes could agree with the consensus mechanism on the authenticity of the BL which could be revalidated in every step of the transportation process.

Every single step involved within the smart contract based BL would be recorded on the blockchain with full transparency granted to every party (Company XY, personal communication, November 30, 2018). Instead of sending the BL several times with a courier between the parties, the blockchain solution would provide one single BL visible to all parties in real time which could tremendously cut costs related to the back and forth transportation of the BL.

Furthermore, with the smart contract approach, the loss of the BL is practically not possible as it would be uploaded onto the blockchain with every party holding a copy of the original. Due to the fact that a smart contract runs on self-executing computer codes, the execution of the BL agreements could become automated.

Accordingly, after certain events, as for example when the cargo arrives at the port of delivery, the concerned node could approve the discharge of the cargo, and the smart contract would automatically trigger the permission of realising and handing over the cargo from the carrier to the importer as already agreed to in the code. Therefore, the whole business operations would become more streamlined throughout the whole process.

Frauds could also be prevented as the BL is immutable and consistently stored on the blockchain making every alteration attempt immediately visible to the network, requiring a consensus to approve the alteration (Company XY, personal communication, November 30, 2018).

4.3.2.4 Potential Benefits

Several benefits could emerge in utilising the blockchain technology with the smart contracts for digitising the BL processes. According to the blockchain expert, there are two key benefits, affecting every interested party. The first key benefit is that the BL would create more efficiency as every party would be an active part of the creation process in real time as the BL would always be accessible for every node in the network. Hence, if all parties could work together on the same version, the “bilateral ping pong” of creating drafts would be prevented (Company XY, personal communication, November 30, 2018).

The second key benefit of this approach is that the excessive expenditure of time, related to the transportation of the BL´s via couriers would be tremendously reduced as the BL could be simply uploaded to the network with immediate access provided to all parties.

That would not only lead to savings related to courier costs but would also prevent a delayed BL which would diminish costs as demurrage caused by delays. Since the information of the BL´s would be due to the blockchain approach immediately available to all concerned parties, involved banks could pre-audit the BL and verify it with the letter of credit which would speed up the overall verification.

Moreover, as the current process of handling paper-based BL´s allows for fraudulent attempts, the key feature of the immutability provided by the blockchain, could potentially add a higher security standard to the BL processes (Company XY, personal communication, November 30, 2018).

4.3.3 Blockchain-based Container Release

The last concept deals with a blockchain-based releasing approach of containers at the port of Hamburg in Germany the so-called “Release Order based on Blockchain” project in short “RObоB”. The project is a collaboration between several major companies, among others the Hamburg based port-communication-systems provider DAKOSY which leads the project (Schwanke, personal communication, January 18, 2019).

The collaboration aims to examine the possibility of blockchain-based application in port logistics in order to evaluate possible economical as well as ecological gains (Schwanke, personal communication, January 18, 2019). Hence, in the following, the “RoboB” concept will be critically analysed. The hereby acquired data is based on the interviews held with Mr Schwanke and Mr Malzahn.

First, the current approach of releasing containers at the port of Hamburg will be discussed, following with the hereby involved issues. Afterwards, the blockchain solution will be analysed in order to subsequently determine the possible benefits of the blockchain solution.

4.3.3.1 Current Approach of Releasing Containers at the Port of Hamburg

The current approach of releasing the containers from the carrier to the logistics provider at the port contains the following steps. First, as soon as the carrier arrives at the port of discharge and receives the reimbursement for the transportation of the container, he issues accordingly a "release reference" for the containers (Schwanke, personal communication, January 18, 2019). Afterwards, the reference is communicated through two channels to the recipient of the container (logistics provider) and the port authority.

The reference is related to the Bill of Lading as for one BL there is one release reference. The port authority on the on hand receives the reference electronically with the so-called "EDIFACT" message. The logistics provider, on the other hand, receives the reference commonly manually on the phone or in an email issued by the respective carrier (Schwanke, personal communication, January 18, 2019).

Subsequently, the logistics provider forwards the release reference to the trucker (haulage company) or to a subcontractor who is requested to pick up the container at the port and to transport it accordingly to its destination. To do so, as soon as the trucker arrives at the port to take over the respective container, he has to show the particular release reference, commonly in as an SMS or paper form to the port authority (Schwanke, personal communication, January 18, 2019).

The port authority, in turn, is then able to authenticate the release reference in which they compare it with the reference they prior received from the carrier. Accordingly, the port authority only releases the container to the trucker, when the release reference is valid. With this approach, the reference is communicated several times through several means between the parties which is a complicated process leading to frequent discrepancies between the parties (Schwanke and Malzahn, personal communication, January 24, 2019).

However, not all parties suffer equally from this process. As for the carrier, the main business is the transportation of the containers from one port to another and as soon as the containers arrive at the port of discharge, the main business for the carrier is more or less completed. For the logistics provider though, who is in charge of the pre-carriage as well as the transportation of the container from the port to the destination, this process can be tedious and quite costly (Schwanke and Malzahn, personal communication, January 24, 2019).

4.3.3.2 Issues of the Current Process

This process is not efficient since the manual-conducted transfer of the release reference leads to disruptions in the communication flow. Moreover, as the whole process is not automated and the involved parties are utilising different information-gathering systems, delays are predestined which leads to additional expense.

Another issue is that the process of releasing the reference is not regarded equally important among all involved parties since as aforementioned, there is no significant added value to the carrier for optimising the process for whom the business is only to transport the container between the ports. For the logistics provider time is essential as he aims to transport the goods as quick as possible to the customer (Schwanke and Malzahn, personal communication, January 24, 2019).

Moreover, as the majority of the data communication process is based on manual processes, there is also the possibility that inaccurate data gets transmitted which further complicates and ultimately delays the whole process. Therefore, everything that delays the process ultimately delays the delivery of the goods.

That is also problematic for manufacturing companies who depend on the timely delivery of their carriage as it is crucial for complying with their production flows. To put it in a nutshell, the most critical issues regarding the release of containers at the ports, are delays related to the inefficiency of the current concept which lacks in automatization (Schwanke and Malzahn, personal communication, January 24, 2019).

4.3.3.3 Blockchain Solution

The "ROboB" blockchain solution for releasing the reference aims to automate the whole process by reducing manual interfaces between the involved parties. Instead of communicating the release reference to the logistics provider and the port authority, the carrier uploads the release reference onto the blockchain network.

Subsequently, every party involved immediately receives the same copy of the reference and validates it accordingly. With this, it is essential that the basic process of the container release remains almost the same in which only the right of taking over the container is communicated through other means, namely through the blockchain. Hence, only the exchange of the right for overtaking the container would be communicated through the blockchain in the form of an arbitrary hash. Only the involved parties would be allowed to join the network and access the data (Schwanke and Malzahn, personal communication, January 24, 2019).

Therefore, the network would probably be designed as a private blockchain as the concerned parties have an interest to not to disclose their business relations to outside parties. According to the interviewees, to be successfully implemented, the blockchain approach has to overcome the following challenges: First, the concerned parties have to collaborate which is challenging as the port of Hamburg has about 40 carriers and several hundred logistics and haulage providers. Another challenge is that all the affected systems have to be synchronised and adjusted towards the blockchain approach (Schwanke and Malzahn, personal communication, January 24, 2019).

However, due to the variety of concerned parties and conflicting interests, the project aims to generally determine whether the blockchain technology would benefit the process or not. The final evaluations of the project are expected to be submitted in 2020 (Schwanke and Malzahn, personal communication, January 24, 2019).

4.3.3.4 Potential Benefits

The benefits of adopting the blockchain technology for releasing the containers could potentially benefit all involved parties.

First of all, in utilising the blockchain technology for uploading the release reference to the blockchain would automatically remove manual interferences and therefore enormously reduce inaccurate data transmitting (Schwanke and Malzahn, personal communication, January 24, 2019).

Another key benefit is the fact that the whole process would become more automated and thus would speed up processes in port logistics. That would yield to costs savings for every party even for the carriers which would accordingly save time. The blockchain process would additionally increase security as the blockchain implies a built-in security standard especially the access protection of valuable information. If the "ROboB project is successful, the overall benefit is expected to be a general qualitative improvement of the data flow in port communications (Schwanke and Malzahn, personal communication, January 24, 2019).

4.4 Comparing a Blockchain with a Conventional Database

After analysing possible concepts of implementing the blockchain technology in logistics and supply chain processes, in the following, it is important to distinguish a blockchain from a traditional database. Businesses thinking about to implement the blockchain technology into their processes should prior assess the blockchain approach with emphasis on the related pros and cons as although the blockchain technology is per se a database, there are fundamental differences related to a conventional database, especially in the respective functionalities (Schwanke, personal communication, February 20, 2019). Therefore, the following chapter aims to compare a traditional database with the blockchain technology.

The first part of the chapter explains the general concept of a conventional database, followed by examining the idea of the distributed databases. Subsequently, the key differences of both a conventional database and a blockchain database are to be determined.

Accordingly, the chapter concludes with the respective use cases for both concepts. To prevent misunderstandings related to the openness of the blockchain, in the following only the public approach of the blockchain will be examined and compared with the conventional database.

4.4.1 Conventional Databases

A typical database is a data structure in which different kinds of information get stored. It utilises a client-server network architecture, in which the user (referred to as a client), can modify the data stored within the database, which is typically administrated by a designated authority managing a centralised server. The authority validates a client's credentials prior to providing access to the respective database. Collectively known as the CRUD commands, a client can perform four general functions within a conventional database which are: create, read, update and delete (Cf. Tabora, 2018; Ray, 2017 a).

The following illustration represents a typical spreadsheet database which is the most popular form of a database used by individuals and companies as it is designed to store a high amount of information in a clear and easy manageable structure (Cf. Tabora, 2018; Ray, 2017 a).

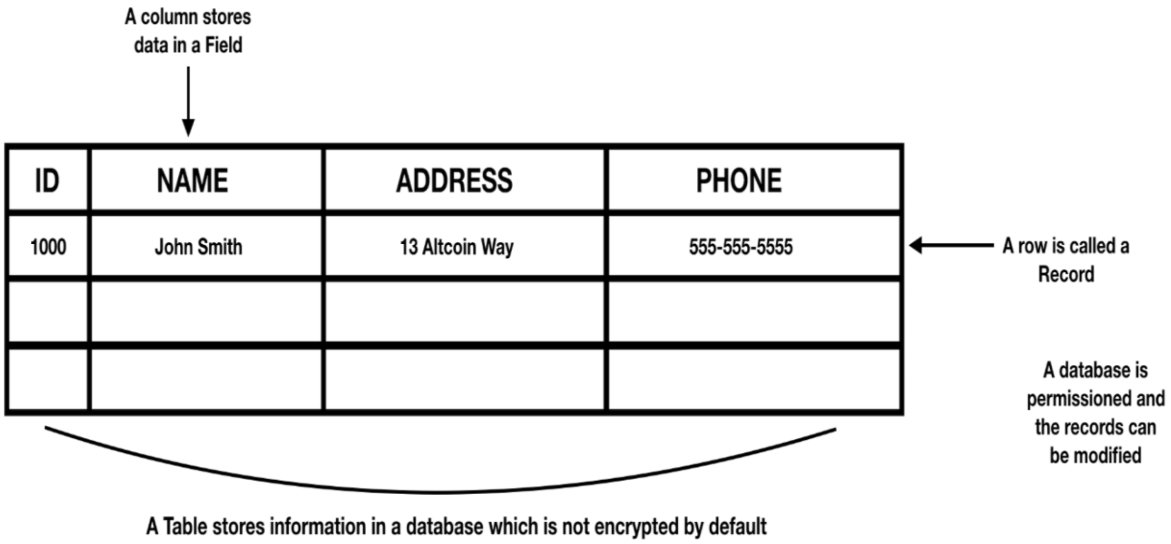


Figure 9: *Typical Spreadsheet Database (Tabora, 2018)*

Initially, conventional databases were structured to store flat file hierarchical systems which enabled the simple storage and accumulation of data. As data was getting more and more complex, the databases adopted the relational storage process. A database management system organises the information within a database.

Although a database can structure the data storage in many forms, the most popular utilisation is through the relational database which stores each data in a table e.g. storing data in a spreadsheet in which a row indicates an item (subject-specific called attribute) and a column indicating the respective properties of the item (above table).

Since the relational database enables one to interconnect several databases with each other, it enormously facilitated the storing of complex data structures. Furthermore, a relational database is able to structure data in different manners, for example in a collection of schemas, tables, queries or reports (Cf. Tabora, 2018; Ray, 2017 a; Rouse, n.d.).

4.4.2 Distributed Databases

A distributed database is similar to an ordinary database with the difference that portions of the distributed database are stored on a set of computers located in multiple distributed physical locations (Its.bldrdoc.gov, 1996). The processing and synchronisation of these databases are distributed among several nodes which are maintaining and representing a data communication network. A centralised distributed database management system (DDBMS) is responsible for structuring as well as managing the data in a logical manner in order to administer the data as if it were stored in the same location (Özsu and Valduriez, 2011 pp. 2-4).

Consequently, the DDBMS enables the periodical synchronisation of all data to ensure that the occurred updates and deletes which are performed on the data at any location are to be automatically synchronised among all nodes within the network (Rouse, n.d.).

Furthermore, a distributed database can be structured in a homogenous or heterogeneous manner. The nodes in the homogeneously distributed database network are all aware of each other and are running the same underlying hardware involving the same database systems as well as the same operating systems. Whereas in a heterogeneous distributed database network, the nodes need not necessarily be aware of each other and they could use different databases, hardware or database applications (Cf. Thakur, n.d.; DBMS, 2017).

Whether distributed or not, a database always requires a certain degree of control commonly involving a single entity/ authority to fulfil this task. Moreover, a database is permissioned in which users require permission to join the network or at least functionalities of it. Hence, a database is highly centralised which provides the required security and trust into the network (Cf. Tabora, 2018; Ray, 2017 a).

4.4.3 Blockchain Database

The database of the blockchain contains blocks with a certain number of transactions and as soon as the transactions are bundled, the block can be approved and verified by the network in order to be added as a new block to the blockchain.

A block also stores transactions of previously verified blocks, hence, as illustrated in the following figure, the blockchain database stores data as a “linked list” in which all blocks are interlinked with data from the previous blocks (Cf. Ganne, 2018 pp. 115-116; Christidis and Devetsikiotis 2016 pp. 2293-2294).

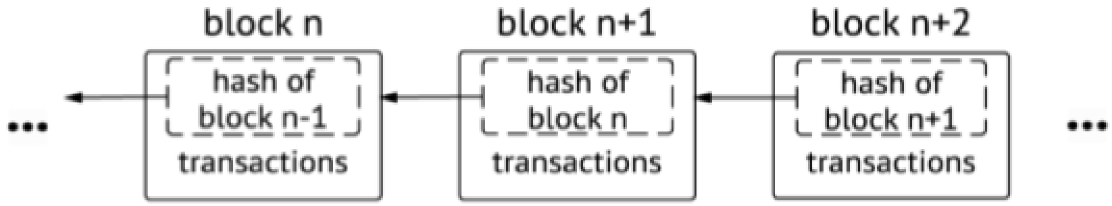


Figure 10: *Structure of a Blockchain Transaction (Christidis and Devetsikiotis, 2016 p. 2293)*

The key aspect of the blockchain database is that it can be distributed among all nodes involved in the network with decentralising the processing and managing aspects. Thus, if one computer is shut down or gets hacked, the single point of failure would be prevented. With utilising a consensus algorithm as the PoW mechanism, the database of the blockchain is governed by the whole community instead of a single authority. It is an immutable database meaning that once a transaction is added to the blockchain, it cannot be altered (Cf. Christidis and Devetsikiotis 2016 p. 2293; Ganne, 2018 p. 10; Tabora, 2018).

However, to understand practical use cases for the blockchain technology, it is essential to determine the key differences of the two databases beforehand. Hence, the following section aims to compare the blockchain approach with traditional databases.

4.4.4 Key Differences

The main differences between a blockchain and a distributed database lay in the respective structure and functionalities as illustrated in the following table.

DATABASE	BLOCKCHAIN
Centralized	Decentralized
Permissioned	Permissionless
Requires administrator	No administrator

Table 1: *Key Differences between a Conventional Database and a Blockchain (Tabora, 2018)*

The blockchain by its underlying design provides basically two general functions based on the “append-only” structure in which all data added to the blockchain is permanently and immutably stored within the “chain of blocks” (Cf. Ray, 2017 a; Morabito, 2017 pp. 22.23; Ganne, 2018 p. 113).

These functions are the write and validate functions in which nodes can retrieve and approve data from the blockchain. The writing operation enables participants to add (append) data as a subsequent block to the blockchain. By linking the hashes of the blocks with each other, every new block gets appended to the blockchain. Whereas in a conventional database, the structure allows clients to easily modify and delete data which is simply not possible in the blockchain network (Cf. Ray, 2017 a; Tabora, 2018; Ganne, 2018 pp. 10-11).

Another major difference between a blockchain and a database is that a conventional database uses a client-server network architecture that means that the control of the database is consistently maintained by the administrator (centralised entity) who runs the database and issues permits to other nodes requesting to join the network. In contrast, in the blockchain approach, the network is maintained through several nodes in a distributed structure. All nodes are able to freely participate in the blockchain network and to verify the data that is recorded and stored on the blockchain in which they have to reach consensus. All of these nodes participate in the operation and administration of the network (Cf. Ray, 2017 a; Tabora, 2018).

Although there are several approaches of structuring a blockchain with the aim of restricting its openness (e.g. private blockchains), the general idea of the blockchain is to distribute its ledger among the participating nodes avoiding any centralisation (Nakamoto, 2008 p. 1). Therefore, data can be distributed among the network without requiring an intermediary or administrator to validate transactions and maintain the network. Moreover, in a blockchain network, the respective consensus mechanism ensures the validation of the data communicated within the network as well as the corresponding synchronisation across the community (Schwanke, personal communication, February 20, 2019).

In a traditional database the transparency is more or less restricted as usually, only the central authority enjoys full visibility of the content in the database.bAny requests from nodes go through this central entity which holds the power to either accept or reject a request. In a blockchain it is different as there is no central authority, the transparency is granted to every node equally, and any requests go throughout the network validating itself (Cf. Schwanke and Malzahn, personal communication, January 24, 2019; Ganne, 2018 p. 56).

Accordingly, the different inherent structures and functions of a traditional database and a blockchain lead to several advantages and disadvantages which are to be examined in the following assessment part of the thesis.

4.4.5 Deciding whether to use a Conventional Database or a Blockchain

First of all, it should be mentioned that generally it highly depends on the individual circumstances whether or not to utilise the blockchain technology, as for some businesses the blockchain approach would not be suitable while in other cases it would be more profitable to adopt a blockchain application instead of using a standard database.

For many companies who are dealing with high amounts of data, conventional databases with a centralised management system are better solutions to accommodate their data traffic since they are designed to scale masses of records and transactions within seconds. For example, the centralised online payment system PayPal scales up to 1300 transactions per second compared to only about seven transactions per second in the Bitcoin ecosystem (Cf. Wüst and Gervais, n.d. p. 3: Medium.com, 2018 c). On the other hand, when there is a lack of trust between several parties across multiple locations, the blockchain approach may provide a suitable solution for exchanging data (Wüst and Gervais, n.d. p. 2).

5 Assessment

This chapter measures the key benefits of the blockchain technology as well as challenges and limitations the technology is currently facing. In the first section the advantages of blockchain approaches are to be analysed. This is followed with examining the challenges of the blockchain with emphasis on the current limitations concluding with a SWOT illustration. The final section is concerned with the legal consideration of the technology especially related to smart contracts.

5.1 Advantages of the Blockchain Technology

As the blockchain technology introduced new means of storing and processing valuable data, many businesses could potentially benefit from blockchain-based applications. Especially companies who wish to disintermediate third parties while struggling with trust issues with their counterparts. In the following, the key benefits provided by the blockchain technology are listed.

5.1.1 Decentralisation and Disintermediation

The first key advantage of the Blockchain-based approaches is the fact that applications running on a blockchain platform do not require a central administrator who runs the network as transactions are basically processed via the community of nodes with reaching a consensus on the respective processes. Thus, every participant of the blockchain network simultaneously creates the same shared record of transactions without the need for an intermediary requested to validate. As the blockchain technology aims to provide a decentralised databases model in which the data is distributed among several nodes, the blockchain approaches are accordingly highly fault tolerant (Cf. Antonopoulos, 2014 p. 181; Swan, 2015 p. 27 Morabito, 2017 p. 69; Greenspan, 2016).

The nodes which participate within the network are constantly comparing data with each other, assuring that data matches previous records on the blockchain ledger. Since each piece of data gets copied to all nodes in the network, security immensely increases. Hence, if a node gets hacked, the hacker would need to manipulate the data additionally on all other nodes in the network which deters attacks against a blockchain network.

Accordingly, the single point of failure is prevented as the blockchain network does not rely on only one node but on the whole community. To put it in a nutshell, the blockchain approaches allow different parties (with different interests) which have trust issues to share valuable data without the need of a central entity managing the network (Wüst and Gervais, n.d. p. 2; Greenspan, 2016).

5.1.2 Improving Trust Issues

By utilising the blockchain technology with the decentralised verification process of transactions, third parties are not required any more to replace trust issues between parties. The third party or trustee is replaced by utilising the particular consensus algorithm of the blockchain network. Involved parties who have different interests in the supply chain can rely on the self-administered approach of the blockchain.

Moreover, by establishing the blockchain technology as the underlying infrastructure of the communication process, the involved parties are able to interact with each other with equal rights and responsibilities which potentially enhances their relationship in which they do not have to be concerned with which degree they can or cannot trust each other (Cf. Antonopoulos, 2014 p. 113; Goldmansachs.com, n.d.).

Instead of further complicating the shipment process by adding an additional party solving trust issues, the blockchain approach in fact "digitises" the attribute of trust by distributing it among the nodes of the blockchain network (Goldmansachs.com, n.d.).

5.1.3 Immutability

Since the blockchain approach stores data in a permanent and immutable chain of blocks, the participating nodes can be sure that the relevant information is accurate and validated. That also increases the security aspects of the blockchain since the immutable audit trail proves the authenticity of every piece of data making it reliable and tamper-proof (Cf. Antonopoulos, 2014 pp. 163-164; Morabito, 2017 p. 71).

5.1.4 Security

As the (public) blockchain runs without a central authority, it makes fraudulent attacks like service denial attacks extremely difficult since there is no single point of failure which adds security to the network.

Altering a single transaction within the blockchain requires an enormous recalculation of the hashes for every block added after the modified block which enhances the security protection. Hence, the blockchain consists of a consensus mechanism which replaces a central authority but still provides a transparent and trustworthy concept for data transactions.

Furthermore, thanks to the sophisticated hashing mechanism and the public key infrastructure of the blockchain, the blockchain offers a high degree of security among its network. Moreover, tampering with data on blocks of a blockchain requires an unreasonable amount of computer resources making it virtually unprofitable (Cf. Gramatke and Sallaba, n.d.; Ganne, 2018 pp. 10-11; Tabora, 2018).

5.2 Challenges and Limitations Facing the Blockchain Technology

As it seems, the blockchain technology has lots of critical advantages which could provide unprecedented possibilities for several industries. However, since the blockchain is a relatively new technology, there are also challenges and weaknesses that currently limit a broader adoption. In the following, there are some general weaknesses of the blockchain technology.

5.2.1 Size

A further issue related to the (distributed) blockchain is the fact that when a blockchain gets bigger, it automatically requires more space for storing data, hence slowing the whole network down.

The size of the Bitcoin blockchain, for example, is already bigger than 200 GB (as in January 2019), and most nodes are not able to download and update the whole blockchain in which they are only able to copy a part of it (Cf. Statista.com, 2019; Swan, 2015 p. 82). That is caused by the fact that it simply takes longer to copy the blockchain ledger with an increasing size. Depending on the internet capacity, it may take hours or even days to obtain a completely updated blockchain (Swan, 2015 p. 82).

5.2.2 Consensus Mechanisms

Due to the design of the blockchain technology, a consensus mechanism is required to validate the respective transactions and maintain the blockchain network. However, there is no optimal consensus mechanism for all blockchain applications as they highly differ with respect to the individual use cases. All consensus mechanisms related to the blockchain technology have their specific flaws.

In the PoW mechanism in which miners get incentivised via transaction fees to mine blocks, the fees automatically increase as soon as the demand is high. Keeping transaction fees low or even removing them would lead to severe issues for the network as it requires miners to validate transactions. On the other hand, the higher the transaction fees, the more deterred the nodes get in participating in the network (Cf. Resende, 2017; Ganne, 2018 pp. 117-118).

In the PoS approach, the disadvantage is that the higher the stake of the validator within the network, the higher the probability to be selected to mine the blocks, making PoS consensus more or less unfair (Cf. Morabito, 2017 pp. 11-12; Blockgeeks.com, n.d. b). The PoA consensus mechanism requires validators to be selected beforehand who manage and maintain the network which tends to be a more centralised consensus mechanism (Cf. Medium.com, 2017 a; Curran, 2018).

5.2.3 Scalability

The decentralisation as well as disintermediation of the respective blockchain networks lead to serious scalability issues. Since each block of the blockchain has a fixed size and capacity, increasing the transaction volume is not possible unless major modifications of the blockchain technology are made. Moreover, the speed is also restricted always depending on the consensus mechanism which takes about 10 minutes to complete. However, as the scalability issue is regarded as the major obstacle of the blockchain approach, there are serious attempts to overcome it as there are developments as the lightning network which promises to enormously enhance the scalability. Before the blockchain can become a mainstream adopted technology, it has to overcome the issue of its low scalability (Cf. Morabito, 2017 p. 135; Ganne, 2018 pp. 90-93; Schor, 2018).

5.2.4 Inefficiency

Since the initial idea of the blockchain technology is that the network is typically not governed by a central authority, the nodes in the network have therefore to fulfil the verification processes of the transactions.

The consensus mechanisms such as PoW are highly are considered as inefficient and wasting valuable computational power since by design every node performs the same task continuously. Consequently, an enormous amount of energy and resources is unnecessarily required. As a part of the random selection process of validating a block, the capacity throughput of the blockchain is relatively low. Hence, it makes the blockchain less efficient than centralised transaction process providers (Cf. Antonopoulos, 2014 p. 277; Swan, 2015 pp. 82-83).

5.3 SWOT Analysis

The following SWOT illustration summarizes the overall key advantages and disadvantages as well as the opportunities and challenges of the blockchain technology related to logistics and supply chain.

Internal	**Strengths**	**Weaknesses**
	- Traceability - Transparency - Trust - Distributed nature - Immutability - Equality - Reliability - Faster processing of transactions - Single source of truth	- Scalability - Inefficiency in regard to functionalities (only write and validate functions) - Consensus mechanisms (all have their issues) - Lack of leadership - Absence of standards - Size restrictions - Irrevocability of smart contracts
External	**Opportunities**	**Threats**
	- Improvement of overall supply chain visibility - Guarantee for authenticity of data - High security standard - Disintermediation - Reduce fraud - Acceleration of processes - Reduce documentation costs - Being the underlying technology for the IoT environment - Elimination of ambiguities	- Still in development phase - Lack of understanding - Legal and regulatory obstacles - Uncertainties about successful implementation in a complex environment - Uncertainties of digitising vital documents - Lack of required collaboration of parties (highly competitive nature of logistics sector)

Table 2: *SWOT Analysis of the Blockchain Technology in Logistics and Supply Chain (own illustration)*

As discussed in the analysing part of the thesis, there are indeed effective application possibilities of the blockchain technology to optimise logistical and supply chain processes. The benefits of the blockchain are unique and the actors could increase their efficiency by utilising an appropriate blockchain solution. Nevertheless, as discussed, there are critical challenges which limit the overall potential of the blockchain technology.

Due to the fact that the blockchain can be programmed in a versatile way, there is a plethora of advantages and disadvantages regarding the specific use cases of the respective blockchain application. However, since the blockchain technology is in this thesis discussed from a generic perspective without going into the details of the technicalities, the above SWOT analysis just summarize the general advantages and challenges of the technology in logistics and supply chain which are kept to a minimum.

5.4 Legal and Regulatory Considerations

Besides the earlier mentioned challenges and limitation related to possible applications of the blockchain technology into the logistics sector, there are also legal and regulatory discrepancies about the jurisdiction of the whole concept of the blockchain approach. Due to the rapid development of the blockchain technology, laws and regulations have not yet fully defined the legal status of the innovative technology.

What further complicates the matter is the fact that the diversity of the logistics industry involves numerous laws and regulations across multiple parties with partly conflicting interests. Even with disregarding the current digital revolution the logistics sector is currently facing, there are still many legal discrepancies between the actors, involving international and national regulations, laws and jurisdictions (Company XY, personal communication, November 30, 2018).

Therefore, the blockchain technology leads to uncertainties about overcoming legal considerations and regulatory limitations. As there are attempts to digitise transportation documents with the blockchain technology, legal issues automatically arise since there are specific jurisdictions clearly defining the legal status of these documents. For example, as the BL is a legal document, in many jurisdictions, it is required to present the original BL in its paper form to respective authorities (Cf. Company XY, personal communication, November 30, 2018; Tricoli, 2018). The customs authorities in Brazil, for instance, require from every importer to submit the original BL to the port authorities, therefore digitising the BL for shipments to Brazil would be currently a considerable issue (Company XY, personal communication, November 30, 2018).

However, when considered from a logical part, when more and more companies adopt the blockchain technology into their supply chain processes and the respective legislations amend their regulations to facilitate the adoption of blockchain-based applications, countries with restricting jurisdictions could be pushed to adjust their policies to facilitate possible blockchain applications in order to stay competitive.

At the current stage of development, the legal regulation of the documents involved in logistical processes is one of the key issues restricting a wider acceptance of blockchain-based applications in the logistics sector (Company XY, personal communication, November 30, 2018).

6 Conclusion

The following chapter contains important findings as well as the conclusion of the thesis. First, in order to provide a sophisticated summary, the two predetermined research questions are to be answered. Subsequently, the final section concludes with a summary of the overall findings of the thesis.

6.1 Answering the Research Questions

1. **What is the blockchain technology, how does it work and what are the potential key advantages of adopting it into logistical processes?**

The first research question was about analysing what the blockchain technology is as well as determining the key advantages of the blockchain technology. As in the literature review described, the blockchain approach belongs under the umbrella term distributed ledger technologies in which data is distributed among the involved participants.

This kind of technology is a new concept of recording valuable data in a new distributed approach while commonly disintermediating third parties. The blockchain particularly stores data within a “linked list” of blocks which contain specific information about the stored data and the hash of the previous block making the blockchain ledger immutable. Additionally, the transparency and security mechanisms of the blockchain technology grants all in the supply chain involved parties a high degree of equally distributed trust.

The key advantages of adopting the blockchain approach into the logistics process are versatile. It could be utilised as the underlying technology for valuable data exchange directly between the involved supply chain actors while simultaneously disintermediating third parties. The information involved in the transportation process, as well as the documents, could be uploaded to the blockchain network and therefore provide one single source of truth. Whether it is the VGM data or the release reference at the port of discharge, all participants involved in the network would be able to receive the immutable data immediately and track who uploaded the information at which exact time.

Moreover, the feature of smart contracts enables for the digitisation of documents as for the BL or the letter of credit, which could potentially enormously speed up whole transportation processes as well as decisively reduce the transportation costs. Indeed, the blockchain approach could provide strategic advantages to companies which is why a plethora of major actors in the logistics sector are developing their own blockchain-based solutions in which they expect future gains.

2. **What are the risks and key challenges facing a potential blockchain adoption and how likely is its integration into the logistics sector?**

Due to the fact that the blockchain is a relatively new technology which is still in the developmental phase, there are also key challenges and limitations the technology is currently facing. The second research question was about how to address these challenges as well as to critically assess to which extent the blockchain technology could be integrated into the logistics sector and supply chain processes. Hereby, the scalability is a significant limitation of the (public) blockchain compared to conventional databases. The processing time of transactions is not competitive enough to attract a broader interest.

Moreover, new communicating issues could occur when involved blockchain participants are not yet at the same technological level as their counterparts. That could mainly affect the small and medium-size companies which lack the means of immediately adopting widespread blockchain applications within their supply chains. Besides the technical challenges, the blockchain technology also has to overcome legal and regulatory issues as the general jurisdiction of the blockchain technology is still in progress.

Further, it will be challenging to adjust already implemented regulations and laws related to digitising transportation documents. As mentioned by the interviewee Mr Schwanke, the parties involved in the logistics sector are quite diverse with conflicting interests, so it could be challenging to convince all parties to collaborate on one single blockchain platform simultaneously. However, it is essential to establish only a few blockchain platforms for the logistics industry since customers do not want to use several blockchains on several platforms.

The question also arises as to how blockchain-based applications would correspond with existing systems since every company uses their own inter-firm information gathering systems. Therefore, it is unrealistic that the technology would be introduced immediately across all processes. Instead there would probably be a transitional phase in which the current systems should be able to communicate smoothly with the blockchain applications. The outcome of the particular blockchain concepts depends mainly on the collaborations as all parties would have to work together and adjust their own inter-firm systems towards a single blockchain platform which is a crucial requirement for widespread acceptance of the technology.

According to Gartner's hype cycle (appendix 2), the attention around the blockchain technology is currently cooling down, and entering the "*trough of disillusionment*", which indicates that the overall recognition around the technologies is fading. The blockchain technology will likely reach the "*plateau of productivity"* within the next couple of years in which the blockchain technology will probably be widely adopted.

6.2 Summary of the Thesis

The blockchain technology could indeed facilitate processes in the logistics sector. By providing one source of truth, blockchain-based applications could accelerate supply chain processes and thus, reduce transportation costs, benefiting all involved parties. Moreover, ambiguities would also diminish as all parties would be able to track all steps involved in the transportation process more efficiently.

As determined in the analysis of the thesis, there are plenty of use cases for the blockchain technology, whether simply transmitting data as the VGM or the release reference up to more complex documents as the BL stored within a smart contract, the blockchain has the potential to optimise the whole logistics sector. Hence, it is undeniable that the blockchain approach with its unique merits will potentially affect business models, at least improving trust issues between parties in the logistics sector as the value of trust in the ecosystem of a blockchain network is in fact digitised. Further, the blockchain approach provides a kind of equality between all parties which could further facilitate the collaboration between them.

However, there are still significant challenges the blockchain technology has to overcome in order to gain widespread adoption. The digitalisation of the logistics industry is in full progress and many leading technological innovations as big data, internet of things and machine learning are aiming to optimise and automate data flows in supply chain processes. All the interviewees emphasized that the blockchain technology could be adopted as the underlying infrastructure to connect all of these innovations in the current digitisation of supply chain processes (Logistics 4.0). With this, it is of utmost importance that the parties in the logistics sector collaborate and develop blockchain applications together.

Once the blockchain overcomes more or less the aforementioned challenges, especially the legal aspects, the technology could gain more application possibilities as well as importance throughout the logistics sector.

To put it in a nutshell, at the current stage of development, it is not possible to make any sophisticated predictions about the impact the blockchain technology could have on supply chain and logistics.

Nevertheless, according to the interviewees, due to the actual benefits of the innovative technology, the blockchain will probably be adopted to facilitate supply chain processes. The question hereby is to which degree the blockchain technology will have an impact. Whether on a small scale with minimal applications as improving the information transfer like the VGM data, or on a larger scale as being the underlying platform for exchanging contractual agreements like the BL with utilising smart contracts. Only time will tell to what extent the blockchain technology will manage to disrupt the more or less outdated procedures of transmitting valuable information in the logistics industry.

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Appendices

Appendix 1- Interview Guide

Part 1) Allgemeine Fragen zur Blockchain

Fragen gestellt an: Company XY und DAKOSY

- Wie würden Sie Ihre bisherigen Erfahrungen mit IT Systemen in der Logistik beschreiben?
- Seit wann beschäftigen Sie sich mit der Blockchain Technology?
- Welche Erfahrungen haben Sie mit Blockchain Anwendungen in der Logistik/ Supply Chain?
- Warum sind Sie daran interessiert, Blockchain in Ihrem Unternehmen zu implementieren?
- Wie „reif“ ist Ihrer Meinung nach die Blockchain Technologie zum jetzigen Stand?
- Wie würden Sie das allgemeine Verständnis der Blockchain Technologie in Ihrem Unternehmen beschreiben?
- Wie würden Sie die Blockchain Technologie in der Logistik im Vergleich zu anderen Technologien einschätzen (Vor- und Nachteile)?
- Wo sehen Sie aufgrund Ihrer Erfahrung das größte Potenzial für die Blockchain in der Logistik/ Supply Chain?
- Sehen Sie potenzielle Blockchain Anwendungen in der Logistik eher in den öffentlichen oder privaten Blockchains?
- Was sind die Einschränkungen für die Blockchain Technologie in der Logistik/ Supply Chain

Part 2) VGM bezogene Fragen

Fragen gestellt an: Company XY

- Wie sieht der bisherige VGM Informationsverlauf aus?
- Wie effizient ist das bisherige VGM Konzept?
- Was sind die Schwachstellen?
- Inwiefern kann die Blockchain diesbezüglich implementiert werden?
- Welche VGM Informationen würden in der Blockchain gespeichert werden?
- Würde jede involvierte Partei eine identische Kopie der Information bekommen?

- Was sind die (technischen) Herausforderungen für eine erfolgreiche Implementierung?
- Inwiefern besteht eine Limitierung für das Blockchain VGM Konzept?
- Würde die Blockchain parallel zu dem bisherigen System laufen?
- Würde die Blockchain eher öffentlich oder privat sein?
- Wie realistisch ist eine erfolgreiche Implementierung?
- Was erhoffen Sie sich durch die Implementierung der Blockchain für die VGM Prozesse?

Part 2) "RObоB"/ container release bezogene fragen

Fragen gestellt an: DAKOSY

- Wie verläuft das bisherige Konzept der Freigabe von containern am Hamburger Hafen?
- Wie effizient ist das bisherige Konzept?
- Was sind die Schwachstellen und Probleme?
- Inwiefern kann die Blockchain diesbezüglich implementiert werden? / wie genau funktioniert RОboB?
- Welche Informationen würden diesbezüglich in der Blockchain gespeichert werden?
- Würde jede involvierte Partei eine identische Kopie der Information bekommen?
- Was sind die (technischen) Herausforderungen für eine erfolgreiche Implementierung?
- Inwiefern besteht eine Limitierung für das Blockchain Konzept?
- Würde die Blockchain parallel zu dem bisherigen System laufen?
- Würde die Blockchain eher öffentlich oder privat sein?
- Wie realistisch ist eine erfolgreiche Implementierung?
- Was könnten die potenziellen Vorteile des RObOB Projektes sein?
- Was erhoffen Sie sich durch die Implementierung von RОboB, was sind die Vorteile?

Part 3) Smart Contracts/ Bill of Lading bezogene Fragen

Fragen gestellt an: Company XY und DAKOSY

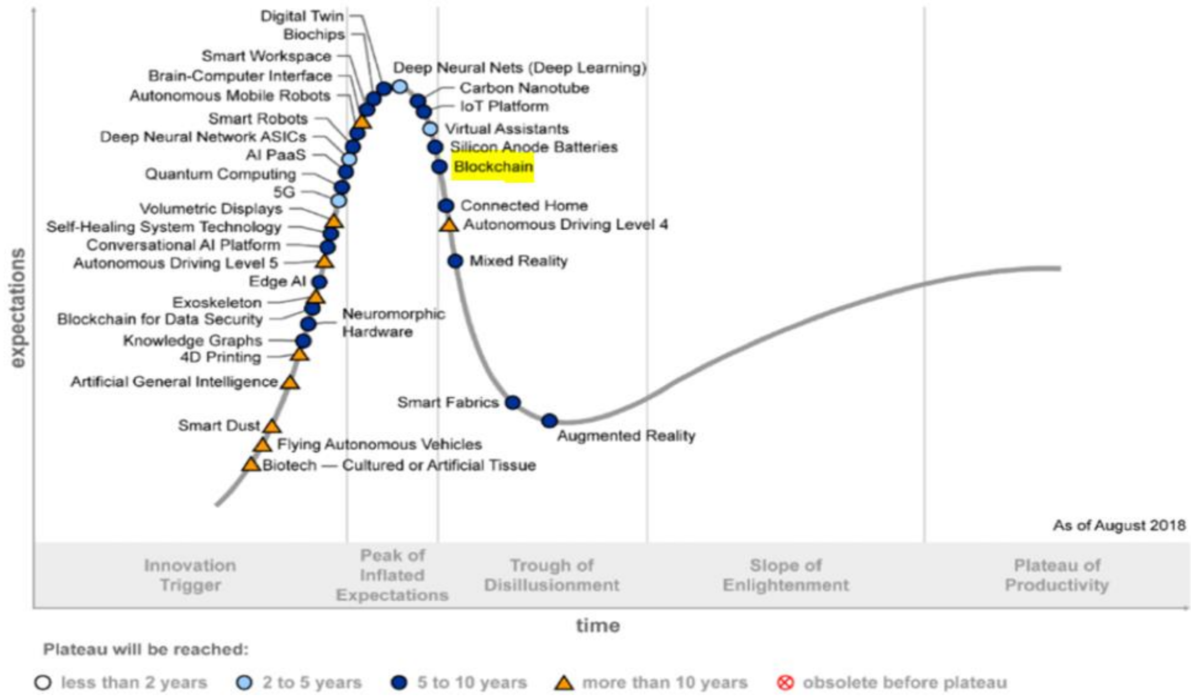
- Welche Möglichkeiten bieten Smart Contracts in der Logistik?
- Inwiefern kann die Blockchain (Smart Contracts) die Prozesse bezgl. des BLs optimieren?
- Arbeitet Sie an Smart Contracts? Falls ja dann mit der public oder private Blockchain?
- Was erhoffen Sie sich durch die Implementierung der Blockchain für die BL Prozesse?
- Was sind die (technischen) Herausforderungen für eine Implementierung?
- Wie realistisch ist eine erfolgreiche Implementierung?
- Wie ist die Blockchain (Smart Contracts) rechtlich zu definieren?
- Wie sieht es mit dem rechtlichen Aspekt der Smart Contracts Anwendungen aus?
- Inwiefern besteht eine Limitierung der Smart Contracts in der Logistik?

Part 4) Abschließende Fragen

Fragen gestellt an: Company XY und DAKOSY

- Sehen Sie andere Probleme in der Logistik/ Supply Chain, die durch die Blockchain gelöst oder optimiert werden könnten?
- Wie würden Sie die Signifikanz der folgenden Werte in Bezug auf Informationssysteme in der Logistik beschreiben?
    - Datenschutz (Kontrolle über vertrauliche Daten)
    - Transparenz (Sichtbarkeit des Logistikprozesses)
    - Vertrauen (Bereitschaft, Daten mit Kunden/ Partnern auszutauschen)
    - Rückverfolgbarkeit
- Was sind die wesentlichen Unterschiede zwischen einer Blockchain und einer traditionellen Datenbank?
- Was sind die Vor- und Nachteile zwischen einer Blockchain und einer traditionellen Datenbank?
- Sind Sie der Meinung, dass die Blockchain in Zukunft einen wesentlichen Aspekt der Logistik/ Supply Chain ausmachen wird?
- Möchten Sie noch etwas hinzufügen?

Appendix 2 - Gartner's Hype Cycle for Emerging Technologies 2018



Appendix 2: *Hype Cycle for Emerging Technologies 2018 (Gartner, 2018)*

Declaration of Authorship

I hereby certify that this thesis has been composed by me and is based on my own work, unless stated otherwise. No other person's work has been used without due acknowledgment in this thesis. All references and verbatim extracts have been quoted, and all sources of information, including graphs and data sets, have been specifically acknowledged.

Date: 28.02.2019

Signature:

Sabri Asmar