General Management MBA

Evaluating the Applicability of Blockchains in the Pharmaceutical Supply Chain

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Abstract

The term Blockchain is currently on everyone's tongue. The technology is attributed partly revolutionary, but also disruptive properties for a number of economic sectors. In the current discussion, the purposes are usually narrowed to the keywords Bitcoin or Smart Contracts but they actually go much further. (PwC Deutschland 2017) This paper is dedicated to the evaluation of the applicability of blockchains in the pharmaceutical supply chain in collaboration with the international pharmaceutical company Boehringer Ingelheim.

The pharmaceutical industry, in particular the pharmaceutical supply chain in Europe, is a highly complex, strictly regulated, GxP relevant and sensitive area that is currently undergoing tremendous changes in terms of industry 4.0 or the product safety and serialization plan that was rolled out by the EMA in a delegated act becoming effective beginning of 2019 (European Medicines Agency 2016) to further eliminate counterfeits. Blockchains may be an answer to some questions and challenges the pharmaceutical industry will be confronted with in the near future. Since the blockchain technology uses a decentralized database from technological point of view it can take over many more functions that were not applicable to currently used centralized platforms. Trust and transparency are created when platforms are non-manipulable and independent and for this reason, blockchain technology can be even used to interact in certain processes without any trusted third-party authority which saves time, a lot of paper and also money. Additionally, the whole system becomes less vulnerable to manipulations. (Heinen 2017)

These are all important parameters in the pharmaceutical supply chain so blockchain might add all these aspects to a new level. In order to provide concrete recommendations of actions a model that helps identifying relevant processes for blockchain technology is developed.

Key Words: Supply Chain, Blockchains, Pharmaceutical Industry, PSS, Smart-contracts

Table of Contents

List of Figures

List of Tables

List of Abbreviation

AI	Artificial Intelligence
API	Active Pharmaceutical Ingredient
AR	Augmented Reality
B2B	Business to Business
BCT	Blockchain Technology
BiTA	Blockchain and Transport Alliance
CHC	Consumer Health Care
DIN	Deutsche Industrie Norm (en. German Industry Standard)
DLT	Distributed Ledger Technology
EMA	European Medicines Agency
ERP	Enterprise Resource Planning
EU	European Union
FDA	US Food and Drug Agency
GDP	Good Distribution Practice
GMP	Good Manufacturing Practice
IBAN	International Bank Account Number
ID	Identification
IoT	Internet of Things
ISO	International Standard Organization
IT	Information Technology
PII	Personally Identifiable Information
PKI	Public-Key Infrastructure
PoW	Proof of Work
PSS	Product Safety and Security
QR Code	Quick Response Code
RFID	Radio Frequency Identification
RPA	Robotic process automatization
SSRN	Social Science Research Network
WHO	World Health Organization
WiFi	Wireless Fidelity

Executive Summary

What do diamonds and the pharmaceutical industry have in common? Certainly both industries deal with finished goods that frequently become subject of manipulation or theft. Additionally, in both industries it is of utmost importance to establish a secure and reliable supply chain that allows tracing back the origin of processed goods to ensure a sustainable manufacturing process in order to meet social and political standards and requirements. The only problem so far was that no reliable technology existed that provided a secure but still transparent environment to store and access product-related data. The answer comes from an unexpected area namely the finance sector. Blockchains are the underpinning technology of the hyped phenomenon called Bitcoin a cryptocurrency that has the potential to not only revolutionize the financial sector but also many more industries. If a technology is reliable and secure enough to transfer money why not applying the technology to other industries and processes as well that have similar high standards and regulations.

Although being less shiny than the world of diamonds the thesis deals with the future applicability of blockchains in the pharmaceutical supply chain. The pharmaceutical industry is facing many challenges now but even more in the future for instance counterfeits, parallel trade and increasing regulatory demands as well as higher complexity in cross-border shipments. Particularly supply chain organizations must go through a change process to remain compatible in the future. Generally, pharmaceutical supply chains are very complex and require a high level of security, integrity and regulatory adherence. All those challenges seem solvable with the new blockchain technology at the first glance since blockchains are the epitome of security and transparency. Blockchain technology itself is well examined in literature and journals however hardly any intersection between blockchain technology and pharmaceutical supply chain organizations is applicable. Additionally, due to the very limited public research and missing concrete proof of concepts with advises for companies about how to make use and benefit from the technology, pharmaceutical companies are struggling to find a process or area to start with. This thesis takes up the problem of missing research in this particular area and aims to answer four different research questions.

First, the main parameters that influence the application of blockchain technology as well as the desired features of any new technology are explored. In order to answer this question, intensive literature research is carried out but also interviews with experts either having a concrete business or academic background are conducted. The second research questions aims to identify the main internal and external process in pharmaceutical supply chain organizations that are po-

tential candidates for blockchain technology. In this course, a decision tree is developed that helps companies in the future to identify suitable processes even without being too familiar with blockchain technology. To deliver some concrete ideas how blockchains really could change pharmaceutical supply chains, the third research question deals with the question to which extent and where exactly blockchains change processes. Again, intense literature review and interview studies provide the required data to answer the questions. In addition, the burning question about the explicit added value of blockchains is taken up. Lastly, the most significant obstacles and limitations of blockchain technology are discussed and ideas about how to eliminate and avoid risks are provided.

In general, the thesis is based on literature research however in order to at least partially close gaps in available literature and to deepen the knowledge in certain areas, interview studies were conducted as well. As this thesis aims to provide concrete actions for recommendation and have a rather practical nature without jeopardizing the required academic standards, an additional case study with a cooperation partner from the pharmaceutical industry is adduced.

The thesis proves that blockchain technology will most likely gain a considerable impact on pharmaceutical supply chain organizations – and other industries or businesses – and should be considered by respective stakeholders as an opportunity. However, the results of the thesis also show that blockchain technology is still in an early stage and not yet mature enough to be blindly rolled out in all areas without trading off opportunities against limitations. In order to profit from blockchains in the future and gain a competitive advantage, pharmaceutical supply chain organization should identify and decide carefully on the applicability of blockchains in certain areas, using the introduced decision tree, and develop a clear strategy about how to roll out blockchains and how to turn the technology into a value adding aspect.

To briefly provide a glance at the concrete outcome of the thesis; generally the advantages of blockchain technology meet the requirements of supply chain organizations. The literature researches as well as the interview studies state that privacy, security and internal reliability are the most important features of any technology in the pharmaceutical industry. All three characteristics are fulfilled by blockchain technology. Blockchain technology is beneficial to all processes that involve intermediates that shall be bypassed in the future as well as processes that require high data integrity. Moreover, blockchain technology is suitable for processes that involve multiple remote partners that are lacking a trust base. It is also an interesting technology for processes that deal with tracing and tracking proof of origins and transfer of rights and goods. In the course of the thesis, the concrete case processes are clustered into financial and logistical supply chain activities. The question of the added value to supply chain organization is difficult to answer and certainly one of the biggest obstacles of blockchain technology. The available data in literature is vague and predictions about monetary impacts of blockchain technology on supply chain organizations must be treated with caution as it is difficult to quantify the added value of companies based on the available information. Other advantages that can be obtained with blockchain technology are increased transparency and traceability, higher level of automatization and following reduced costs and raising operational efficiency, a reduction of falsified drugs and theft as well as contract enforcement and management with the help of smart contracts plus higher collaboration rates in end-to-end supply chains. The main obstacles and limitations of blockchain technology are of different nature. Before being ready for a mass implementation, some technological aspects must be improved. In addition, common standards are insufficient and internal law is not yet aligned on blockchain technology. Besides the technological and legislative aspect, the adaption rate of blockchain is fairly low mainly due to a missing proof of concept and attractive blockchain offers by big stakeholders.

To sum up, blockchain is a promising technology across many different industries, particularly meeting the demands of pharmaceutical companies and supply chain organizations. With its practical nature, supported by a case study, the thesis provides a valuable input in research of blockchain applications in the pharmaceutical industry that was so far rather blank.

1. Introduction

1.1 Background

Blockchains, the technology underpinning the Bitcoins phenomenon, could revolutionize the world economy and could lead to a change in paradigm. (Tapscott and Tapscott 2016) Although the technology itself has been launched already ten years ago by Satoshi Nakamoto the economy especially business outside the financial sector only slowly realizes what a break-through technology blockchains are and how big the potential could be for other businesses.

Going more into detail the technology behind Bitcoins comes upon broad interest in different industries. Stakeholders in the pharmaceutical industry start becoming more and more interested in the new technology, wondering whether it could help providing answers to ongoing changes on the market for instances track and trace projects, anti-counterfeiting and smart contracting. Since the blockchain technology has proven its usefulness and high level of security, one or the other big pharmaceutical company is eager to join alliances with young start-up is in the blockchain are in order to find customized technology-solutions. (Shirra 2017)

Why is the pharmaceutical industry, in particular interested in the new technology? Pharmaceutical supply chains are failry complex and require a high level of security, integrity and regulatory adherence. Companies are constantly looking for possibilities to increase the security without raising costs. Especially the problem with counterfeits on the market and parallel trade is a big problem not only for pharmaceutical companies but also for patients. “The WHO roughly estimates that 10% of medicine worldwide is counterfeit and rises to 30% in emerging regions […] In addition to creating a security gap in the supply chain, the current infrastructure is also inefficient in anticipating drug shortages or drug recalls - it lacks clear visibility into its inventory. (IEEE 2017) All those challenges seem solvable with the new blockchain technology at the first glance since blockchains are the epitome of security and transparency. That’s why applying blockchain technology to major supply chain processes can eliminate many severe risks.

A first attempt to contribute a solution to the above mentioned topic came from a joint venture between Chroniclead and LinkLab, called the MediLedger project. Chornilead is a US American technology start-up heavily involved into blockchain technology whilst LinkLab is a supply chain consulting group. Both companies enlarged their project team by four big pharma and health care heavyweights; Genetech by Roche AG, Pifzer, Amerisource Bergen Corp. and McKessen Corp. Together they are aiming to create a new operating model for the supply chain 4.0 based on blockchains in order to improve the security along distribution chains. (Lopez 2017) The approach is mainly influenced by the Drug Supply Chain Security Act enacted by the US congress in 2013 and “outlines steps to build an electronic, interoperable system to identify and trace certain prescription drugs as they are distributed in the United States”. (FDA 2017) Although the European Medical Agency has enacted a similar delegated act concerning the safety and serialization of prescription medicines that becomes effective already four years earlier than that in the United States, no concrete, publicly accessible pilot project can be found in the European zone. Since no data is available on this topic it can only be assumed that European pharma companies are more reserved with regards to changes or as Hofstede calls it Uncertainty Avoidance whilst US companies dare more to experiment on a “green field”.

1.2 Problem Definition

Blockchains, as a technology itself, as well as blockchains in connection with supply chain management have been sufficiently examined in literature and journals however no intersection between blockchain technology and pharmaceutical supply chain has been subject of research lately. Almost no data is available in the present literature about pharmaceutical companies that are running pilot projects or enterprises offering customized solutions for pharmaceutical companies. Currently only one big project is public where multiple big pharmaceutical companies grouped up in USA in order to improve the security along the supply chain. (Lopez 2017) Even though one single big project is running, the knowledge about concrete implementation possibilities of blockchains is fairly limited in the industry. Leading experts in this discipline estimate that it will take another five years of research and development until blockchain becomes applicable in big pharmaceutical markets due to many challenges in the implementation. (Shanley 2017) Due to the little public research in the area of pharmaceutical supply chain and the missing recommendations for action as condense of studies, companies are struggling to find a process or area to start with. A simple, understandable, non-technological model that helps companies to identify which processes can benefit from blockchains and how potential risks and hurdles can be minimized is currently missing. To sum up, the technology is advanced and well-proven but the practical use of blockchains especially in the European pharmaceutical supply chain is in its starting stage.

1.3 Purpose

The general purpose of this thesis is to figure out the parameters influencing most significantly the applicability of blockchains in internal and external pharmaceutical supply chain processes. Based on the outcome of the first research phase, a general evaluation model shall be developed that will help the pharmaceutical companies to identify the processes on which block-chain can be applied. In addition, the thesis aims to identify other internal processes or businesses that could possibly benefit by implementing blockchains. In addition, the intention is to determine all challenges and risks a pharmaceutical company could face when launching block-chain technology and how these obstacles can be reduced or eliminated.

The thesis contributes another aspect of blockchains focusing on their applicability in the pharmaceutical supply chain, an area that has not been focused in previous research papers. The outcome of the thesis is an evaluation model for the applicability of blockchain technology to any process in the pharmaceutical supply chain which is rather a practical involvement in ongoing researches. Since blockchain technology will only add value to the economy once it is usable for daily business, companies are not interested in a research about the ultimate definition of blockchains and a conceptual analysis but in recommendations for actions about how to apply blockchains simply to the processes. Therefore the thesis with its evaluation model and first applicability tests in collaboration with an international company will meet the market needs. Additionally, the developed framework and qualitatively collected data in the interviews can help to challenge existing theories and promote further surveys, broader case studies or future re-search papers. Moreover, the developed evaluation model could be slightly adjusted and adopted to different business areas and processes that are worth to explore possibilities to use blockchains in the future.

1.4 Aim and Research Questions

In reference to the purpose of the thesis and the general research problem the paper deals with the following research questions, aiming to meet the overall objectives:

RQ1: Which parameters influence the applicability of blockchain technology in major internal and/or external supply chain processes in the pharmaceutical industry?
RQ2: What are the main processes in the pharmaceutical supply chain that would be subject of the evaluation?
RQ3: How will processes be changed by applying blockchain technology and what is the added value for companies?
RQ4: What are the most significant obstacles and risks for applying blockchains in the pharmaceutical supply chain management and how can they be removed?

1.5 Focus and Delimitations

This thesis will focus on the evaluation of the applicability of blockchains in internal and external major supply chain processes in the pharmaceutical industry only. However, it will pro-vide an outlook to which other internal processes and businesses blockchain technology could be extended as well. As the emphasis of the thesis lays on the applicability of blockchains from a business point of view rather than a technical one, the thesis will only provide a perfunctory explanation about the underlying blockchain protocols and technological specifications, sufficient to understand the further context of the thesis. For more detailed information about the technology behind blockchains, it is recommended to read for instance Nakemoto's White Paper. (Nakamoto 2008) All analyses and provided results remain of theoretical nature as the time limitation of the thesis did not allow to run proof-of-concept such as a blockchain pilot in a specific pharmaceutical company even though the thesis includes a case study. The case study itself only attempts to answer the underlying research questions from a business point of view in order to add another more practical facet to the academic framework.

1.6 Thesis Outline

The thesis consists of seven chapters in total. Figure 1 Thesis Structure illustrates the framework and hence the guiding thread of the thesis. Close inspection reveals not only the structure of the thesis but also the focus of each chapter as well as how the content of each section is related to each other.

Whilst the first chapter serves as an introduction to the research matter, providing information about the research problem, purpose and status quo, the second chapter explains the applied methods and critically reflects upon the thesis' approach. The third chapter deals with the thesis' frame of reference. It classifies the pharmaceutical industry, supply chain management and blockchain technology from an academic point of view. Moreover, it provides an overview and advantages and disadvantages of blockchain technology. The chapter aims to provide an understanding about the research object and paves the way for the fourth chapter. This chapter deals with business sectors that appear to be promising candidates for successful blockchain applications. In this context, besides the pharmaceutical industry, a special focus is put on the finance sector, as the origin of blockchain technology and the chemical industry, a very similar business environment to the pharmaceutical one. It aims to identify similarities and possible synergies of blockchains in different business sectors. In order to gain first-hand information, several interviews are conducted whose results are incorporated into the discussion. The fourth chapter closes with an outlook about how the industry will most likely deal with the hype of blockchains. The fifth chapter fully concentrates on the underlying case study. First of all a description of the company is provided. Afterwards, the chapter attempts to establish concrete recommendations for action on how blockchains could possibly be implemented in the future. The main source of implementation results from a subject-related interview with a collaboration partner. The sixth chapter combines the research findings and condenses the results gained throughout the preceding chapters by answering the research questions explicitly. The final chapter critically discusses the results of the thesis but additionally, reflects upon the contribution to research and limitations faced. It also provides an outlook about possible future research topics that arise from the thesis.

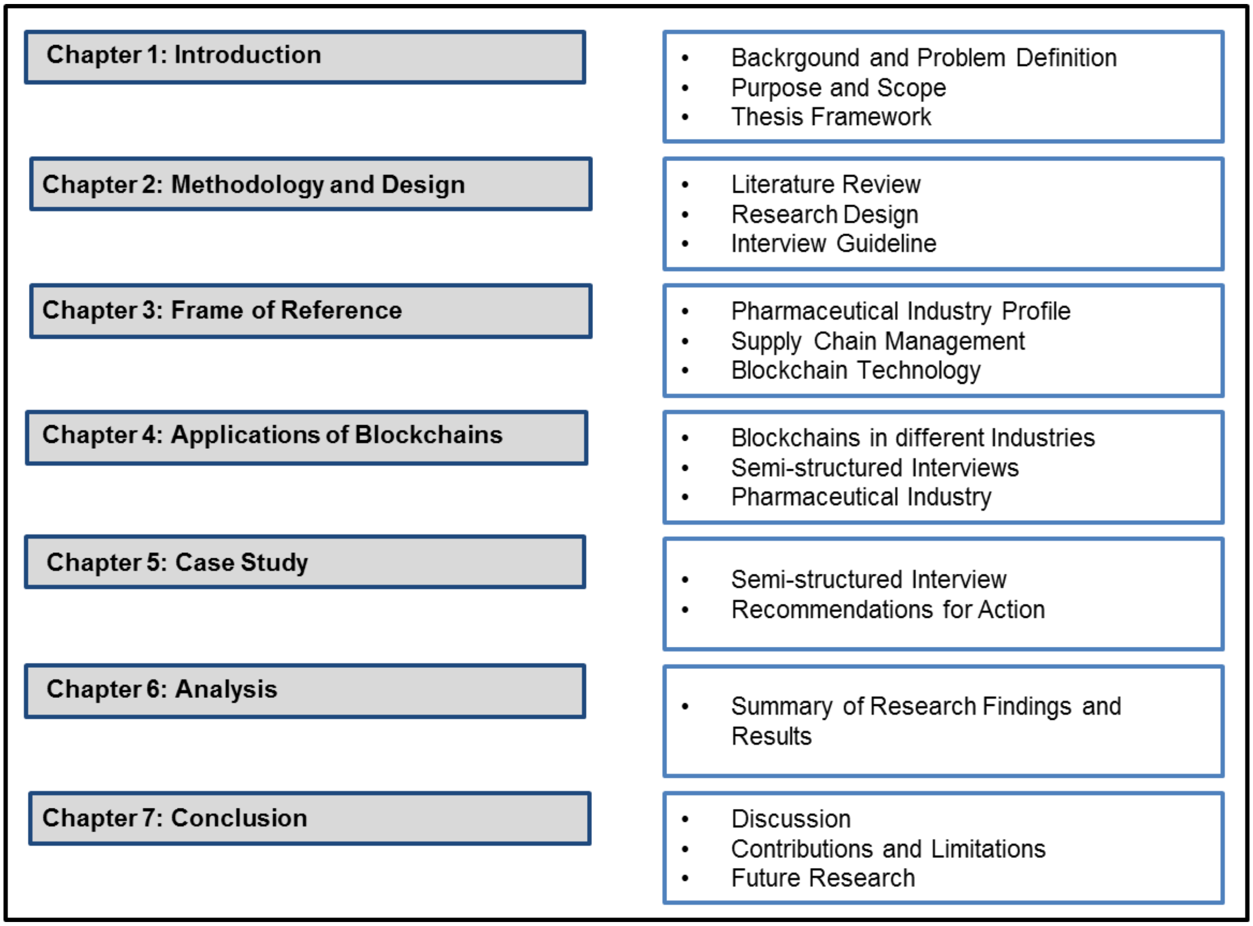

Figure 1 Thesis Structure

2. Methodology and Design

The second chapter deals with the applied methodology and design of the thesis. Each of the three sub-chapters describes the purpose of selected methods as well as the procedure of conduction and the way of documentation. When determining appropriate research approaches and methods, it all comes down to “using the time and other resources in an efficient manner in order to be able to create as much new knowledge as possible”(Björklund and Paulsson 2014) limited by factors such as existing data, time, financial sources and access to knowledge. As the thesis aims to target a specific research problem, it is not sufficient to solely review secondary data but to create a base of primary data in particular by conducting interviews with experts.

Whilst the section Literature Review draws a focus on opportunities, challenges and gaps in current literature and research, the second section Research Design presents a high-level plan of the logical research structure finishing with a critical reflection of applied methods and quality of the study in the chapter Critical Reflection.

2.1 Literature Review

First of all, general literature related to the topic of the thesis was reviewed in order to understand the available knowledge in the research field, the complexity and possible underlying theories. On one hand the literature review aimed to provide a broad overview about characteristics of blockchain technology, the pharmaceutical sector and its special supply chains, on the other hand, the literature review step reveals gaps in current research and addresses open points to be further explored during the thesis.

Due to the novelty of the thesis’ topic and the fact that basically daily new developments, ideas and research findings are published, the main challenge throughout the literature review was keeping up with the pace of research and always referring to the latest publications while meeting academic requirements. Therefore the literature review was meant to focus mainly on journal articles and conference papers. Books were rarely used due to the risk of containing outdated information since developments in blockchain technology happen frequently and rapidly. Regarding the quality of consulted journal articles and conference papers it has to be mentioned that mainly Google Scholar, SSRN, Research Gate and search system from the University of Technology Vienna were employed. The results were entered and managed in a search diary, technically supported by Citavi[1]. The list of references was narrowed down in a multi-step approach, filtering out low-quality and outdated sources as well as those that focused solely on technological and mathematical aspects of blockchains. Afterwards the sources were clustered and rated

[1] Reference management program.

by their trustworthiness and relevancy, applying the criteria of VHB-JOURQUAL3 and the Academic Journal Guide (Aussenegg 2018).

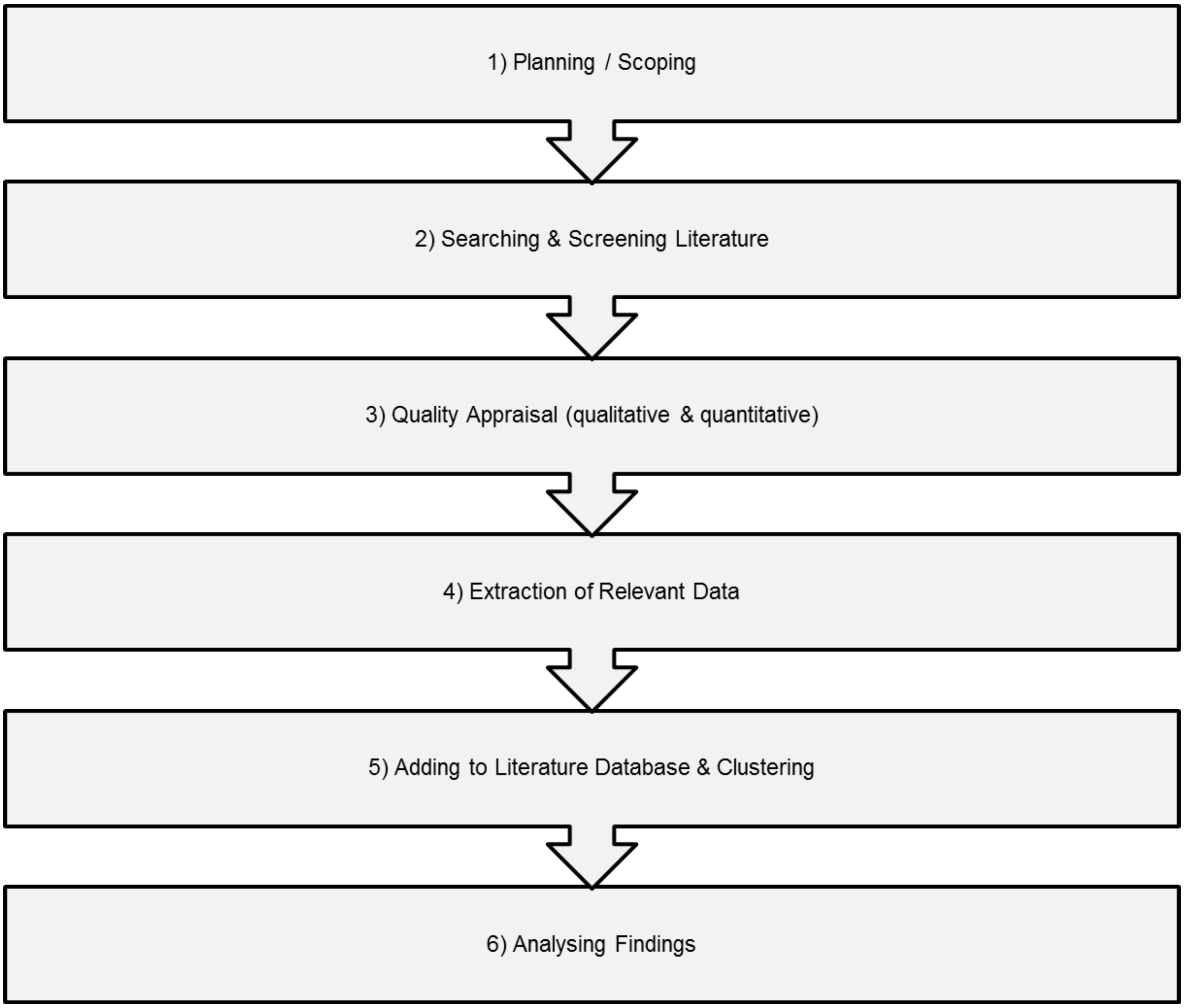

Figure 2 Literature Review Approach

In addition, publications from companies particularly from Boehringer Ingelheim and business consultancies were used in order to gain information about the status quo of blockchain implementation in the pharmaceutical industry and supply chain management. This was necessary since results from Web of Science hardly delivered data about the adoption rate of BCT and concrete success or failure stories from the industry.

2.2 Research Design

Generally, the design of a thesis should provide a logical sequence of how the underlying research questions are being answered. (Yin 2008) In order to sufficiently answer the four research questions of this thesis quantitative and qualitative research methods are applied. The chapters 3. Frame of References and

Every organization that rolls out blockchain technology in the future and carries out a transformation from common technologies to the hyped blockchains can find guidance in the four leadership principles by Jack Welch. Every change project must be attached to a clear vision and target statement in order to become successful. To make changes happen, companies must hire and promote only true believers. This requires a very good human resource management. Hand in hand goes the third advice to remove resisters even though their overall performance might be satisfactory. Only one non-believer can jeopardize the whole change process. Last but not least, in order to be a real change organization, companies must become brave enough to dare looking into new opportunities for instance blockchain technology although not every detail of it is assessed yet. Changes must be seen positively as more as a chance rather than risk. (Bergmann and Bungert 2011)

4. Applications of Blockchains are based on quantitative research using mainly secondary data bases such as journal articles, conference papers and books. The method of literature review was chosen to deliver input for both sections since a large number of data was available and accessible. In addition, the information could be fairly easily collected within a short time frame and with limited financial resources. (Björklund and Paulsson 2014) The discovered gaps that became apparent during the literature review in research and the missing data about the real applicability of BCT in the pharmaceutical industry could only be sufficiently addressed by using primary data sources. Consequently, semi-structured interviews, as stated in detail in chapter 2.3 Interview Studies were conducted in order to support chapters 5. Case Study and partially chapter 6. Analysis. (Björklund and Paulsson 2014) The condensed data from these interviews in combination with the available literature shall address all research questions.

As stated before and confirmed by the literature review, the topic of the thesis is very newsworthy with missing information in particular of practical nature. In order to answer research questions and create a thesis that is consistent in itself with a high level of practical relevancy, a case study approach has been chosen. This method allows a deep dive into characteristics, opportunities and limitations of BCT as well as an evaluation of the added value for pharmaceutical supply chains. In order to meet the academic requirements of a thesis, the list of interview partners has been extended by experts form different industry fields but pharma aiming to achieve a general applicability of research findings.

This case study has been conducted in co-operation with the Boehringer Ingelheim RCV GmbH & Co. KG. The company has been chosen for multiple reasons; Boehringer Ingelheim is a research based, family-owned pharmaceutical company (Boehringer Ingelheim RCV GmbH & Co. KG 2018) belonging to the top 20 in the industry.[2] It is operating world-wide and provides a wide range of supply chain activities that is a crucial success factor for the thesis as well as the interest in the new blockchain technology and the budget to follow up the outcomes of this paper. (SAPa 2018)

Following, this case study was based on two different methods; one the one had document analysis and on the other hand six semi structured interviews, using both, predetermined questions with bound answer options as well as open-ended questions with unbounded answer possibilities. (Yin 2008) The aim of the case study was to determine the applicability of blockchain technology in the pharmaceutical industry with all its facets from a practical point of view. In return, the thesis seeks to provide clear go's or no-go's for the implementation of blockchains in the pharmaceutical supply chain and to determine the added value for companies, using Boehringer Ingelheim as an example representing all pharmaceutical companies with the same characteristics.

To sum up, the study contains parts of descriptive, explorative and explanative characteristics all aiming to answer the underlying four research questions. (Björklund & Paulsson 2014)

2.3 Interview Studies

Since the six interviews that were conducted during the development of the thesis contribute a fairly valuable part to the overall outcome of the thesis, this chapter provides more detailed information about the set-up and execution of the interviews. Additionally, more information about the chosen interviewees is provided.

Beforehand it was decided to set-up the one-to-one interviews in a semi-structured way using both predetermined questions with bound answer possibilities and open answers. During the execution of multiple semi-structured-interviews it is important to always apply the same structure and sequence of questions in order to avoid interviewees being affected by previous answers and to keep a certain level of comparability. (Höst et al. 2006) Semi-structured interviews were chosen to be the most appropriate form of interviews for the purpose of this thesis, as they combine the advantages of both alternatives; unstructured and structured interviews. Structured interviews are easy to replicate and it is comparably easy to rest the reliability of results. Due to

[2] Ranked by revenue (Christel 2017).

the given structure, of the interview both the interviewer and the interviewee have a guidance to follow which simplifies the conduction of the interview. In addition, both participants can prepare themselves easily which saves time. On the other hand, the structured interview, with pre-set question is less flexible than unstructured ones and the interviewer cannot ask questions impromptu in order to react on responses from the interviewee. Vice versa, the unstructured interviews are more flexible and questions can be adapted and changed during the execution of the interview that might result in more detailed responses. On the other hand guidance is missing that may mislead the direction of the interview and results are partially distorted. Additionally, in order to use the full potential of an open, unstructured interview, the interviewer must bring the ability to build rapport with the interview and know how and when to probe. Taken into consideration the experience of the interviewer and the limited time, a semi-structured interview adds most value. In order to mitigate the disadvantage of inflexibility, it has been decided to add one very open question to the interview guideline in which the interviewee can share more thoughts on the respective topic. (Yin 2008; Bryman and Bell 2015)

All interview partners of this thesis were carefully selected either based on their experience in blockchain technology, their knowhow in academic research or their relevant experience in certain areas of business. The interviews were conducted in a face-to-face method or via phone, depending on the location and reachability of the interviewees. An overview about the interviewed persons can be found in Table 1 Interview Partner.

Table 1 Interview Partner

Name	**Profession**	**Company**
Mr. Patrik Ziman	Head of Regional Supply Chain Management	Boehringer Ingelheim RCV GmbH & Co. KG
Mr. Darryl Glover	Principal and Chief Clinical Officer (CCO)	iSolve LLC
Mr. Maneesh Grover	Lead Architect in Solutions and Emerging technologies	Wipro Limited
Mrs. Prof. Dr. Lydia Bals	Professor of Supply Chain & Operations Management	Mainz University of Applied Sciences
Mr. Alexander Tscherteu	CEO and Member of Executive Board	Heta Asset Resolution AG
Mr. Sebastian Dencker	Director Compliance Europe	Ecolab

Besides the pre-set interview questions and the open question in the end for anything popping up additionally, all interviews start with a rating on the most important features of any technology in the interviewee's area of expertise. Initially, it was supposed to be asked in a question, however, test runs with subject groups showed that the results are distorted due to a very different perception of importance. In order to not jeopardize the reliability of results, it was decided to transform the question into a grid in which the interviewees could rate each feature with a number between one and five, presenting the level of importance. A second test run, applying the grid for rating the importance of certain technology features created more reliable data so the grid was applied to the final interview structure.

Header
Interviewer
Interviewee
Date

General Part
Background Information about the interviewee (e.g. profession, role and experience with blockchains)

Rating Grid

Feature	1	2	3	4	5
Costs					
Privacy					
Transparency (internal)					
Reliability					
Security					
Scalability					
Latency					
User-friendliness					

Questions (open and closed)

Signatures

Figure 3 Interview Guideline

Figure 3 Interview Guideline illustrates the schematic structure of the established interview guideline. For all interviews a written and signed protocol is applicable in the appendix, summing up the most important facts of each interview. As the interviewer was not to record several interviews, for the sake of unity, it was decided to make extensive notes for all six interviews.

2.4 Critical Reflection

Reflecting the quality of the study, three main parameters are adduced; validity, reliability and objectivity (Björklund and Paulsson 2014). The next sections elaborate on the underlying standards of the thesis.

Validity describes to which extent the gathered and measured data really applied to what needs to be measured in order to answer the research problem. Throughout the thesis extensive literature review was conducted in two different fields; on the blockchain technology itself as well on the characteristics and challenges of pharmaceutical supply chains. In addition, multiple interviews were executed in order to gain more in-depth information on certain aspects of the research topic or where more data was needed to fill in the gaps of current applicable research. (Björklund and Paulsson 2014) As generalizability is part of the validity aspect and addresses the question whether the results are universe beyond a specific research context, the list of interview partners has been extended by experts from different branches and the case study delivers valuable insights in the practical applicability of research results.

All gathered information was entered and managed with a reference management program and filtered in a multi-stage process ensuring the best possible level of relevancy and quality. Therefore it is evident that validity of the study is secured by a complete chain of verification in the iterative development of the thesis' model.

Following the aspect of validity, **objectivity or universality** is another parameter to determine the quality of a study. Objectivity refers to the question, to which dimension values affect the study. (Björklund and Paulsson 2014) The reason and motivation for choosing and applying certain methods were extensively described in this chapter aiming to maintain a high level of transparency. In addition, the thesis is universally applicable since it focuses on a generic business situation of pharmaceutical supply chains and the outcome of this research could be applied by any pharma company trying to evaluate the applicability of blockchains in supply chains and on the other hand it could contribute to further research in different contexts.

The **reliability** deals with the probability to which extent the iterating the data collection would lead to the same research results. (Björklund and Paulsson 2014) As the topic of the thesis is characterized by a high level of novelty and fast progress in research a repeated data collection would most probably not lead to the same results. It is caused by the nature of the topic that the level of reliability is limited. In order to mitigate the risk of low reliability the author withdrew data from multiple sources, documented the usage of each reference carefully and explained the motivation of applied methods in detail.

In order to meet the standards of transparency this sub-chapter additionally explains briefly why other common methods in research, besides the **case study**, were not applied for this thesis.

Following (Björklund and Paulsson 2014) an **experiment** is classified as primary data “collected for the purpose of being used in the current study”. (Björklund and Paulsson 2014) Taking into consideration the limited time available it was decided that an experiment actually in this case more a testing of the applicability of blockchain in the pharmaceutical supply chain would have required quite a significant level of simplification so it was questionable whether the results from the test run fulfill the requirements of university, validity and significance. Therefore it was decided not to apply an experiment.

A **survey**, classified as well as primary data, was not applied since it requires a large number of people. It usually falls under the classification of quantitative research since it included information that can be measured and evaluated. However, for the purpose of gathering general information about the research topic, the literature review has been chosen as it provides a sufficient output but required less resources. In addition, for the second part of the thesis experts were needed in order to generate a deeper understanding of very specific aspect of a research problem. Qualitative studies in form of semi-structured interviews are more adequate to address this need. (Björklund and Paulsson 2014)

Observations could not be conducted as this form of research requires existing blockchain systems in pharmaceutical supply chains that could be investigated. However, no real-life business case was published by any company, stating that blockchain technology is adopted and used in the supply chain.

3. Frame of References

In line with the first, introductory chapter, the frame of references is blockchain in the light of pharmaceutical supply chains. The chapter aims to transfer theoretical background knowledge about the characteristics of the pharmaceutical industry, its unique set-up and requirements of supply chains and blockchain technology. Thus, it builds the base to understand the following parts and ultimately the conclusions of the thesis.

3.1 Pharmaceutical Industry Overview

As this thesis aims to evaluate the future applicability of blockchains in the pharmaceutical supply chain management, first of all, a brief overview about the worldwide pharmaceutical sector is provided; consisting of key figures and an outlook on economic development. In order to estimate later on whether blockchain is a promising technology for the pharmaceutical industry as well, it is important to first capture the status quo and understand what matters in this sector of industry.

Generally, the pharmaceutical industry consists of enterprises that develop, produce and distribute drug, capturing their earnings from either newly-developed medications or generic products. The ultimate goal of all companies in this sector is to prevent or treat diseases and to create a better life for their end-customers – the patients. Patients is a broad term in the pharmaceutical industry since it covers all types of patients starting with human beings to any kind of pet or livestock. Besides its variety of end-customers, the pharmaceutical industry itself that is reported in many economies under the chemical sector can be subdivided into five types; prescription medicines, consumer-health-care (CHC) medicine, biosimilar, bio pharmaceuticals and the animal health business. The top five therapeutic areas in human pharmaceutical business (ranked by sales) will by Oncology, Antidiabetics, Anti-rheumatics, Anti-virals and vaccines according to projections, see also Figure 4 Top 5 Human Pharmaceuticals Therapy Categories.

Therapy area	2016 WW sales (US$B)	Projected WW sales 2022 (US$B)
1. Oncology	93.7	192.2
2. Antidiabetics	43.6	57.9
3. Anti-rheumatics	53.3	55.4
4. Anti-virals	48.5	42.8
5. Vaccines	27.5	35.3

Figure 4 Top 5 Human Pharmaceuticals Therapy Categories (Deloitte 2018: 6)

The pharmaceutical industry is dominated by US-American and European pharmaceutical companies. In 2016 the global pharma market reached revenue of 1,105.2 billion US Dollars. Overall, the pharmaceutical industry shows a constant but moderate growth even during the financial crisis as depicted in Figure 5 Overview Worldwide Pharmaceutical Market. With the help of new technologies, such as blockchains (Deloitte 2018) it is expected that the pharmaceutical industry will grow up to 1.3 trillion US Dollars in 2020 with an annual growth rate of 4.9%. (Nead 2017)

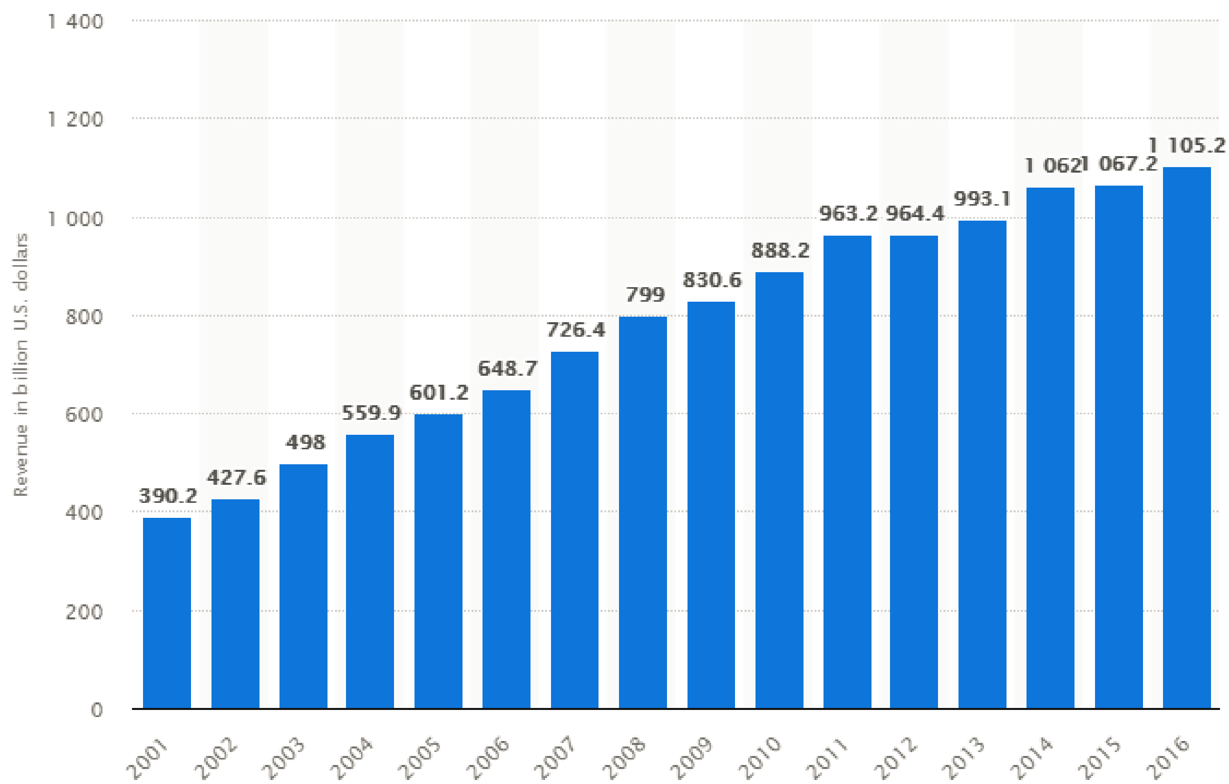

Figure 5 Overview Worldwide Pharmaceutical Market (Statista 2017a)

After this general introduction a more detailed analysis is carried out following the principles of the PESTEL tool. It helps to explore the macro factors impacting an organization or in this case an industry.

From a global perspective, many governments reduce the healthcare budgets due to saving plans. In addition, the pressure on the pharmaceutical industry grows by stricter regulations, longer clinical testing and more complex admission procedures for new medications. The reduced budgets are reflected in the increased pressure on pricing when accessing either new markets or launching new products. The overall geopolitical environment is currently changing looking at just some examples the new political direction of the US, the biggest pharmaceutical market, the Brexit negotiations in the EU and the Middle-East-Conflict. (Deloitte 2018) Those uncertainties impact the development of the pharmaceutical industry. With regards to European **politics**, a tendency to harmonize local healthcare politics on a European level is applicable.

One example is the delegated act that comes effective from February 9th 2019 trying to prevent falsified medicines in the future by adding product safety and serialization (PSS) features for instance a QR code to folding boxes of prescription medicines in the future. (European Council and the European Parliament 2011) This aims to decrease counterfeits and increases transparency in the pharmaceutical market. However, in order to implement those PSS, pharmaceutical companies face tremendous efforts to change their supply chains and systems. Another very specific European problem is the parallel trade[3]. Pharmaceutical companies try to prevent parallel trade by closely monitoring the quantity of products that are on the market. Parallel trade is not only a problem for pharmaceutical companies that are losing sales, thereby reducing their return on investment, but also from a patient perspective, parallel trade is not preferable. This solely European phenomenon has a strong impact on reference pricing in pharmaceutical companies. (Costa-i-Font 2015)

From **economic** point of view, the pharmaceutical industry faces two topics. On one hand, the population is growing and people live longer which naturally increases the market of the pharmaceutical industry. On the other hand, the health care budgets are tighter and more and more buying groups are established that form big chains with a high purchasing and negotiation power. This leads to an increased pressure on pricing for pharmaceutical companies, but in the long run, the pharmaceutical market is growing by 160 percent between 2017 and 2030, with India being major growth driver, which projects a positive trend for the sector. (Statista 2017b)

Regarding the **social** and **cultural** factors, pharmaceutical companies will need to increase their awareness towards new social media strategies to approach future patient groups and companies that want to maintain or gain a competitive advantage, will most likely have to pay attention to a changing customer relationship management. In the future, it will become even more important to transparently communicate to all types of customers – wholesalers, hospitals, doctors, pharmacies and patients – provide more educational services and improve the customer service overall. (Ernst & Young Global Limited 2017)

Technology is one of the most important macro factors and can turn into a real growth driver if the pharmaceutical industry allows the new technologies to unfold their benefits (Indian Pharmaceutical Alliance 2018). Besides the social media platforms, other technologies such as 3D printing, all-in drug discoveries, personalized medicines, telemedicine, cloud-computing and last but not least, blockchains are introduced. Social media platforms and telemedicine have revealed

[3] Parallel trade describes the effect of drugs being moved from lower-value to higher-value markets, especially in Europe due to national price differential.

the possibility to improve engagement of pharmaceutical companies with end customers in a more simple but compliant way. As mentioned before, the clinical testing becomes more and more complex for pharma companies. Crowd-sourced input might foster the patient experience, increase the patient retention and ultimately might result in patients self-selecting to join clinical trials. (Deloitte 2018) However, throughout all literature, blockchain is the most prominent and promising technology in the pharmaceutical industry as it is supposed to address new solutions in different areas of the industry, for instance contracting, security and end-to-end concepts. Further details are provided in the 4th chapter.

Multiple and incisive changes in the advertising law, disharmonized health care laws and worldwide tax reforms increase the complexity in the pharmaceutical market tremendously. (Deloitte 2018) A looming trade ware between, the USA, Europe and China as well as political tendencies to seal economies off from global trade (Khan n/a; Stratfor Worldview 2017) will make it more difficult for the pharmaceutical industry to obtain first of all the overview and secondly the margins. More and more emerging countries such as Russia make it mandatory to companies having at least one production step in the local market in order to participate in business. This artificially increases the complexity of supply chains for pharmaceutical companies and lowers the margin. If companies are reliant on sales in those countries, they have no other option than following the new regulations and set-up at least one productions step in the countries of final destination for medicines. Those countries, in contrast, can boost their local labour law as companies will have to employ people locally to perform parts of the manufacturing process. Besides the emerging markets, also USA is blustering with such requirements.

Corporate sustainability and **ecological** awareness are trends in the society and hence, have to find its ways to the agendas of pharmaceutical companies. The environmental challenges for pharma companies start with high energy consumption to the demand of rare resources and the emission of potentially harmful substances into the ecological cycle. “Trying to achieve sustainability in business operations has become more of a requirement than just an option due to increased global concerns […]” (Leblanc 2018) so finding new eco opportunities in order to meet the aspirations becomes a key success factor for pharmaceutical companies in the next years.

3.2 Pharmaceutical Supply Chain Management

In order to understand certain possibilities of blockchain applications in the pharmaceutical supply chain management, this section studies the classification of supply chain management from an academic point of view and aims to point out the characteristics of pharmaceutical supply chains in particular. Although intensive research took place in the area of supply chain management, reliable researches with a focus on pharmaceutical supply chains are rare, hence the combination must be created during this chapter.

3.2.1 Classification of Supply Chain Management

According to Porter (1998) all accruing activities in a company can be classified either as primary activities or secondary activities. The classification itself depends on whether an activity is directly involved into the production and merchandizing of a product or not. All activities that are directly involved in the manufacturing and selling of goods are considered primary activities. Michael Porter considers five primary activities; inbound logistics, operations, outbound logistics, marketing and sales and services. In contrast, infrastructure, human resources, technology development and procurement are defined as secondary activities. (B2U 2018) Figure 6 Porter's Value Chain illustrates the common primary and secondary activities of a company.

Michael Porter explains that the importance of each activity cluster might vary depending on the industry however all of those five primary activities are part of the value creation process to a certain extent. In addition, Porter claims that the ultimate goal of each company is supposed to be creating goods in such a way that the costs for creating this product are lower than the added value, profit, they fetch. (University of Cambridge 2016) The below shown value chain is the result of value adding upstream supplier and downstream customer activities that are part of a bigger value system.

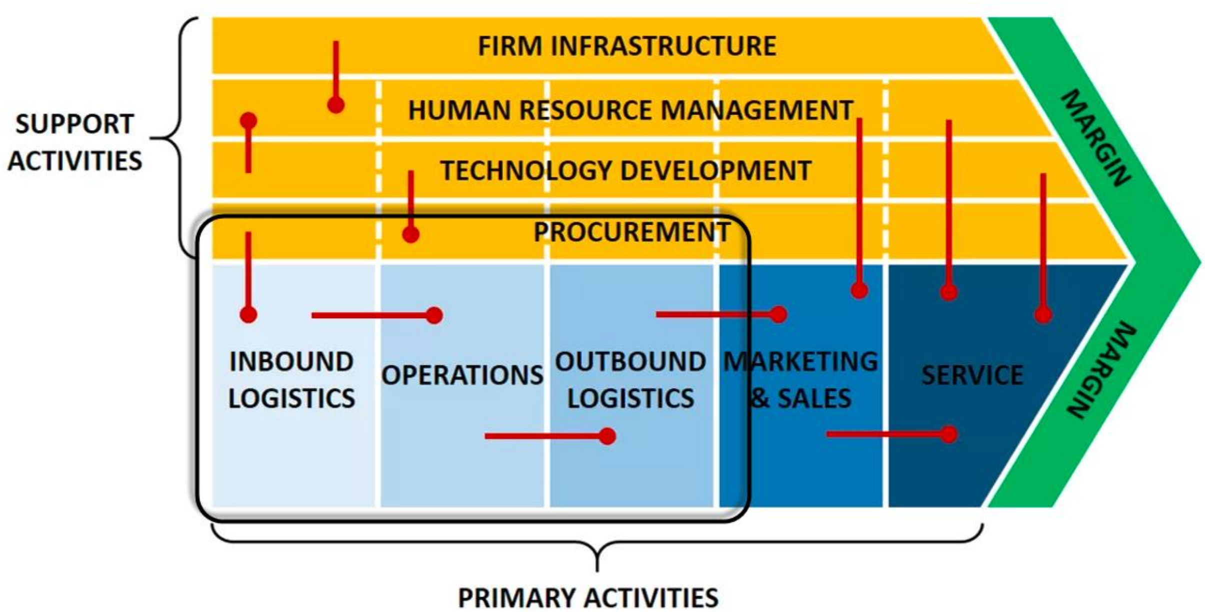

Figure 6 Porter's Value Chain (B2U 2018)

In order to draw a bow to supply chain management, in a second step a definition of supply chain management must be provided and secondly the activity categories of Porter that fall under the responsibility of supply chain management must be identified.

One possibility to define supply chains and subsequently supply chain management is provided by Porter. According to Michael Porter (1998), the term supply chain is applied to refer to a network of organizations that cooperate to transform raw materials into finished goods and/or services for customers (OECD 2010). Contrary to Porter, Fawcett, Ellram and Odgen (2013) define supply chain management as “the design and seamless, value-added process across organizational boundaries to meet the real needs of the end customers”. (Fawcett et al. 2013) They draw the scope of supply chain much wider and include all type of value chains; material, information and even financial flows. However, they do agree with Porter that overall SCM is considered to be a network of different intra- and inter-organizational areas that are responsible for managing activities along a supply or value chain. (Porter 1998)

To sum up, a supply chain is a network of various manufacturer, service providers, resources, activities and technologies that are involved in the transformation of inputs into outputs. All actors are linked with each other through product, information and monetary flows as depicted in Figure 7 Integrated Supply Chain.

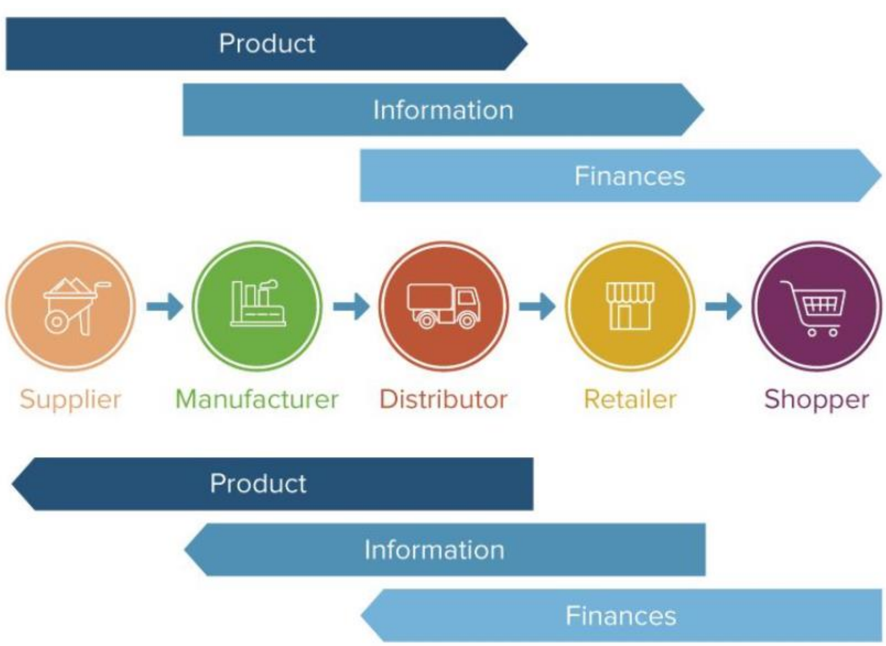

Figure 7 Integrated Supply Chain (Smartsheet 2018)

After defining the term supply chain and the responsibility of a supply chain management, in particular, when referring to the value chain of porter, one differentiation is open; the difference between logistics and supply chain management. In general, supply chain management is a fairly wider concept than logistics. Whilst logistics is mainly a planning orientation and framework that aims to create a single structure for the storage and flow of goods or information, supply chain management is based on this existing framework and focuses on interfaces and coordination of processes. (Christopher 2011) The main focus of supply chain management is creating a competitive advantage while the main focus of logistics lays in meeting customer requirements. It is important that both terms shall not be used interchangeably. Although both cannot exist without each other, it can be argued that logistics, as an activity itself, is part of supply chain. (Bisk 2018) Other classifications are available in research however for the further context of the thesis, it is anticipated that logistics are an activity within supply chain.

3.2.2 Characteristics of Pharmaceutical Supply Chains

Due to the complexity and highly regulated environment of the pharmaceutical industry for instance GMO and GDP standards, also its supply chains must be adopted slightly to meet their purposes. An analysis by Savage, Robert and Wang (2006) revealed that no other business sector has as many regulations and controls as the pharmaceutical industry. The pharmaceutical supply chain starts with the manufacturing of raw materials, mostly from chemical production. Afterwards the raw materials[4] are turned into active ingredients[5] and then into active pharmaceutical ingredients[6] (API). In a subsequent step, the API is turned into bulk drug substance[7]. Afterwards the drug bulk product is packed and a final quality release takes place. The finished goods are delivered either to an additional company warehouse or directly national or regional

[4] "A raw material, intermediate, or an API that is used in the production of an API and that is incorporated as a significant structural fragment into the structure of the API. An API Starting Material can be an article of commerce, a material purchased from one or more suppliers under contract or commercial agreement, or produced in-house. API Starting Materials are normally of defined chemical properties and structure" (REGISTRAR CORP 2018).

[5] „Any component of a drug product intended to furnish pharmacological activity or other direct effect in the diagnosis, cure, mitigation, treatment, or prevention of disease, or to affect the structure or any function of the body of humans or other animals. Active ingredients include those components of the product that may undergo chemical change during the manufacture of the drug product and be present in the drug product in a modified form intended to furnish the specified activity or effect" (REGISTRAR CORP 2018).

[6] "Any substance or mixture of substances intended to be used in the manufacture of a drug (medicinal) product and that, when used in the production of a drug, becomes an active ingredient of the drug product. Such substances are intended to furnish pharmacological activity or other direct effect in the diagnosis, cure, mitigation, treatment, or prevention of disease or to affect the structure or function of the body" (REGISTRAR CORP 2018).

[7] "A finished dosage form, for example, a tablet, capsule or solution that contains an active pharmaceutical ingredient, generally, but not necessarily, in association with inactive ingredients" (REGISTRAR CORP 2018).

wholesalers, depending on the set-up. In rare cases a direct shipment to hospitals or pharmacies takes place. Usually the fine distribution to pharmacies and hospitals is carried out by local wholesalers. In the end, the drug is either administered to patients in hospitals or the medicine is purchased in pharmacies. The whole process is illustrated in Figure 8 Pharmaceutical Supply Chain.

Figure 8 Pharmaceutical Supply Chain (Dhuri 2013)

Throughout the whole pharmaceutical supply chain materials and goods have to be shipped and stored under strict temperature control. In addition, in contrast to other industries, the majority of goods the pharma industry deals with have expiry dates, which means once goods reach their expiry date or for instance the transport or storage temperature range was exceeded or deceeded, goods must be destroyed. This leads to a very high destruction risk. Moreover, pharmaceutical companies have to adhere to strict terms of reference, issued by local or regional health authorities such as the EMA or FDA. For instance, in case a new side effect appears that must be mentioned on the leaflet, the whole packaging design must be changed and the variation must be implemented on the market in accordance with local requirements to remain compliant. This means, pharmaceutical companies have to closely monitor their stock levels and even more important, whether available stock can be sold in every final country of destination. So pharmaceutical supply chains are not only heavily regulated by more than one entity, the must remain as flexible as possible to be competitive but also compliant on the market. Another aspect that shapes the design of the pharmaceutical supply chain is the fact, that most of the business is so called business-to-business. There is no direct connection between the manufacturer and the final customer, the patient. It becomes even more complex when considering that in fact patients purchase the medicine but for instance prescription medicine is occasionally reimbursed by insurances or national health care institutions. So behind the patient, there is another indirect “customer”. (Savage et al. 2006) This becomes a very crucial factor when it comes to price negations. In summary, the pharmaceutical supply chain has plenty of internal interfaces but also external, powerful organizations and stakeholders such as government agencies, hospitals, clinics, contract manufacturers, drug distributors, pharmacy chains, retailers and independent research organizations.

3.3.3 Future Trends

It is important to identify the prevalent trends and fundamental drivers to obtain a better understanding of the pharmaceutical supply chain structure. Supply chain is the backbone of the pharma industry and plays even bigger role in the future in terms of achieving a competitive advantage or not. Generally, the rate of change, also fostered by new technologies, is increasing drastically. Hence pharmaceutical supply chains must prepare themselves to be flexible and capable of adapting quickly to any trend and changing business environment. (PwC 2011) The most significant trends that are supposed to shape the supply chains in the next years are artificial intelligence, advanced analytics, IoT, intelligent things, conversational systems, robotic process automation immerse technologies and by far one of the most interesting ones, blockchains, is discussed during the thesis. Artificial intelligence (AI), especially in terms of decision making can shape supply chains drastically in the future as it would free up currently bound capacities for higher-order use cases for instance strategic development or planning whilst AI takes over simple decision making on operative level. Similar to AI, advanced analytics could possibly take over tasks that currently depend on human judgement by making proactive decisions in regards to sourcing, planning and distribution. Another future scenario in supply chain management are intelligent things, less abstract, intelligent warehouses. The concept is nothing new and under testing with autonomous cars in the automotive industry. Intelligent things will be particularly becoming important in asset-centric, product-centric and service-centric industries as the pharmaceutical one. The IoT model could for instance help to better utilize assets and subsequently lower throughput times and decreased costs of goods in manufacturing. This would help to face the continuous cost pressure in supply chain. More details are provided in chapter 4.1 Best Practices of Blockchains in Industries in combination with blockchain technology. Nowadays, conversational systems are used in virtual personal assistants. In the future, particularly in customer services that are part of supply chain management, the technique could be used to process payments, deliveries and complaints. Again, more human capacity would be freed up to focus on more value adding, strategic tasks. Robotic process automatization (RPA) increases efficiencies and cuts costs by structuring mass data in order to automate existing manual tasks with just a minimum system enhancement effort. Augmented reality (AR), classified as an immersive technology, will impact supply chain for instance in manufacturing and warehousing processes. AR can help to better utilize storage space, process pick and pack activities or support maintenance of manufacturing assets. (Pettey 2018) Last but not least a big future trend is blockchain technology. Especially in combination with smart contracts, blockchains have the potential to make some other trends even obsolete. How blockchains can be used in different types of industries is evaluated in a subsequent chapter.

3.3. Blockchains

This sub chapter builds on the previous chapter and deals with the definition, terminology and technology behind the blockchains. It aims to explain the added valued, consequences and limitations of blockchains and paves the way for possible areas of implementation in the pharmaceutical supply chain that will be discussed later on in chapter 4.2 Blockchain Technology in the Pharmaceutical Industry and 5. Case Study.

3.3.1. Terminologies and Common System Architectures

Any software system is based on a specific architecture. The architecture determines how every single component of a system is organized and related to each other. Generally, it can be distinguished between two different approaches that act like antidotes; centralized and distributed software systems. In centralized systems every node[8] is connected to only one central component whilst in distributed system the nodes are linked to each other either directly or indirectly without being linked to one central component. (Drescher 2017) Figure 9 System Architectures visualizes the set-up of the two models. The circles represent the various system components, nodes, whilst the lines emblematize the connections between the nodes.

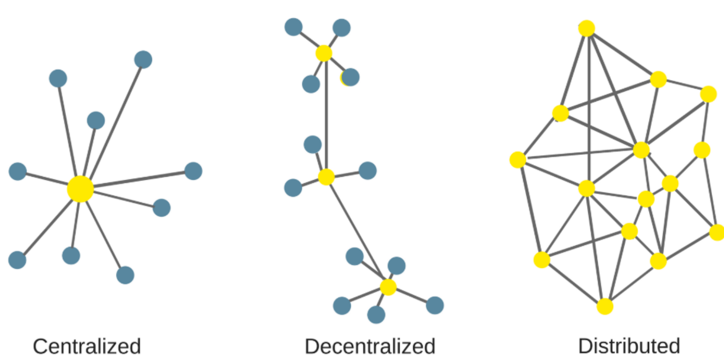

Figure 9 System Architectures (DAXX 2018)

[8] A node represents a system component.

As usual every system has both advantages and disadvantages. Since the two systems can be understood as antidotes to each other, the advantages of one are the disadvantages of the other. For simplification purposes, the arguments are clustered in below shown Table 2 Advantages and Disadvantages of System Types. The advantages and disadvantages of blockchain technology itself are discussed in detailed in the following paragraph 3.3.3 Characteristics of Blockchains.

Table 2 Advantages and Disadvantages of System Types

Variant	Advantages	Disadvantages
Centralized Systems	▪ Superior in system security ▪ Reduced system complexity ▪ Easier system maintenance ▪ Lower coordination and communication efforts ▪ No dependency on other networks	▪ Inferior in system reliability ▪ No ability to grow naturally ▪ Higher financial strains ▪ Lower computing power ▪ Higher risk of data loss
Distributed Systems	▪ Superior in system reliability ▪ Capability to grow naturally ▪ Lower financial strains ▪ Superior in processing power ▪ Lower risk of data loss	▪ Higher system complexity ▪ Inferior in coordination efforts ▪ Inferior in communication efforts ▪ Higher dependency on networks ▪ Higher security hazard

Besides the two above mentioned antidotes, a third type that is a subset of distributed systems is available. This is of importance, since the subset type paves the way for blockchains applications nowadays. Look wise the **decentralized systems** appears to be a hybrid of both; the centralized and the distributed system, as shown in Figure 9 System Architectures. However, the main difference between distributed and decentralized systems is the way how and where a certain decision is made inside the network. Another difference is the way how information is distributed via the control nodes in those systems. In decentralized systems, every node makes a decision for itself. The result is based on the aggregated decisions by every node. (Eager 2017)

Whenever software is designed the underlying question is, which architectural type to choose in order to achieve the main goals of the software and to satisfy the customer – in case of the pharmaceutical industry it is anticipated that the main targets are security, transparency and reliability. In any way, every system has its own advantages and disadvantages and influences the way how all functional and nonfunctional aspects of a systems can be achieved.

Exactly this is the point, when blockchain technology enters the stage since it promises to combine the advantages of common distributed systems with extremely high software integrity.

3.3.2 Blockchain Technology

In 2008 the hype gradually started, when the so called blockchain technology was first introduced in the market by an anonymous programmer using the pseudonym Satoshi Nakamoto (200). The blockchain technology itself was developed as a base for the digital crypto currency *Bitcoin*. Therefore it is not surprising, that many people know about *Bitcoins* as it is more tangible but do not know that the underlying technology of Bitcoins could be of utmost importance for many other areas of business, providing that it can be adjusted, transferred and applied to other processes. (Iansiti and Lakhani 2017) Figure 10 History of Blockchain Technology briefly captures the history of blockchain technology starting in the early 1990's with the introduction of distributed network architectures, the release of Nakmoto's white paper in 2008 until today, when blockchains are enjoying growing popularity not only in the IT sector but also in other areas of business. (DHL Trend Research 2018)

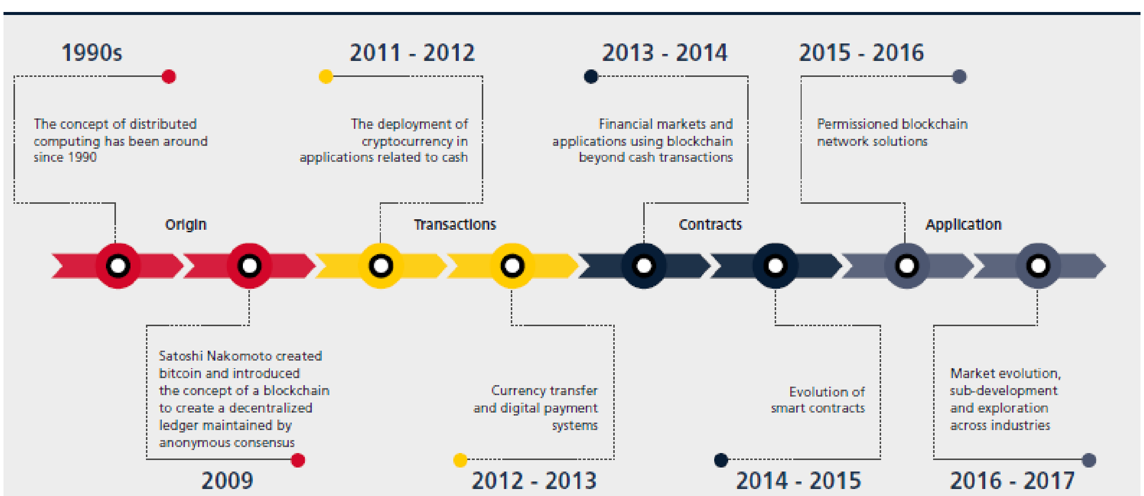

Figure 10 History of Blockchain Technology (DHL Trend Research 2018)

3.3.2.1 Defining Blockchain Technology

According to academic research, blockchain is defined by Nakamoto as follows "[…] blockchain is a tree shaped structure with the genesis block at the root, with each block potentially having multiple candidates to the next block. pprev and pnext link a path through the main/longest chain. A blockindex may have multiple pprev pointing back to it, but pnext will only point forward to the longest branch, or will be null if the block is not part of the longest chain." (Pastoor 2016) Although this definition was provided by the programmer of blockchains, it does not necessarily help to quickly capture the nature of blockchain. Therefore a second less technical definition is adduced. As laid down by Lemieux (2006) blockchains are "[…] a distributed transaction data base in which different computers – called nodes – cooperate as a system to store sequences of bits that are encrypted as a single unit or block and then chained together". Lemieux (2006) also emphazises that "Blockchains and distributed ledger technology promises trusted and immutable records in a wide variety of use cases involving recordkeeping, including real estate and healthcare" (Lemieux 2017).

The definitions and in particular the scope of what is considered a blockchain vary in academic research therefore it is difficult to find the one and only definition of blockchain. The definitions differ from each other especially in one aspect; the question whether blockchains can only contain transactions as stated for instance by Loop (2016) and Lemieux (2017) or whether blockchains can transfer all types of information as claimed for example by Iansiti and Lakhani (2017). Another controversial point is that how similar the structure of future blockchains must be to the initial Bitcoins in order to fulfill the criteria of blockchains.

Condensing the various definitions blockchain can be described as a decentralized and distributed ledger-technology[9] that enables users sharing databases and gather any kind of transaction of data in a secure way. Blockchains make intermediates, earlier acting as trusted third parties, obsolete and liberate data exchange in a reliable and forgery-proof environment. (DHL Trend Research 2018)

For the following parts of thesis, it has been decided to apply a broader definition of blockchains as different areas of usage – in particular pharmaceutical supply chains in this thesis – call for different structures and technological solutions that ultimately result in blockchain structures that differ from its initial purpose to serve a digital crypto currency. The underlying definition of the thesis traces back to the introduced ideas of Iansiti and Lakhani (2017).

[9] Distributed Ledger Technologies; distributed ledgers use independent nodes to record, distribute and synchronize any transaction in their electronic ledger. Blockchains create data blocks that are linked to each other and create a block-chain consisting of different data blocks (Natarajan et al. 2017: 2).

3.3.2.2 Set-up and Functionality of Blockchains

Despite the fact that the thesis does not aim to provide in-depth knowledge about the technological characteristics of blockchain, the main aspects that become important from business point of view are described as it is vital for understanding the areas of implementation later on. Any blockchain can be considered a peer-to-peer network, so a decentralized and distributed environment, in which all nodes, computers, record, share and verify transactions.

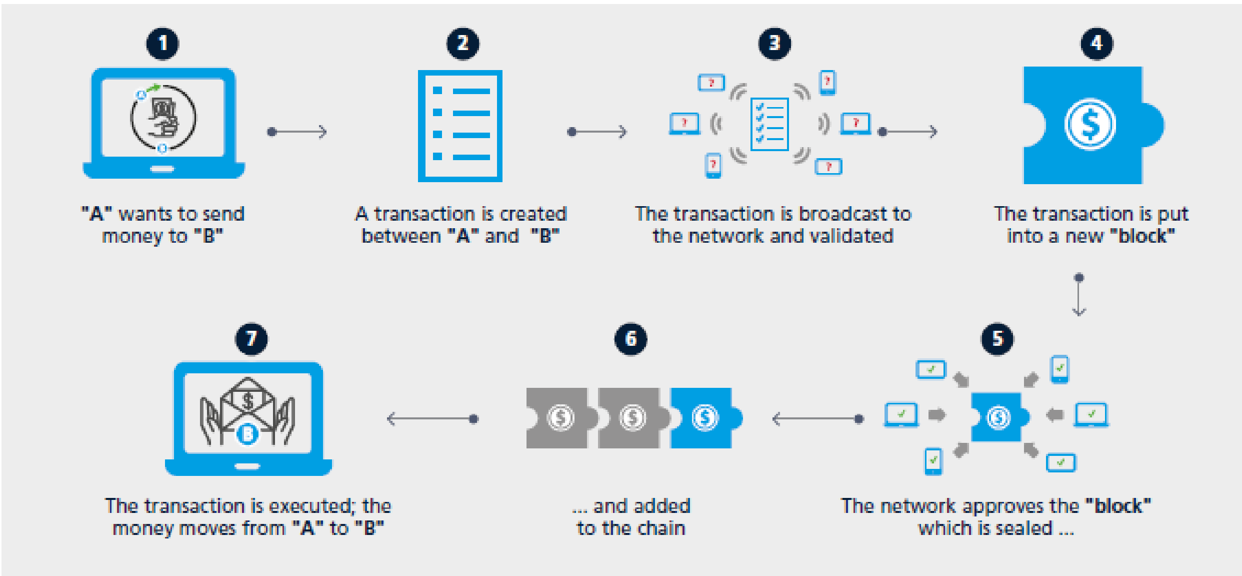

Figure 11 Method of Operation (DHL Trend Research 2018)

Figure 11 Method of Operation explains that once any transaction is started or added to the ledger, it is broadcasted into a network of nodes, system-components, and validated with a specific algorithm. The validation by each user is verified because every user electronically "signs" the transaction by applying public-key cryptography[10]. (Hackius and Petersen 2017) Afterwards the transaction is combined with other transactions, creating a block of data. The block itself is added to a chain of blocks in a transparent and immutable way using the consensus algorithm[11]. Once the new block of data is added to the existing chain, the transaction is closed. (Sanghera 2018)

Generally, it has to be distinguished between public and private blockchains since the structure differentiates slightly. In **public blockchains** anyone can participate, provide computing power and broadcast transactions. Any transaction made is also publicly applicable. In contrast, in **private blockchains** only safe listed users can join the network thus only verified and members

[10] Although using public-key cryptography, users can remain anonymous as the keys are not matched with any real life identity (Hackius and Petersen 2017).
[11] Details on the algorithm are provided in chapter 3.3.3 Characteristics of Blockchains.

can share transactions. (Schütte et al. 2017: 11) In addition, due to the restricted access, users can be assigned to different user profiles containing different permissions. Still both types of blockchain are decentralized peer-to-peer networks where each user keeps a copy of a shared append-only ledger of digitally signed transactions and in both, immutability is insured. (Jayachandran 2017)

3.3.3 Characteristics of Blockchains

3.3.3.1 Advantages of Blockchains

Since a blockchain "is a distributed digital ledger of transactions that cannot be tampered due to the use of cryptographic methods" (Pilkington 2016). The three main characteristics of blockchains are visualized in Figure 12 Basic Properties of Blockchains. As every technology, blockchains have advantages and disadvantages that must be balanced out when deciding to move onto a new technology. The following section provides a detailed overview about the most common opportunities and potential limitations of blockchains. The clustering becomes important in the course of the thesis as the key points are linked to demands in the pharmaceutical supply chain at a later stage.

Figure 12 Basic Properties of Blockchains (Hackius and Petersen 2017)

One of the omnipresent advantages of blockchain is the **immutability** of the technology. The high level of security is achieved by using cryptographic hash and the public-key function. All transactions broadcasted by users of the blockchain are summarized and a data block is created. With the help of a cryptographic hash function, the single blocks are connected with each other and a chain of blocks is created. During the process the transactions are being transformed into a hash value. (Jiang et al. 2018) The hash is a kind of fingerprint of the data block. If the data is changed, the hash is changed as well. However, due to the one-sided direction, each hash only fits to one specific data block. When a second block is created and linked to the existing block, the hash of the second block is a combination of the new data and the data of the first block. Thus, the fingerprint of the first block becomes part of the second block. If a third block is added, its hash contains the data of the second block – that already includes the data of the first one – and the data of the third block. This continues indefinitely. Summing up, in every block the hash of the previous block and its own hash are stored. The only exception builds the first block that solely contains its own data and starting hash. In case someone manipulates data in a block, the hash of the block is automatically changed. But, since the hash has changed, the hash value does not match the data in the subsequent blocks anymore – as it was explained that every block contains the fingerprint, the hash, of itself and the previous block. Due to the mismatch and the chain breaks, the manipulation is revealed. Consequently, in order to manipulate a blockchain it is not enough to just modify/delete one block of data and recalculate the hash value, in order to cover up the manipulation of the chain, the hash values of all blocks on all computers of blockchain members have to be recalculated. This is almost impossible and hence, the blockchain can be considered an immutable system. (Dobos 2018)

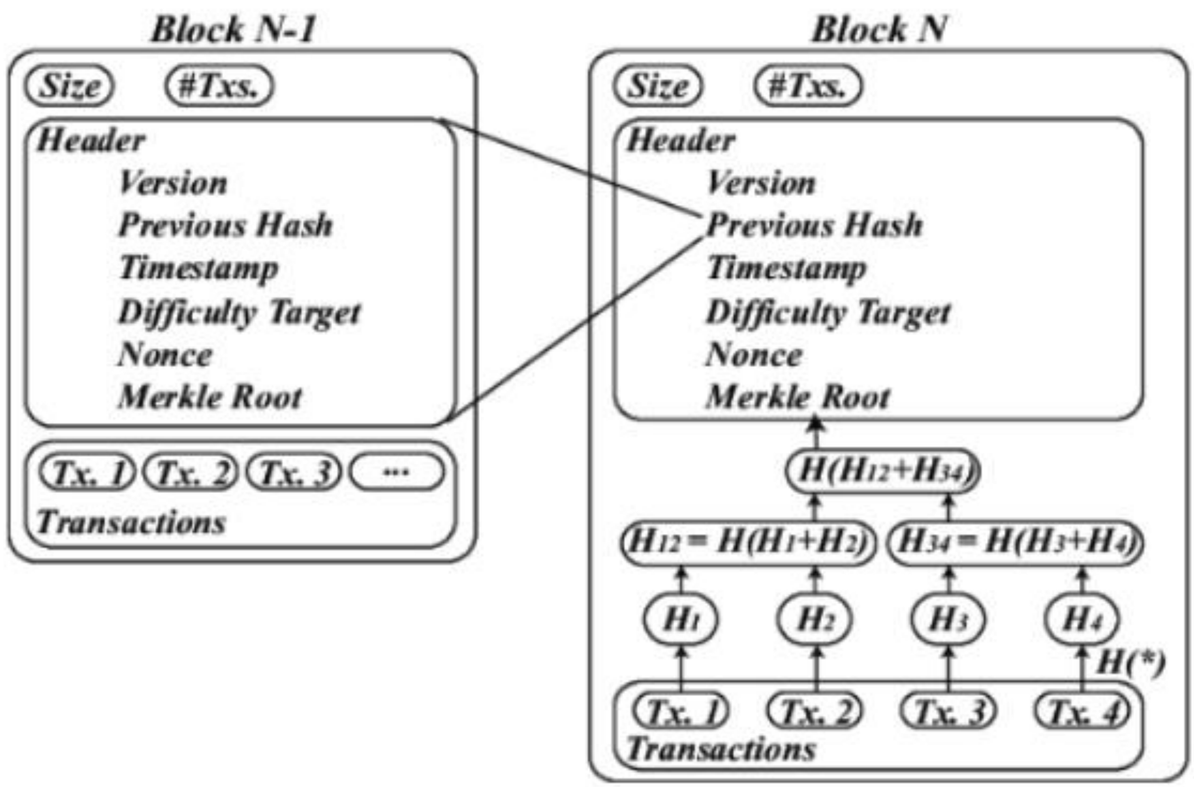

Figure 13 Structure of a Traditional Blockchain (Jiang et al. 2018)

Figure **13** Structure of a Traditional Blockchain depicts a common blockchain with two transactions or data blocks. The first block contains the data of the respective transaction and in addition, information that is stored in the header; the version / location of the block in the complete supply chain, the time of creation, a nonce[12] and a merkle root[13]. (Jiang et al. 2018) The merkle root is a result of the hash values of individual transactions. The created hash values are hashed, paired and hashed once again until a single top hash remains. The remaining top hash is the so called merkle root. In order to validate the blockchain, first the serial blocks must be verified by including into every block the hash value of the previous one. Thus, it can be ensured that no data block is manipulated throughout the blockchain without notification and ultimately the crash of the block chain. (Franco 2014)

Besides the hashing, a second tool, called public-key function, is used to ensure integrity of blockchains. Public-key functions are used to provide a secure digital signature whereby a kind of pair of keys is created, containing a private and a public one. This process is supported by algorithms. Both keys are interlinked but they serve different needs; whilst the public key is transparent to everyone, the private key is kind of a pin code. In simple words, the public key can be compared with the IBAN of a user and the private key is the pin code to access the account. (Franco 2014)

Figure 14 Public-Key Infrastructure illustrates how the PKI works. In simple terms, when the sender shares a transaction, the user creates a digital signature first in order to verify. Afterwards, the block of data and the hash value are created. The block is encrypted with the private part of the key. The recipient receives the information and the encrypted hash value. On the base of this, the receiver creates another hash value and transaction. With the help of the public key of the sender, the recipient can decrypt the hash and has to compare it with the one of the sender. In case both hashes match, it is ensured that the information is unaltered and from the sender. (Franco 2014; DHL Trend Research 2018)

[12] A nonce is a random number used in cryptography to ensure uniqueness and to prohibit the iteration of transactions.
[13] In information technology and cryptography merkle hashes / merkle trees refer to a method for providing a digital signature in order to authenticate a message.

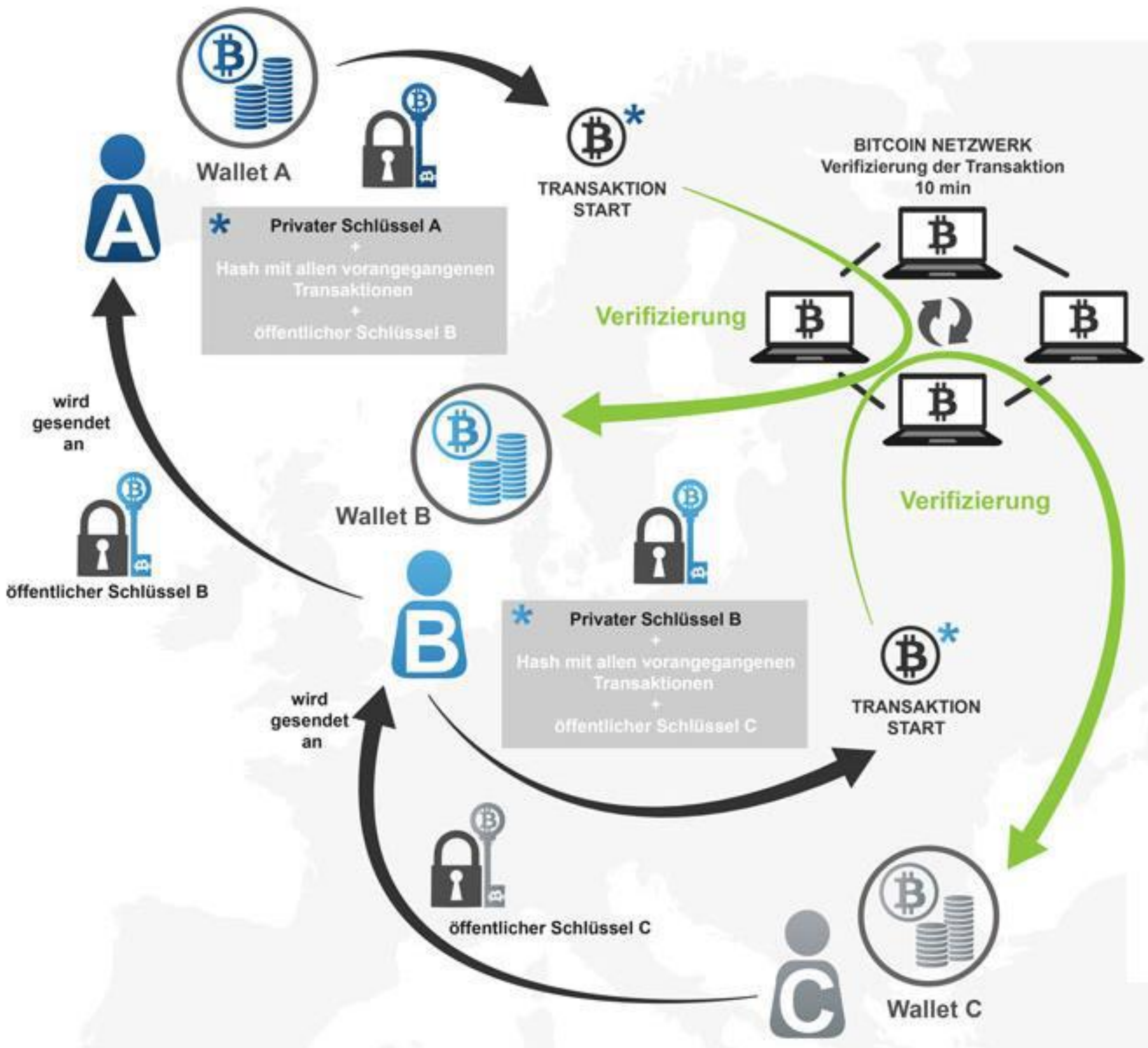

Figure 14 Public-Key Infrastructure (Franke 2018)

Another major advantage of blockchain is supposed to be the increased **transparency** and **traceability** compared to common networks. Whilst in common networks every user is storing and modifying copies of data sets, blockchain enables users to access a shared set of data. So every user is having access just to one set of data and can rely on not working on a copy of data but on the latest and most accurate data. This increases the trust into the blockchain systems. (DHL Trend Research 2018) Hand in hand with the transparency, blockchains also guarantee increased traceability that is of big interest in some industries. Blockchain allows users to trace back the origin of information for instance the origin of certificates but also the origin of materials and goods. Currently only technologies such as WiFi or RFID can be applied to trace back the origin or flow of data and goods. In the future, blockchains could simplify and speed up the process which would be an important benefit. (Heinen and Borgers 2017)

Despite the increased transparency and traceability due to blockchains, the new technology also guarantees an increased level of **privacy**. Whilst this seems to be an advantage for some users, others claim that this is a severe problem of blockchains since users could hide. The group of researchers arguing that blockchains increase privacy refers back to the public-key method explained in Figure 14 Public-Key Infrastructure. Others argue that even in blockchains no **anonymity** can be achieved. It is rather considered to be **pseudonymity** since users stay anonymous using a pseudonymous account. (Iansiti and Lakhani 2017) In regards to privacy, it has to be mentioned that depending on the point of view, it could also be a disadvantage.

An additional, even though minor advantage could be possibility to use blockchains for **asset management** in the future. The same logic can be applied to asset management and for traceability. Using blockchain it makes it easier to coordinate the ownership of any digital property. It would simplify the process of transferring the ownership of digital assets. (DHL Trend Research 2018)

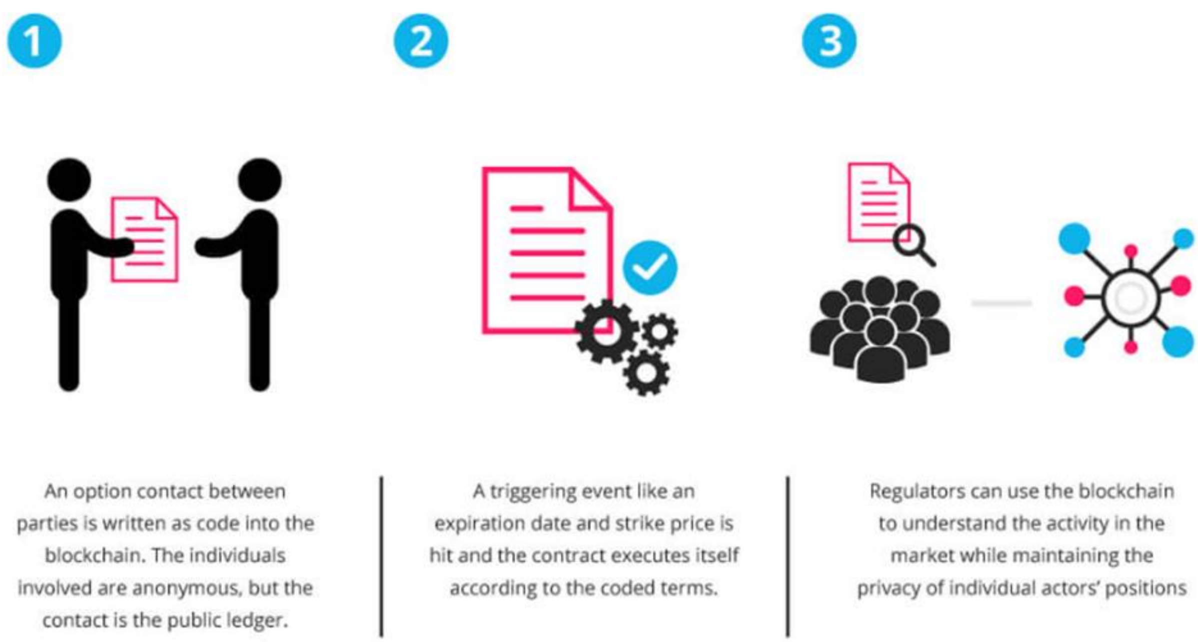

Figure 15 Smart Contracts (Blockgeeks 2016)

Another promising usage of blockchains could be **smart contracts**. Behind the term smart contract, a self-executing, blockchain-based software is hidden that can run automated processes on pre-defined events. Hence, smart contracts are basically electronical contracts, containing triggers for actions, which were aligned beforehand with all involved contractual parties. (DHL Trend Research 2018) Figure 15 Smart Contracts illustrates the most prominent characteristics of blockchains.

Smart contracts could replace numerous private clouds or ERP systems of different companies by providing an integrated platform. This would simplify the system landscape among business partners and increased homogeneity and therefore decreased costs for adaption of interfaces. (Heinen and Borgers 2017) In addition, smart contracts increase the independency from intermediates and safety. Neither third-parties such has intermediates can manipulate neither the contract nor the document itself could be hacked and modified due to the application of blockchains. Because of the decreased number of involved parties and the higher automation rate, the whole process is accelerated and by the end of the day time is money, so it even increases savings. (Blockgeeks 2016)

3.3.3.2 Disadvantages of Blockchains

As every emerging technology, also blockchain has certain disadvantages, risks and limitations that have to be evaluated in order to see the big picture. So regardless its hype and its obvious potential some challenges require adaptions before blockchain can be rolled out in all industries. The main ones are summarized in the following paragraph.

Blockchains are not an exception when the focus is put on legislative frameworks and regulating authorities. As many emerging technologies also blockchains faces a lack of law and common standards – so **standards and governance** functions are missing.

Besides all public blockchains, trends show that more and more private blockchains will be launched in the future. However, blockchains are barely standardized which bears a risk of lacking integrity although blockchains are known to be very secure. One expectation is Germany that is already represented via the DIN in the International Standard Organization. (International Organization for Standardization 2016) Another attempt to achieve standards is tackled by the Blockchain and Transport Alliance (BiTA) but in scope are only blockchains related to logistics. Additionally, it would be useful to set up an international and public register for blockchains in order to gain transparency over the blockchain infrastructure and to avoid parallel work streams for one and the same type of blockchain. (Schütte et al. 2017) In the future, organizational bodies are required to ensure constitutionality. An international framework is needed that addresses several topics that are currently not yet clear; which legal force do blockchains have (Schütte et al. 2017) and how to deal with the personal data stored data in the ledger. (Deloitte Legal Rechtsanwaltsgesellschaft mbH 2018) This topic gains even more topicality as the European data protection ordinance entered into force as from May 2018 and foresees a much stricter framework for the handling of personally identifiable information (PII).

Some of the most challenging topics are available **capacities** and **resource demands**. One of the main challenges and growth blockers of blockchains is the **throughput** capacity of only seven transactions per second and even up to ten minutes to process Bitcoin transactions whilst for instance a common payment processor handles in average 2,000 transactions per second up to a maximum of 56,000 transactions per second. Certainly, blockchains have a weakness in scalability which will prevent it from growing as long the throughput topic is not solved. (Croman et al. 2016: 106-107) Hand in hand with the throughput capacity goes the **energy** demand of big blockchains. In order to run all transactions, blockchains consume a huge amount of energy. The process of enabling computer hardware to perform mathematical calculations and creation of new blocks is called mining. Hence, PoW mining wastes a lot of energy just to maintain the consensus of a blockchain. (Yli-Huumo et al. 2016). In addition, expensive hardware is needed to process transactions in future blockchains. With increasing throughput times and sizes of blockchains also the energy and hardware demand increases. So two of the main obstacles are the energy consumption of blockchains as well as not yet fulfilled the pre-requisites regarding computing power. Only in case those problems are solved a large-scale roll out of blockchains is possible. (DHL Trend Research 2018)

The **industry adoption and acceptance rate** will ultimately decide whether blockchain becomes a success story in the broad industry or whether it remains hype in the cryptocurrency and among people in the information technology sector. Due to the missing legal framework and the challenges in scalability, it becomes difficult to convince key stakeholders in industries. In particular in highly regulated industries such as the finance, food, chemical and pharmaceutical sector, first a gapless legislative framework must be established before either the whole industry or at least certain process can be moved to blockchains. On the other hand, the added value of blockchains only increases if the number of growing participant community. So currently the blockchain technology faces a dilemma. (DHL Trend Research 2018)

Lastly, another obstacle is frequently underestimated are **organizations and cultures** in the context of blockchain acceptance. As mentioned before, blockchain develops its full potential with a growing number of participants. However, in a first step the future users – in particular the non IT affine users – must be convinced and gain trust in a new technology before it can be rolled out into all business processes. In order to smoothen the transition from common technologies to blockchains, companies and industries should gain knowledge in blockchains, run pilot projects and gain the trust of future users. (DHL Trend Research 2018) This process is strongly interlinked to change management in organizations. Change Management addresses human face of technological changes. A successful large-scale implementation of blockchains must be performed once with a focus on systems and processes and secondly focusing on the people.

As this thesis aims to also provide concrete recommendations for action cross-disciplinary, the following section briefly summarizes the most important aspects of fundamental change management that would be needed when rolling out blockchains technology, in any organization. Kurt Lewin provides an explanatory model that clusters the different phases of change management into three parts; unfreezing, moving and refreezing as presented in Figure 16 3-Phase-Model.

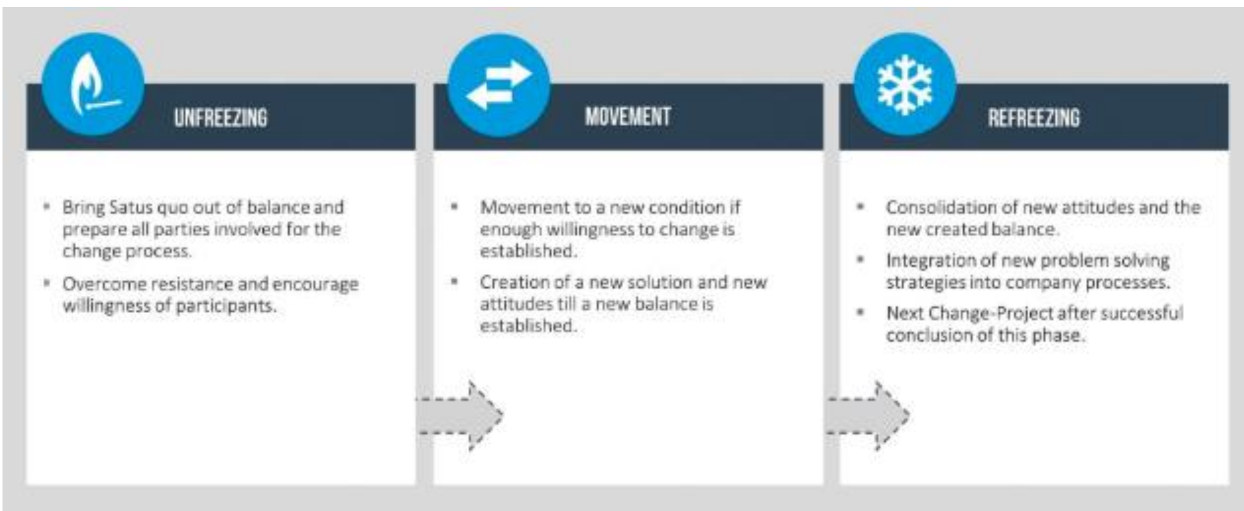

Figure 16 3-Phase-Model (Presentationload 2015)

The unfreezing phase describes the time needed to prepare all involved stakeholders for the upcoming change. The status quo is defined and problems identified. During this phase it is important to clearly communicate the scope and purpose of the change in order to establish a mental readiness. In the second phase, the movement stage, the changes e.g. blockchain technology is introduced and stakeholders gradually get used to a new standard. The phase ends, when all stakeholders are convinced that the change will create an added value. The last phase, called refreezing, is characterized by turning the new standards into routine. If the new status quo is not getting into the subconscious of stakeholders the likelihood of falling back into old patters and subsequently the failure of the change process is high. It is therefore necessary to monitor the adherence to new standards and deviations from the new status quo shall be prevented. (Burnes 2004)

Kurt Lewin's model is comparably old, taking into consideration that it was established in 1947 already however it has not lost any of its impact and topicality. In the subsequent years various models were created as summarized in Table 3 Different Change Concepts. Although all subsequent models show more phases, they all base on the initial phase model of Lewin to a certain extent. The latest models more and more combine the factual level with the emotional level in terms of change management. (Bergmann and Bungert 2011)

Table 3 Different Change Concepts (Bergmann and Bungert 2011)

Author	Phases
Kottler (1996)	(1) Increase urgency (2) Build guiding team (3) Develop the vision (4) Communication for buy-in (5) Empower actions (6) Create short-term wins (7) Do not let up (8) Make changes stick
Krüger (2002)	(1) Initiation (2) Conception (3) Mobilization (4) Implementation (5) Stabilization
Doppler / Lauterburg (2008)	(1) Initial considerations (2) Targeted sounding (3) Creation of project base (4) Communication concept (5) Data acquisition (6) Data feedback (7) Diagnosis and force field analysis (8) Development of concept and action plan (9) Preliminaries (10) Experiments and pilots (11) Decision (12) Roll-out and supported implementation

Every organization that rolls out blockchain technology in the future and carries out a transformation from common technologies to the hyped blockchains can find guidance in the four leadership principles by Jack Welch. Every change project must be attached to a clear vision and target statement in order to become successful. To make changes happen, companies must hire and promote only true believers. This requires a very good human resource management. Hand in hand goes the third advice to remove resisters even though their overall performance might be satisfactory. Only one non-believer can jeopardize the whole change process. Last but not least, in order to be a real change organization, companies must become brave enough to dare looking into new opportunities for instance blockchain technology although not every detail of it is assessed yet. Changes must be seen positively as more as a chance rather than risk. (Bergmann and Bungert 2011)

4. Applications of Blockchains

As blockchain technology matures and grows, more and more areas of usage for blockchains are identified across all types of industries around the world. At a first stage, this chapter aims to introduce and discuss selected, promising examples blockchain adoptions in industries. Hereby a special focus on the finance sector and the chemical industry is set, deepened and based on two interviews with experts from these branches. Whilst the framework of the chemical sector is very similar to the one applicable in pharmaceutical industry, the finance sector differs significantly in its structure. Therefore it is interesting to explore those antipodes. In a second stage, the applicability of blockchain technology in the pharmaceutical industry and more important, in the supply chain management is evaluated. This part of the chapter intends to answer some of the research questions and paves the way for the case study in chapter 5 that deals with the usage of blockchain technology in the pharmaceutical supply chain at Boehringer Ingelheim RCV GmbH & Co. KG. Lastly, an outlook about the further development of blockchains is drawn.

4.1 Best Practices of Blockchains in Industries

The most prominent example of blockchain technology are so called **cryptocurrencies** for instance Bitcoin, the first known digital currency, launched in 2008 or SwiftCoin and Etherum are two alternative examples. The majority of articles and papers dealing with blockchains focus on hyped cryptocurrencies in the financial sector. Since blockchain is much more than just the technology behind bitcoins and there are more areas of usage in the finance sector, the next sub chapter pays detailed attention on that. Bitcoins are digital assets, comparable to currency that can be exchanged via the Bitcoin blockchain. Anyone can participate and join the Bitcoin blockchain as it is classified to be a public network. Pseudo-anonymous users can transfer Bitcoins among each other in a secure and trusted manner. However, as Bitcoins make traditional bank instituted obsolete and bypass any financial institution and legal frameworks are missing, Bitcoins are heavily discussed in business, society and research. (DHL Trend Research 2018)

Another area of blockchain that is still in its early stage of development is the **internet of things** (IoT). The IoT is a global network of linked up human beings and objects. The main target of the IoT is to improve the interaction of humans and machines or solely the interactions among machines. So the overall purpose of IoT is to share information about the status of objects that mirror the manufacture, distribution and consumption of people's life. (Zhang and Wen 2017) However, in order to achieve a complete interconnection of people and objects, a decentralized system must be applied that allows a high level of autonomy. Blockchains would be an ideal technological solution, as it is based on a decentralized system that provides a highly secure environment. One of the obstacles is the prerequisite that blockchains and objects must be clearly connected and assigned. If this obstacle is taken, in the future autonomous machines for instance driverless taxis as suggested by Uber could offer their services and earn money themselves. (Schütte et al. 2017) So independent machines that perform a job and earn money are no longer just science fiction but could be reality soon.

Something very similar to the concept of the IoT is currently investigated in the **automotive industry**. The approach in the automotive industries follows the idea to create a digital twin for every physical asset via the blockchain. The physical asset would broadcast important events and data throughout its lifecycle to a private blockchain with limited access to just a few participants – however due to data protection laws the legal framework has to be investigated further. (DHL Trend Research 2018) This way, not only the "health" of the car can be monitored also every owner, could be registered in a blockchain. This would prevent or at least complicate theft and even more important, the manipulation of certain instruments such as the odometer. (Hill 2017)

Another, even though abstract, branch that benefits from blockchain technology could be the **legal sector** particularly with a link to smart contracts. At the moment, the usage of blockchains in legal environments is difficult as by law a concrete sender and recipient must be known. Due to the pseudonymity and decentralized approach, blockchains do not fall under the common understanding of law. Taking now into consideration that blockchains can and will work on global level, future ways of law enforcement must be aligned. Providing that in the future a harmonized legal framework for blockchains is established, preferably on a global level blockchains can challenge the claim of validity but also allow exploring new ways of law enforcement. Blockchains could simplify contract management in general, starting with the automatization till securing contracts from any kind of retrospective modification. Due to the higher level of automatization of contracts, so called smart contracts, intermediates become obsolete e.g. banks, traders or partially lawyers and the costs per transaction could be reduced significantly. This would make even the smallest kind of transactions profitable or at least cost-neutral. (Schütte et al. 2017) A future example could be a smart contract between a freight forwarder and a supermarket. If the delivery is delayed or the cool chain could not be kept by the freight forwarder on its way to the supermarket, based on the data broadcasted by the GPS and temperature logger of the truck into the blockchain, a penalty for delay could be automatically issued to the freight forwarder and the recipient, the supermarket, would get an automatic information about the delayed arrival of goods. Earlier, first the logger data had to be read out afterwards the paperwork about delay or exceeded temperature ranges had to be written and only then a penalty could be issued. Smart contracts can perform those actions, based on pre-agreed terms, automatically between the contract parties. Other interesting, not yet fully explored areas are the protection of (intellectual) property right, chain of custody and notary public. All based on a secure, distributed peer-to-peer network of blockchains. (DeMuro 2018) However, since most of the pilots in the legal sector are run secretly so far the proof of concept is missing. (Shah 2018)

Connecting to the legal sector, the **media industry** could benefit as well from blockchain technology although the purport in the branch is fairly divided. Whilst some key players in Germany say that blockchain has a great potential to be used in the media industry as well, the neighbors in Austria are more reluctant and argue that until now no company in the media industry has even started with pilot project in this direction. By contrast, in Germany, one of the largest policing groups has founded Bot labs, a start-up that aims to develop solutions for the media industry based on blockchain technology. (Mey et al. 2018) Possible areas of application could be licensing, copyright and the tracking of origins. In addition, blockchain could help to manage the allocation and payment of advertising spaces in the future. (Schütte et al. 2017) However, compared to other industries, the media industry is not as quick as others in the exploration and implementation of blockchains.

Last but not least another very interesting area of application is the **public sector**. Many different areas of the blockchain sector may be suitable to be run via blockchains in the future. Figure 17 Global Blockchain Pilots in Public Sector indicates in what countries blockchain pilots are started and on which aim they strive for. Surprisingly little activity is applicable in the European public sector whist the BRIC states[14] have either one or multiple pilots running. (Karanjia et al. 2018)

[14] BRIC countries comprise Brazil, Russia, India and China.

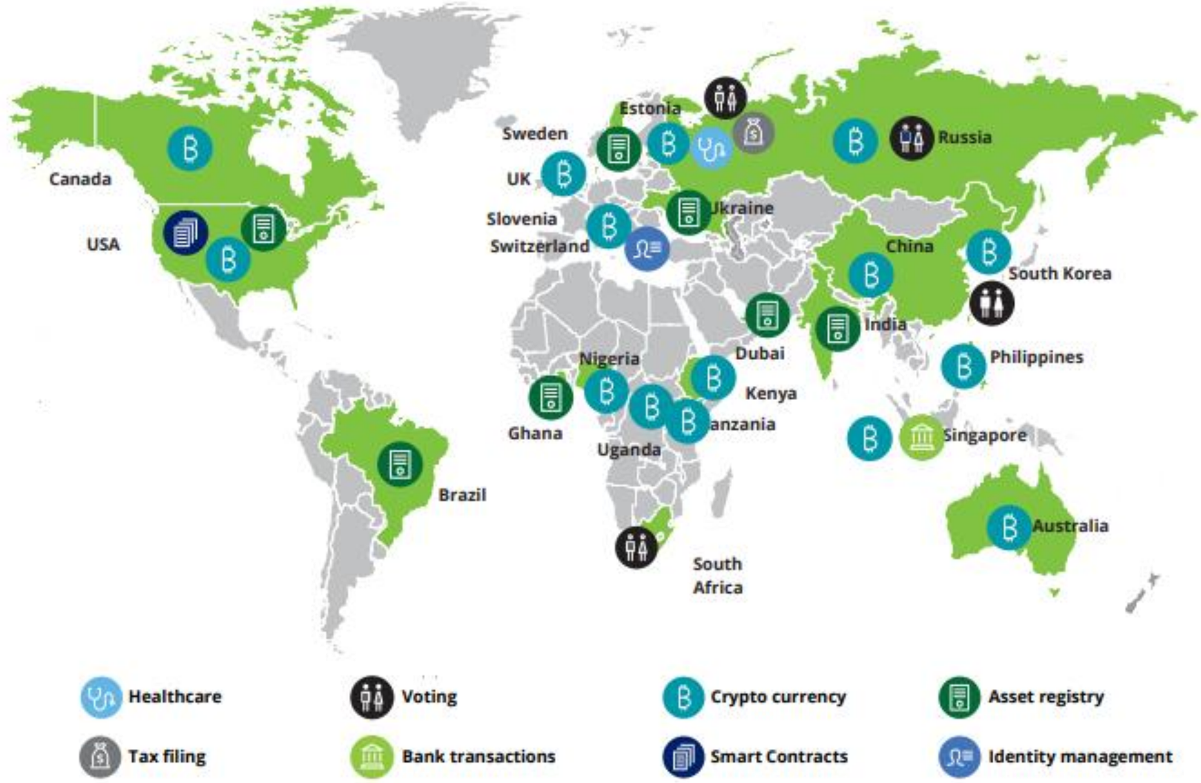

Figure 17 Global Blockchain Pilots in Public Sector (Karanjia et al. 2018)

The blockchain technology has great potential in the public sector, which is underlined by the variety of pilots running on a global level but on the other hand it also bears a risk for authorities because with the help of blockchain, certain authorities acting as intermediates might become obsolete in the future, similar to the fate of intermediates in other industries. The spectrum of blockchain usage ranges from fairly simple e-payments to property and ID management to e-voting. In the future, with the help of blockchains it could be possible to use cryptocurrency for any kind of payment including tax related transactions. In addition, as described under the point asset management in chapter 3.3.3.1 Advantages of Blockchains, blockchains could be used to digitally register any kind of asset or property such as cars or land. Blockchains could support facilitating property purchases and each step of the sale would be verified and recorded on the blockchain. This simplifies the handling but also increases the transparency and last but not least also helps the tax authority taxing the proper assets. (Schütte et al. 2017) Another promising area is the e-voting procedure. In countries with high population where elections become a complex and time intensive process or in countries that suffer from corruption, a voting system based on blockchains could provide a reliable, comparably simple and forgery-proof alternative to common election methods. Another important topic is data integrity. Authorities could use blockchains to verify IDs, certificates, social insurances etc. Overall the public sector offers many different areas to apply blockchain technology to, however it will take a couple of more years, until the every single nuance of blockchain is understood and the full potential of the technology can be used. (Karanjia et al. 2018)

Last but not least, the **darknet**[15] is another possible area of blockchain usage which to a certain extent is interesting to explore, as it plays a significant role in the illegal trade of prescription medicines and also it is important to mention for the thesis' sake of completeness. As the dark net is a legal vacuum it is preferably used for criminal and illegal actions e.g. distribution of extremist ideas, trading of (child-) pornography and arms trade. The main intention of darknet users is to remain anonymous but still maintain a certain level of security. Bitcoins and hence blockchains as the underlying technology gained significant relevancy in the darknet as both provide security and anonymity. As Bitcoin wallets are not linked to someone's real life identity but to a pseudonym users can process payments anonymously so that it is almost impossible for prosecuting authorities to trace back transactions. However, since this thesis aims to identify legal possibilities of blockchain applications, the darknet is excluded from further investigations.

4.1.1 Finance Sector

The most prominent area of blockchain applications and the actual origin of the technology certainly is the finance sector. Hence it is not surprising that almost all academic researches and papers either deal with blockchains in the financial branch or at least refer to approaches that result from financial processes. As the finance sector contributes a significant part to the development and exploration of blockchains and is supposed to be the industry with the most mature pilots, a particular focus is put on this industry.

Overall four major fields of potential blockchain applications in the finance sector can be identified. First of all, blockchains could help accelerating and simplifying any type of payment process, particularly **cross-border payments**. Currently, international bank transactions are comparably complex and costly as many different intermediates are involved. Resulting from the high complexity and costs such payment transactions are not processed continuously but only a couple of times a day. This leads to significant time lags in daily business. Blockchains could reduce, even erase, the disadvantages resulting from high costs and time delays. (Deloitte 2018) In addition, due to the reduced throughput time, the risk of changing foreign exchange rates can be lowered considerably. Besides already mentioned advantages, blockchains increase the security and pri-

[15] The darknet or deep web is a network approximately 500 times larger than the common World Wide Web and beyond the reach of search engines such as Google and Yahoo. The darknet is not a separate physical network but more an application and protocol layer riding on an existing network. It can be considered to be a collection of networks and technologies used to be share digital content in a legal vacuum (Biddle et al. 2003: 155-176).

vacy of any payment system as all payments are based on a so called push-system. This means, users / customers can initiate payments themselves without providing any bank data beforehand. At the first glance this does not convey an impression of increased security, solely increased privacy which is not beneficial to all parties but actually it does bear security advantages for all sides. Due to the decreased throughput times, the risk of chargebacks can be eliminated. Blockchains are based on inherent transaction irreversibility wherefore any kind of fraud originating from balancing entries is identified and prevented. This increases the security for traders although on the other hand the privacy of customers is empowered. (Schütte et al. 2017) Taking into consideration the increasing complexity in data privacy, handling and storing, recently strengthened by the European data protection ordinance becoming effective with May 2018, any payment system that runs transactions without storing customer and payment data turns out to be even more attractive to traders as it limits the risk of incompliance with different local data privacy laws.

Other interesting areas of application are **share trading and stock exchange markets**. Blockchain technology can simplify share trading by eliminating the need of intermediates such as middlemen or even the stock exchange itself. Instead of using the stock exchange, transactions could be run in a decentralized and secure ledger with numerous computers worldwide. So in the future, brokers are bypassed and blockchain technology is used to bring together supply and demand and to actually process the stock exchange. This does not only speed up the whole process but it also increases the trade accuracy. Additionally, blockchains could also change the way how companies could go public in the future. Blockchains, so far the most secure system, could be turned into a 'notary office' that can run fully automated issuance, transfer, coordination and management of private company securities. This would revolutionize the industry. Although it sounds very futuristic at the first glance, this approach is already under exploration by the Nasdaq[16] so it could become reality sooner than later. (Deloitte 2018)

Blockchains especially in combination with **smart contracts** can become useful in the **insurance and real estate area** as part of the broader finance sector. Once the conditions of the insurance policy are defined and agreed by all parties, smart contracts, based on blockchains, can for instance execute insurance payouts fully autonomous without any interference of humans – smart contracts can lead to smart payments in the future. In regards to the real estate sector, smart contracts can take over the monitoring function, checking and verifying numerous payments or any other transaction as part of the contract. (Deloitte 2018) In case of non-adherence

[16] The Nasdaq is a stock exchange in the U.S. and the second biggest in the world by market capitalization. The Nasdaq is located in New York City (Tillier 2017).

to service level agreements smart contracts can send out reminders or initiate corrective actions in case of a breach of contract. Manual workload and costs would decrease whilst efficiency and accuracy increase. (Schütte et al. 2017)

Certainly one of the most promising areas of possible blockchain implementation is the whole **accounting** process even outside the finance sector. Accounting is frequently subject to manipulation mostly triggered by human error. Guidelines such as segregation of duties, careful background checks of employees and intensive audits try to reduce the risk of incompliance. By implementing blockchains processes with regards to data entries, integration and maintenance of multiple books of accounts could be automated and hence human error and / or manipulation could be eliminated. Blockchains could consolidate single book of accounts into a data model that could be run autonomously. In blockchain, due to its distributed architecture, it is nearly impossible to rig data by e.g. backdating contracts as for every single transaction a new has value is created containing a time stamp. In case the data is changed, the hash value of this block is changed as well which leads to a mismatch and the manipulation is revealed (see also 3.3.2.2 Set-up and Functionality of Blockchains. (Deloitte 2018) Currently, two different blockchains are heavily discussed in this context; on one hand as a central register in order to consolidate bookkeeping and on the other hand as a consortium blockchain for customer data. (Schütte et al. 2017) In a consortium blockchain the validation process is controlled by a designated group or function however the right to view data can be provided either to public or again just selected users. (SAP 2018) In case of the finance sector this would mean e.g. major financial institutes would be responsible for entries into the blockchains but all banks could access the customer register which would accelerate the background check of customers and could accelerate the transmission of customer data.

Besides all opportunities some aspects still have to be clarified and technology must become more mature before a nationwide use is possible. In research as well as during the interview, one of the biggest obstacles mentioned is the security issue. Although blockchain technology provides a very high level of security it still bears some risks. In case the private key (see also 3.3.3.1 Advantages of Blockchains) gets lost. Another problem is the latency of blockchains. Currently, the network is not ready to process transactions as quickly as needed to reach a sufficient level of satisfaction by customers. Whilst for the technical problem of insufficient scalability solutions are in the pipeline the missing legislative framework is worrying financial experts more, as stressed as well during the interview. At the moment neither local nor international law fully covers the broad range of blockchains. Customers as well as banks have no concrete legal means in case for instance cryptocurrency stored in blockchains is hacked. Whilst a loss due to theft usually is reimbursed by common bank institutes in a world of cryptocurrencies and blockchains where traditional banks will no longer exist, it is not yet clarified how and if customers are protected. Certainly this is a big hurdle for a broader roll-out of blockchains as it addresses one of human's basic needs[17]; the physiological needs as in case of no money neither food nor accommodation can be afforded and secondly the safety needs that ask for protection, law and stability according to Maslow. (McLeod 2018) Whenever basic emotions are affected, the human component of change management shall not be under estimated.

Whilst the first section remains fairly theoretical, the second part focusses more on the "voice of the business". In order to obtain first-hand and unfiltered information of financial processes and blockchain usage, an interview with Mr. Alexander Tscherteu has been conducted. The interview aims to understand the requirements of the financial industry, the pre-requisites of blockchain usage and how blockchains can create an added value for companies. Besides those facts, the interview with an expert from the financial sector attempts to find out how and if the challenges of blockchains differ in various types of industries especially in contrast to those in the pharmaceutical one. Solely from the type of business, the finance sector and the pharmaceutical industry have little in common in the first glance. Whether this also applies to blockchains, shall be evaluated in the interview.

According to Mr. Tscherteu the most important features of any technology being used in the finance sector are costs, privacy and security. The financial branch is highly regulated and the data fairly sensitive, in this respect it is not much surprising that those three features are considered to be most important. On the other hand, characteristics such as user friendliness and latency are considered to be less important. The scalability of any technology as well as the internal transparency and reliability are rated to be neutral. Although the results are withdrawn from just one representative of the finance sector, the nature of the industry and its underlying needs can be identified. In combination with the academic research, the interview completes the picture and solely from a demand point of view, blockchains would be a suitable technology as they are meeting the main requirements.[18]

[17] According to Maslow physiological needs are biological requirements that are important for human survival such as air, food and drinks. If those needs cannot be sufficiently satisfied, the human body cannot function optimally. Until those basic, physiological needs are not fulfilled, all other needs become secondary. Besides physiological needs also safety needs are classified as basic needs of human beings. Safety needs refer to the desire of humans for any type of protection that can be achieved by health, security and property for instance (McLeod 2018).

[18] Interview: see also Appendix 5: Interview Protocol 5.

Mr. Tscherteu sees the main area of blockchain applicability in basic services for instance execution of payments or any type of security servicing. Blockchains allow running those types of processes in a more simple way and hence the costs are reduced. Reducing the cost disadvantage is by far one of the most important aspects as banks are under constant cost pressure. In addition, traditional banks see themselves faced with new entrants on the market, offering similar services but for less money due to specialization. Blockchain technology might help banks to cut costs and create a competitive advantage if using the advantages of blockchains smartly. Although Mr. Tscherteu emphasizes the advantages of blockchain technology and notices the added value, he also stresses that blockchain technology is still in an early stage and far away from being an implementable package for financial providers. Besides the missing legal framework he sees that biggest obstacle in the transaction pace. The more information is stored in blockchains, the longer the chains become and the slower the whole system. As long as developers have not solved the issues with the throughput times and energy demands, quicker standard solution will remain first choice although not offering such a high level of security as blockchain simply due to the fact that time is money and in this regard blockchains are inferior.[19]

"The future of finance could be without banks but with transactions approved automatically in seconds or minutes". (Tondreau 2016) To sum up, blockchain technology definitely has the possibility to change the design of the traditional finance sector by increasing profits due to a higher level of automatization creating more efficiency and due to the nature of blockchains more security. On the other hand blockchain technology poses a considerable risk to traditional banking as in theory only computer software is needed to run payment transactions in a peer-to-peer network, no bank account or intermediate. Going even beyond traditional banking also with regards to public record management blockchains could be of great use to society. However, institutes have not yet decided whether blockchains are more friends or foes since depending on the perspective BCT can appear to be an opportunity and threat. (Tondreau 2016)

4.1.2 Chemical Industry

Contrary to the finance sector, the chemical and pharmaceutical industries seem to have much in common. Unfortunately, no standardized classification and differentiation of the chemical and pharmaceutical industry is available, at least not on a European level. Whilst in some European countries the scope of the chemical industry is strictly limited to the development, manufacturing and distribution of chemicals referencing to the NACE 20[20] of the Statistical Classification of Economic Activities in the European Union, in others the chemical industry comprises more as-

[19] Interview: see also Appendix 5: Interview Protocol 5.
[20] The NACE 20 is a classification of economic activities in the European Union (Eurostat 2008).

pects for instance the pharmaceutical, hygiene, rubber and plastics sector. (Cefic 2018) For the purpose of this thesis, a narrow interpretation of the chemical industry is applied that only comprises the plain research, development, manufacturing and distribution of chemical products. Subsequently, the pharmaceutical industry is considered to be an independent industry sector. However, the chemical industry provides the base, the active pharmaceutical starting ingredients, for the subsequent process steps in the pharmaceutical industry. So from a supply chain point of view, certain dependencies are applicable.

Due to the fact that the pharmaceutical and the chemical industry are linked to each other, in terms of blockchain applicability and requirements to any technology, it can be assumed that both industries act similar. Currently three major areas of blockchain application in the chemical industry could be identified.

As in the chemical industry scalability is an important topic. All around the globe, large chemical parks can be found that are shared among different companies, aiming to create synergies due by jointly using for instance the infrastructure or energy production. In order to secure accesses to such networks and resources, companies agree to long-term contracts. On one hand this secures the production pipeline on the other hand long term contracts are fairly inflexible. In case the market changes and access to different resources or just in different amount of resource capacities are needed, with long-term contracts it is hard to achieve. Although it is the aim of all participants to optimize the resources of chemical parks, privacy concerns prevent companies from transparently sharing relevant information. Smart contracts, based on blockchains, could be an alternative in the future. Instead of inflexible, long-term contracts between the chemical parks and companies, smart contracts could regulate the capacities of different production streams in the future and subsequently also apply a dynamic pricing of the interconnecting streams. Blockchains provide a transparent but also secure environment to store all price calculations. The outcome would be a optimally utilized chemical park, an **industrial symbiosis**, that would not be subject to illegal price rigging. (Maxeiner 2017)

Another topic that goes hand in hand with an advantage of blockchain technology in the finance industry is the challenge of **cross-border transactions** (Wong 2018). In the chemical industry, the logistical chains are very broad and usually companies purchase and sell goods all over the world. This leads to a major problem in handling different currencies and exchange rates. Companies doing business in the chemical industry could for instance in the future use digital currencies for internal transactions that are broadcasted in a distributed ledger. An internal digital currency has two big advantages; first of all the transparency of all transactions would increase and secondly the prices of any type of service could be made comparable. Knowing the prices for all types of services within the company's network helps to better allocate work.

Another possible area of blockchain applications are decentralized sales platforms. Particularly in the chemical industry, during the manufacturing process companies need but also produce lots of intermediate products. Often those intermediate products can be used in other production as well, whilst one company is interesting in selling not needed intermediate products, another company is interested in buying an intermediate product for an attractive price. Currently, those transactions are run via central platform such as Alibaba. In the future, those intermediates could be skipped and margins saved by using decentralized sales platforms using blockchain technology. Companies could connect their productions to blockchains and broadcast relevant information for disposition. Smart contracts could take over an automated disposition and sell and buy intermediate products according to production plans. This way chemical companies do not need to share valuable data with competitors but still a secure, automated procurement can be achieved. Due to an increased transparency on actual demands and needs, the prices would become more dynamic and companies could most likely achieve better or fairer prices than now. (Maxeiner 2017)

Obviously, also in regards to supply chain processes, the chemical industry offers great potential for blockchain applications; starting with track and trace, to the handling of paperwork in cross-border transportation to preventing counterfeits. However, as research revealed that there is an immense overlapping between usage of blockchain in the chemical and pharmaceutical supply chain, the topic is discussed only once, in the subsequent chapter 4.2.2 Usage in Supply Chain Management.

In order to evaluate the concrete value of blockchain to the chemical industry, a second interview with an expert is conducted. The interviewee, Mr. Sebastian Dencker, is an expert in the chemical industry, more precisely in the water, hygiene and energy technologies. The rating of important features for any new technology such as blockchains in the chemical industry is similar to the results provided by experts in the pharmaceutical supply chain business. Not surprisingly, a high reliability and security are favorable features. The user-friendliness is rated very high by Mr. Dencker unlike the results provided by experts from the pharmaceutical or finance sector. However, this is not considered the standard but more a personal opinion of the interviewee. The overall idea of blockchain technology and its opportunities is perceived positively, particularly in regards to applications that secure the intellectual property of future 3D manufacturing as well as for the management of digital identities of assets and persons however, Mr. Dencker expects the chemical industry to be rather a quick follower than first mover. The biggest showstoppers are the not yet fully developed technology as well the missing proof of concept. Additionally, Mr. Dencker misses pilot projects that confirm and quantify an added value of blockchain technology to the chemical industry. From the interviewee's point of view, the inhibition threshold of companies to invest into blockchain pilots could be significantly reduced, if common software providers such as Microsoft or SAP offer blockchain solutions that frictionlessly work together with standard software that is already available in industries.[21] So offering blockchains as a complementary technology to existing one would increase the chances of success and propel the adaption of blockchains.[22] The provided arguments, particularly the proposal of offering blockchain technology as a complementary rather than replacing technology, go hand in hand with the perception of the blockchain experts from the healthcare sector and interviewees Mr. Glover and Mr. Grover.[23] Therefore, it can be implied that the limitations but also solutions to current road stoppers are very similar in the chemical and pharmaceutical industry, which strengthens generality of the outcomes of this thesis.

4.2 Blockchain Technology in the Pharmaceutical Industry

The following sub-chapters deal with the question, which processes in the pharmaceutical industry and in particular in the supply chain could be subject of blockchain usage in the future. Similar to the previous paragraphs, first a general overview of blockchain concepts in the pharmaceutical sector is provided. Afterwards the focus is set on solely supply chain relevant actions. The chapter ends with an outlook about future developments in the pharmaceutical supply chain and how they might affect the implementation and design of blockchains.

4.2.1 Status-quo in the Pharmaceutical Industry

Blockchain technology certainly has the potential to unlock new opportunities for pharmaceutical companies and fight particular threats such as theft and counterfeits. According to statistics from Interpol about one million people die from fake drugs each year. It is assumed that up to 50 percent of all drugs distributed via websites are falsified, containing either no active pharmaceutical ingredient (API) or a fractional amount. Particularly, customers in emerging markets suffer from counterfeits as about every third product on the market is fake. (DHL Trend Research 2018) In order to improve patient safety and to either stop or at least make it more difficult for putative manipulators many countries have implemented so called product safety and security features. Those feature e.g. data matrix codes containing random, unique serial numbers shall prevent

[21] Interview: see also Appendix 6: Interview Protocol 6.
[22] Interview: see also Appendix 2: Interview Protocol 2.
[23] Interview: see also Appendix 2: Interview Protocol 2 and Appendix 3: Interview Protocol 3.

consumers from receiving counterfeits in the future. The most prominent initiatives are the delegated act from the EMA that comes into force on February 9th 2019 and the one from the FDA that becomes valid from 2021 onwards. Both initiatives make it mandatory for drug manufacturers that want to participate in local pharmaceutical markets to apply additional tamper evidence safety features on the packaging material. In addition, in the future every sales pack receives a random, unique serial number that is created by a computer just in time and printed on the packaging material during packaging process. Afterwards the serial numbers are uploaded into a network that helps to track each pack in the distribution channel. When a customer buys drugs in the pharmacies or hospitals use it for treatments, the packs are scanned and a computer verifies that the serial number on the pack is correct and matches the data provided by the manufacturing site. This way, patients can be sure that they do not receive counterfeits as those numbers should not be available in the central data base. The only disadvantages lays in the usage of a central network, storing the sensitive serial numbers e.g. in the EU. Blockchains, using a decentralized network, would be a more secure but still transparent solution. Serial numbers could be broadcasted into a blockchain once created. At any stage of the logistical chain it could be clearly tracked and traced from where the product comes, who was responsible for the distribution and storage and if something happens, where the incident in the logistical chain happened. In case counterfeits appear on the market, it could be immediately tracked back at which point they entered the distribution channels. No serial number could be changed, deleted or duplicated after the upload to the blockchain took place. Every single adaption would change the hash value of the block and the manipulation would be revealed (see also 3.3.3.1 Advantages of Blockchains). Whilst the EU remains with a centralized solution, in the USA pilot projects are running to test, whether the objectives of the delegated act could be better met by applying blockchains. To summarize, blockchains could help fighting counterfeits in the market due to increased track- and traceability. This would make the usage of drugs all around the world much more secure. A detailed description about how the process could be designed in the future is provided in the next chapter 4.2.2 Usage in Supply Chain Management as it is strongly related to supply chain processes.

Others focus more on the potential applicability of blockchains during clinical trials. The highly sensitive patient data could be uploaded to a secure blockchain in the future that also allows to share and audit medical records and trial results. At the moment, clinical trial data is fairly difficult to access hence it is difficult to share ideas with important participants. Blockchains could provide a suitable environment to share clinical trial results among involved stakeholders while ensuring a high level of data security and system reliability. The increased transparency could foster sharing data and might leads to unlocking new treatments and gaining efficiency. (DHL Trend Research 2018)

4.2.2 Usage in Supply Chain Management

Supply Chain Management including logistics is by far the most prominent and promising area of blockchain exploration after cryptocurrencies and the finance sector. Why? For a very simple reason; supply chain management is all about coordinating numerous partners starting with manufacturers, warehouse providers, wholesalers and freight forwarders but also financial and insurance service providers. Approximately 60 percent of all B2B transactions are still paper-based and hence sensitive to (human) errors. (Schütte et al. 2017) Every single step in the supply chain costs time and money which conflicts with companies target to deliver preferably quickly, cheap and still in high quality. Blockchains are always worth to consider when multiple partners must work together closely, when intermediates shall be reduced or eliminated and high security, traceability and reliability is required. The pharmaceutical supply chain is a gold mine when searching for possible areas of blockchain applications. What are relevant processes for blockchain technology is described in the subsequent paragraphs in detail.

Before deep diving into the content, first it must be distinguished between traditional supply chain processes dealing with the materials and information flow whilst the second part, less discussed in research, deals with the financial and commercial processes in supply chain. Due to the two different natures and objectives, also the requirements on blockchain differ therefore it makes sense to disassociate both processes from each other. However, in the end both processes run hand in hand and must be seen as a big picture.

4.2.2.1 Logistical Processes in SCM

Although blockchains have the potential to become a superior technology in multiple blockchain processes, during the interviews and academic research four major application possibilities have been identified. Each aspect is being discussed in the following section.

Inbound and outbound logistics, as part of supply chain management, deals on a daily base with plenty of documents, some of them confidential and of high importance. Especially in cross-border logistical chains many documents must be prepared for customs clearances that are attached to the physical goods when shipping. Besides standard documents such as the bill of transport, packing list and invoices, in the pharmaceutical industry also certificates of origin and various testing certificates must be provided for every drug transport. Subsequently, before every air-, sea- or truck-shipment a high amount of paperwork must be processed by logistical staff. Moreover, the environmental aspect is dramatic. Although being in the 21st century, the logistical processes are mainly handled paper-based which means a lot of paper is wasted for every shipment. Overall, it is estimated that out of the total costs for each shipment between 15 – 50% originate from trade-related paperwork. (Hackius and Petersen 2017) Besides the high costs, the paper-based approach also bears the risk of loss and fraud. During long logistical transport in many cases more than one border is crossed and documents are checked by several instances such as customs officers, freight forwarders and other involved parties. Occasionally, it happens that the document set is lost or even worse, it is manipulated which leads in the pharmaceutical industry to a severe risk of patients. (IBM 2018) Blockchain offers large potential to **turn logistical processes into faster and leaner ones** by digitizing transport paper records. With the help of blockchain technology, in the future, trade-related document records could be shadowed in a restricted supply chain that would make paper-based documentation obsolete (Wong 2018). The blockchain connects all involved parties of a logistical chain starting with the manufacturer to the freight forwarder, customs and customers. Via a standardized interface, every party can access the relevant shipment documentation in the blockchain when needed for instance in order to clear the goods at an EU border. No party needs to change its IT systems, solely expanded by an interface to a partner-blockchain. (Hackius and Petersen 2017) This would not only tackle to problem with lost document records during transportation the distributed ledger technology and risk of manipulation as blockchains are considered to be tamper evident.

A second very important area of applicability of blockchains is **transparency and traceability**, particularly in combination with **temperature and humidity monitoring**. Nowadays it certainly is possible track the location of a single truck, sea- or airfreight container via GPS however; in the majority of cases the data is not available in real time. How does it affect pharmaceutical supply chains? Many drugs for instance vaccines must be stored and shipped under certain temperature and humidity conditions. (DeCovny 2018) In case the temperature and humidity ranges are exceeded or deceeded the drugs lose potency. For this reason, pharmaceutical companies equip their shipments with temperature data loggers.

Before every shipment the temperature data loggers must be configured with the correct temperature profile, depending on the type of goods that are supposed to be shipped. Throughout the whole shipment, the temperature data logger measures the temperature and humidity with sensors and stores the data. After completion of the shipment, the temperature data logger is connected to a PC, similar to a USB stick and the stored data is downloaded for a quality analysis.

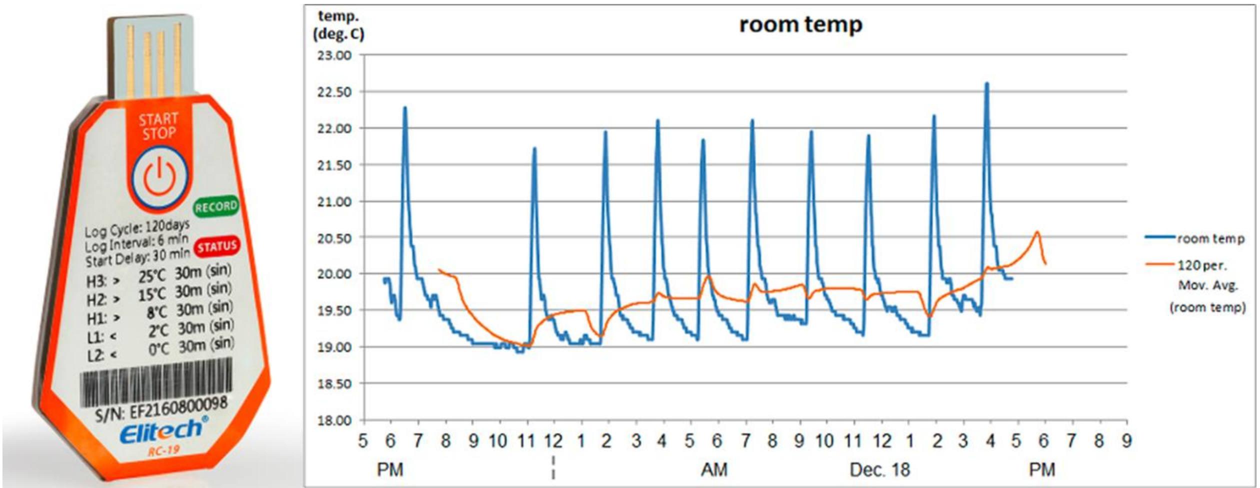

Figure 18 Data Logger and Analysis (Elitech Technology Inc. 2018; Marett 2012)

Figure 18 Data Logger and Analysis **(Elitech Technology Inc. 2018**depicts a standard temperature data logger and an example analysis of measured temperature data. This approach is not only complicated it also bears again the risk of manipulation. Additionally, the companies remain in a "blackout period" until the data logger is read out. Companies do not know whether the shipped goods can be released to the market until the whole analysis is done. During this period, the companies lose a lot of time and hence plenty of money. Another problem lays in the dependency of partners when reading out the loggers. Either the companies, that send goods with data loggers, rely on their counterparts that they stop the monitoring function immediately after goods receipts and timely read out the loggers or they need to wait for the analysis of data until the logger is returned. Again this is highly time-consuming as the counterparts must be audited for proper handling of data loggers and overall it costs a lot of money. Blockchain technology in combination with the IoT (refer to 4.1 Best Practices of Blockchains in Industries) offers a simple but effective solution. In the future, smart devices could be attached to each shipment that autonomously monitor and record the environmental conditions of a transport. Instead of storing the data on the device itself, the data is broadcasted in real-time on a blockchain. This way, the integrity of the shipment and hence the product quality is better and even more important, companies can access the temperature records at any time either during or after the transport. This would enable companies to know where and when exactly a deviation of the temperature budget occurred and the quality analysis that decides on the release of goods could be started immediately, even before the goods reach their final destination. It would save companies a lot of time as the "blackout-period" is erased. Since this accelerates the whole supply chain of goods, patients can get their goods much quicker than now. If this approach is linked to smart contracts, even financial flows connected to single shipments can be simplified, accelerated and automatized in the future (see 4.2.2.2 Financial Processes in SCM).

As mentioned briefly before, blockchains could play a significant role in the **identification and prevention of drug counterfeits** in the future. (Hackius and Petersen 2017) When talking about counterfeits and false medication it must always be linked with the ongoing serialization and partially aggregation projects, initiated by multiple local and regional health authorities such as the EMA and FDA. Those projects deal with the idea to endow every final good with a unique, random identification number that contains quality sensitive information about the product's origin, the batch number as well as manufacturing and expiry date. When manufacturing the product, the serial number is uploaded onto a central server and before handing out a drug at the pharmacy or hospital, the staff is verifying the integrity of the product. At the first glance this sounds like a perfect solution to track and trace a product throughout its whole life cycle however, the crux lays in maintaining the traceability and transparency among the multiple steps of a supply chain. Another critical factor is the data security. In case wrong serial numbers are uploaded onto the server, the counterfeits would not be recognized as such in the final check. Additionally, as the information is stored on a central server it is more threatened by data hacking, data manipulation or data loss. In particular in the pharmaceutical industry, another level of complexity in the supply chain is added by repackaging activities. From time to time, pharmaceutical manufacturers repack existing stock of drugs with updated packaging material for instance containing newer medical treatment notes. In those cases existing serial numbers must be deleted or inactivated and updated ones must be created. This process bears a certain risk of mix-ups and mismatches that could harm end-users. Besides the current approach, using centralized servers to store the data, blockchain technology could provide an alternative that actually is more reliable and secure. (DHL Trend Research 2018) How the process could be designed in the future, is illustrated below in Figure 19 Simplified Blockchain-based Track and Trace System.

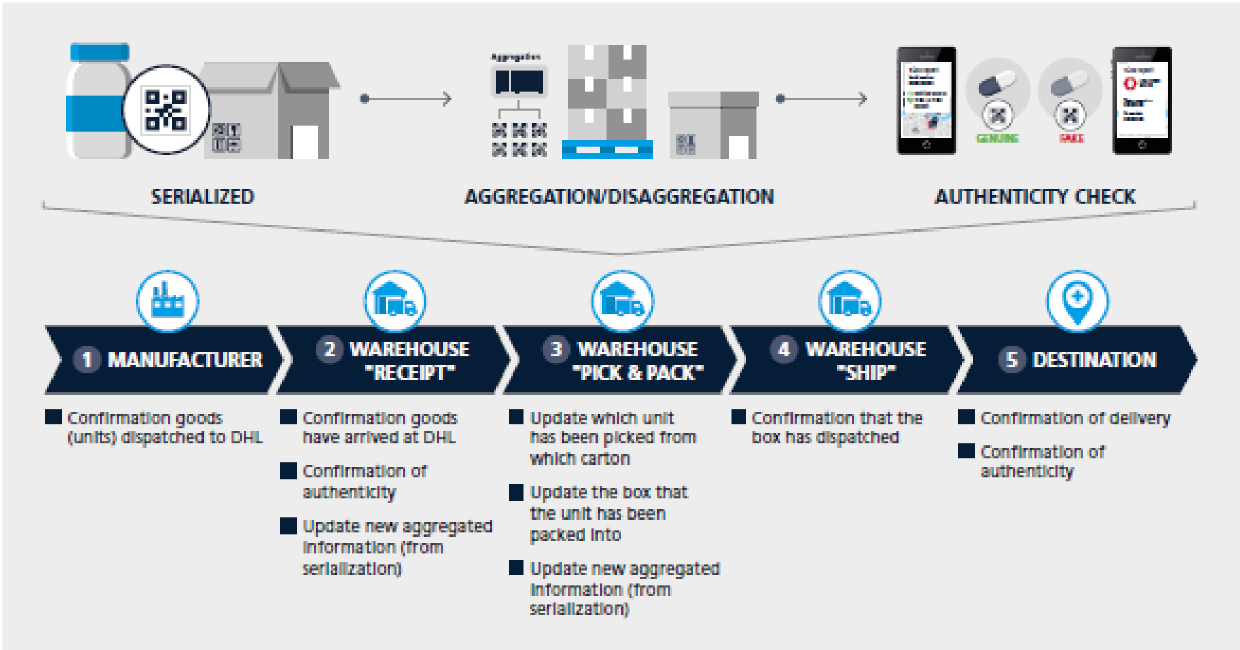

Figure 19 Simplified Blockchain-based Track and Trace System (DHL Trend Research 2018)

Above mentioned concept is based on blockchain technology so instead of using a central server to store serial numbers of millions of drugs a decentralized system, a blockchain, is used to upload, store and maintain product related data. In this model, every step the pharmaceutical product takes from its production, to the wholesaler warehouse, hospital, pharmacy and patient is tracked and broadcasted into the blockchain. At any point of the supply chain, the product related data as the location, manufacturer and current owner but also physical data such as humidity and temperature of the storage environment are transparent, accessible and tamper-evident to involved supply chain partners. By restricting the possibility to upload serial numbers to only registered and audited drug manufacturers the possibility of black-market producers to upload serial numbers of counterfeits is erased. In addition, it is almost impossible for criminals to infiltrate the pharmaceutical distribution channels with counterfeits since at any step of the supply chain during goods receipt and goods issue the product is checked against the data in the blockchain. Goods without a known serial number will not be handed out to end-customers and hence the patient safety is increased. (DHL Trend Research 2018)

Another so far very relatively unknown area that could benefit from blockchain technology is **sustainability** in supply chain management. Pharmaceutical companies are facing increasing pressure from different types of stakeholders for instance regulatory institutes and politics but also from potential customers to shape their supply chains in a more ethical and sustainable way. (Vandevelde 2018) In order to listen to the voice of customers, companies could create something like a “material passport” in the future that is broadcasted into a blockchain, accessible for all relevant users. This material passport could store the whole “life” of a product including the source of raw materials, the place of production steps, the distribution chain and much more. So in the future, users, or in case of pharmaceuticals, patients could perceive the origin and history of a drug they purchase.[24] By increasing transparency and traceability, also customers are empowered and a completely new interaction between pharma companies and patients and physicians would be possible – of course always in scope of legal requirements. Increasing consumer engagement and awareness will most likely lead to a higher motivation of companies to pay attention to ethical and sustainable set-ups of supply chains. Companies that realize the potential of end-customers becoming an active partner in supply chain could possibly gain a competitive advantage as they could use the newly created transparency to promote for instance production in EU, human rights or no child-work. (Vandevelde 2018) In terms of sustainability, material passports in blockchains will increase the longitudinal traceability of any step in the supply chain and can reveal and eliminate redundancies of work and hence reduces the consumption of fairly often rare raw materials and in addition helps to coordinate better recalls and bottlenecks from logistical point of view which would be reflected in lower greenhouse gas emission. (Leblanc 2018) By being able to track and trace consumed material via a material passport in a blockchain, in the future it could be considered to use information for something like a secondary commodity market. Following the principles of a circular commodity, goods that were needed for the production of drugs but not flow directly into the finished good, could be offered on a secondary commodity market to reduce waste.[25]

4.2.2.2 Financial Processes in SCM

Whilst the majority of researches solely focus on the potential of blockchains in logistical supply chain processes, this paragraph draws the attention on the applicability of blockchain technology in financial flows. Supply chain management does not only consist of material and informational flows but also financial ones that are worthwhile to consider. Particularly in combination with smart contracts, blockchain technology can take the handling of financial supply chain processes to a new level.

[24] Interview: see also Appendix 4: Interview Protocol 4.
[25] Interview: see also Appendix 4: Interview Protocol 4.

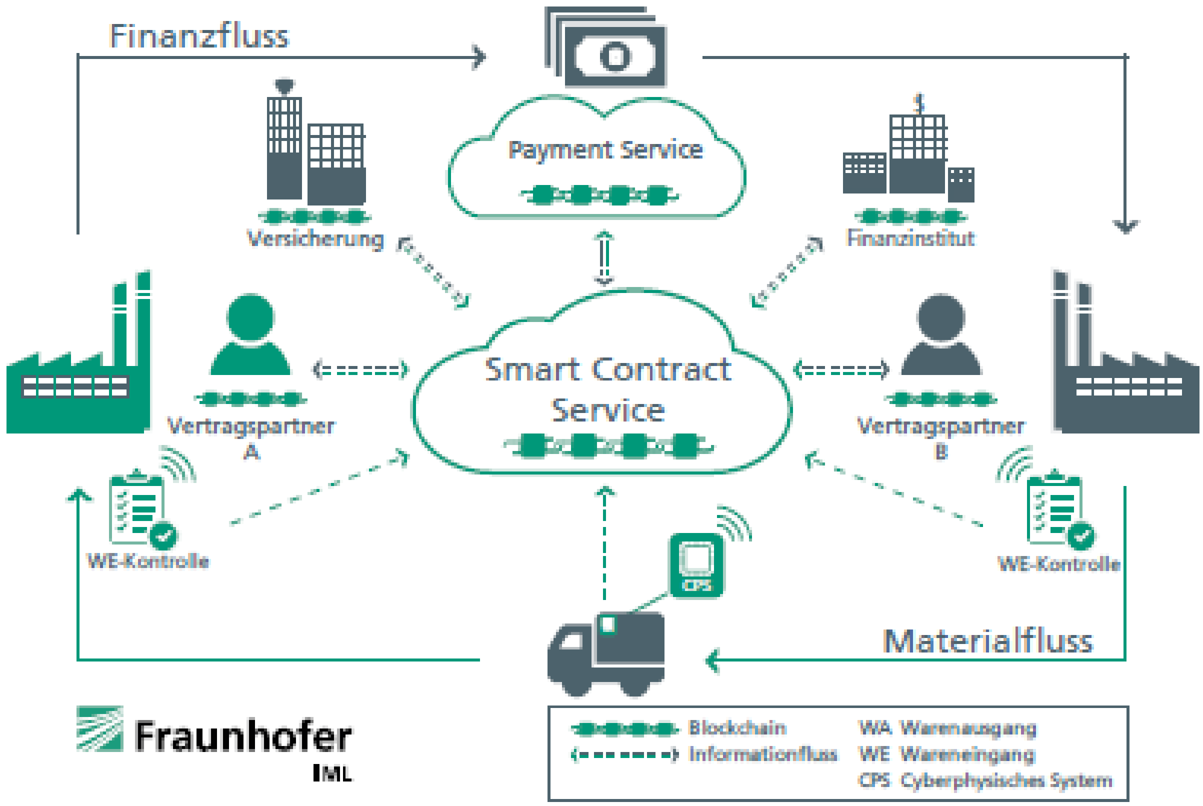

Figure 20 Blockchain-based Supply Chain Network (Schütte et al. 2017)

As mentioned on the last section, it is of utmost importance for pharmaceutical supply chains to maintain a stable, registered temperature and humidity level throughout all storage and transportation steps. Otherwise pharmaceuticals may lose its therapeutic effect. Providing companies would use blockchains to record temperature and humidity data in real-time during shipments, as proposed before, smart, self-executing contracts with logistical partners could simplify related payment processes, insurance payments in case of damage and loss but also the prosecution of penalties in case of a breach of contract. Figure 20 Blockchain-based Supply Chain Network visually shows how smart contracts can be used within a blockchain based supply chain network.

In the concept of integrated, blockchain-based supply chain networks, the blockchain works as a distributed storage that secures irrevocably all relevant information for the smart contract. The smart contract itself, works as a self-executing software, that verifies, based on the stored information in the blockchain, whether certain subject terms of contracts between partners are fulfilled or not. Coming back to the before mentioned example and the illustration, this would mean, in case the manufacturer sends goods to a wholesaler, pharmacy or hospitals, once the counterpart reports back the goods-receipt, smart contracts could independently, without an interaction of human, initiate the payment transactions. In case the temperature deviation would happen during storage or transport and the data is broadcasted into a blockchains, as described in the chapter 4.2.2.1 Logistical Processes in SCM, smart contracts could report the incident to insurances that could immediately issue a credit note for the loss or damage if this is defined in the contractual terms. (Dobos 2018) In parallel, the smart contracts could initiate a penalty to the executing freight forwarder that did not adhere to the provided storage or transportation terms. Additionally, the responsible quality department could be informed via an alert from the system that the records show either a deviation in temperature or humidity and the usability of goods can start immediately, deciding on the blockage or release of shipped materials. (Schütte et al. 2017) Going one step further, on operative level smart contracts could autonomously initiate purchase orders to resupply certain materials in case the pre-set minimum stock level is reached. The decision about how much and when to resupply is based on the stock information stored in the supply chain. This would not only work in an internal supply chain process but also with external suppliers as blockchain technology only provides the secure frame. No participant in an integrated supply chain network must replace internal IT systems; blockchain would just be a simple enlargement being the common ground to share information. This frees up a lot of human capacity on an operative level that could be used for more value adding, complex and strategic tasks. Additionally, the efficiency is increased and the risk of human errors resulting in obsolete stock or stock outs could be decreased, as long as the information in the blockchain is reliable and of good quality.

4.3 Outlook

Condensing the information about possible areas of blockchain adaption in (pharmaceutical) supply chain management, into a decision framework, it can be summarized, that blockchain technology makes sense if one or multiple of below shown aspects apply to a process.

The decision tree is inspired the DHL Trend Research (2018) but adjusted to the needs of the pharmaceutical supply chain and extended by certain aspects that were covered during the interviews with experts from business and research. It supports companies, particularly the management of supply chain organizations, when deciding whether blockchain technology can be applied to a business process in the future or not. In case the answer throughout all or the majority of questions is “no” then blockchain technology most likely is not the optimal solution for the business process. In contrast, if all or the majority of answers are “yes” it makes sense to deep-dive into the process and consider a PoC and pilot. If blockchain technology is determined to be a suitable solution, companies must decide in a last step on the general design of the blockchain; a public, hybrid or private blockchain. This decision strongly depends on the purpose. If data and transactions shall be disclosed and accessible to the public, a public blockchain such as the Bitcoin blockchain is suitable. In case the access shall be restricted to certain parties only the ground for decision is the point of consensus. In case the blockchain shall only be used within one organization or company, a private blockchain model shall be used. On the other hand if the blockchain network shall be used between different partners for instance manufactures wholesales and customs authorities, a hybrid model can be used. A hybrid blockchains combines the advantages of private and public blockchains. The blockchain itself can only be accessed with permission, granted by control functionality that also determines which data is privately accessible and which data is publicly accessible (see also 3.3.2.2 Set-up and Functionality of Blockchains).

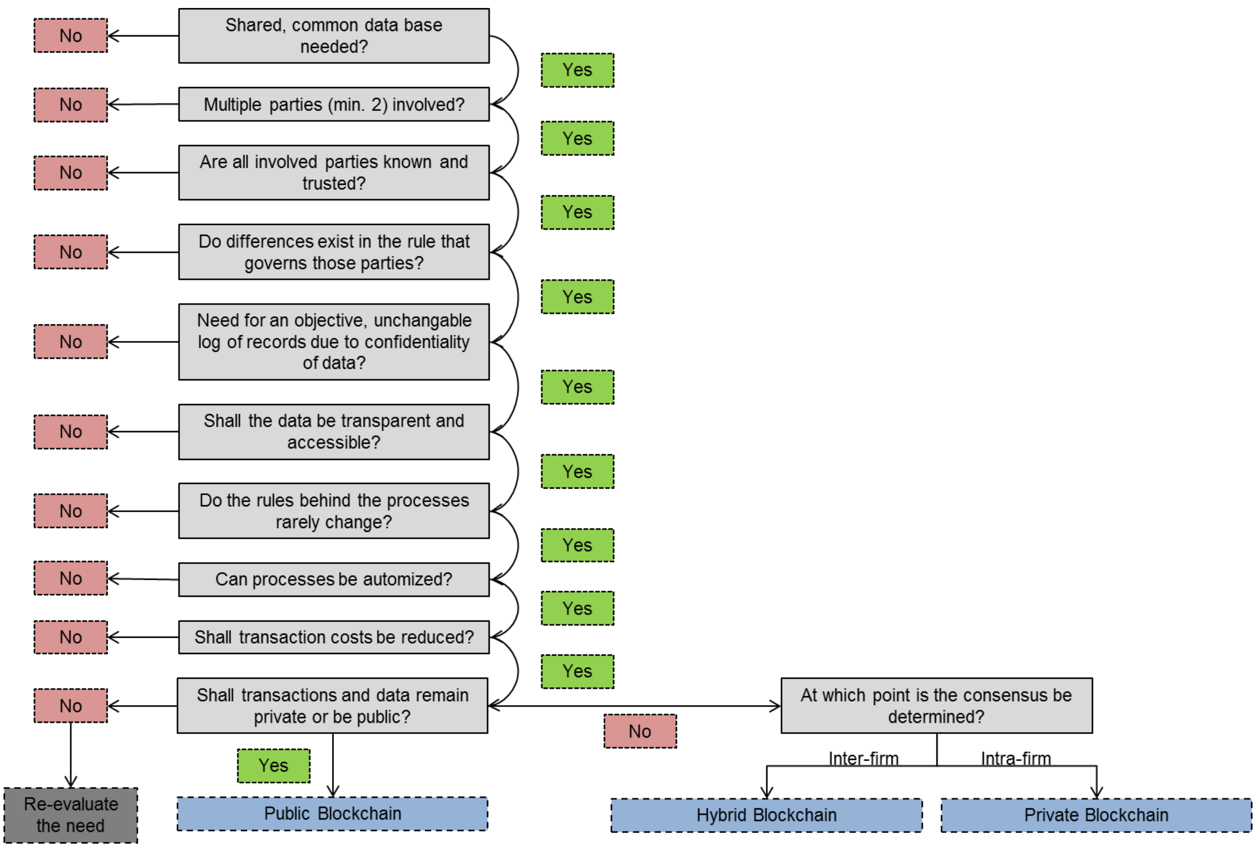

Figure 21 Blockchain Decision Tree[26]

Once it is decided that blockchain adds a benefit to existing processes, the management of companies should carefully initiate the first actions as shown in Figure 22 Implementation Steps.

[26] Own illustration, inspired by (DHL Trend Research 2018).

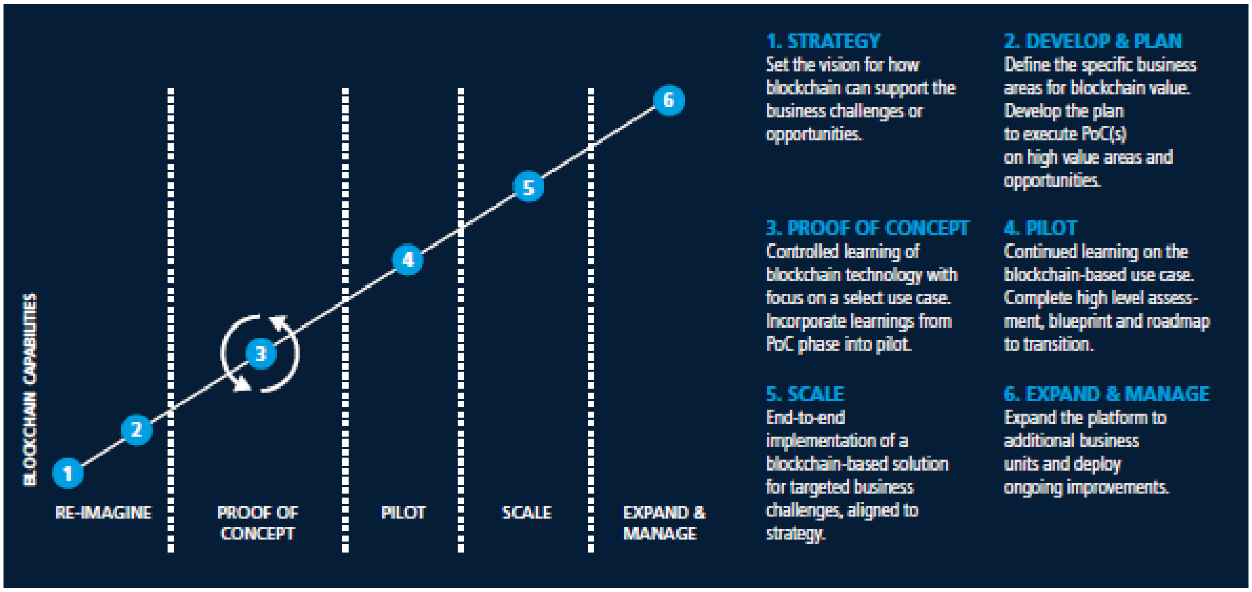

Figure 22 Implementation Steps (DHL Trend Research 2018)

The first step is very important in particular for the management and refers back to the topic of change management, explained in chapter 3.3.3.2 Disadvantages of Blockchains. The management must define a clear vision and mission on why and how to implement blockchain technology in the future. This mind-set must be spread throughout the organization but it only works out if every manager supports the idea of blockchains. In a second step the processes, blockchain shall be applied to, must be identified, using the mentioned decision tree (DHL Trend Research 2018). Following the development phase it is important that a proof of concept is created. This means, in an isolated test system, processes running on blockchain technology are tested in simulations with realistic data. The proto-type must pass all tests before the pilot can be rolled out. (Troy 2018) During the pilot phase, users test the system on a small scale in daily business. This provides valuable feedback about the performance of the system and users get gradually used to the changes. Once the pilot phase is successfully conducted, the blockchain application can be rolled out step by step on a large scale involving more and more users. (DHL Trend Research 2018) The success strongly depends on the acceptance of final stakeholders hence the roll-out plan should be linked to a transparent communication strategy. In addition, it is valuable to explain not only the purpose of blockchain but also the added value to the company e.g. achieving a competitive advantage due to blockchains in certain areas.

5. Case Study

This chapter deals with the potential applicability of blockchain technology at the Boehringer Ingelheim Pharma GmbH & Co.KG, the case study partner. In a first step, the company's profile in particular its distribution network is described. Condensing the knowledge gained in the previous paragraphs about blockchain usage in complex pharmaceutical supply chains, it shall be evaluated in detailed if, where and how blockchains could be implemented at the Boehringer Ingelheim Pharma GmbH & Co. KG. In particular, the focus will be on the question of the added value of blockchains and how it can be quantified and measured. The chapter will conclude with concrete recommendations for action.

5.1 Company Profile

The Boehringer Ingelheim RCV GmbH & Co. KG belongs to the worldwide operating research-based pharmaceutical company Boehringer Ingelheim, headquartered in Ingelheim am Rhein in Germany. Boehringer Ingelheim dedicates itself since 1885 to research and development of pharmaceuticals for humans and animals as well as the production, marketing and distribution. In total, 55,000 people are employed at Boehringer Ingelheim in about 145 affiliated companies around the globe. About 1,500 people work in the Boehringer Ingelheim RCV GmbH & Co. KG located in Vienna, Austria. The regional center in Vienna focusses on medical research, biopharmaceutical production, administration and distribution of drugs. From supply chain point of view, the regional center in Vienna is very interesting, as it is responsible for the fine distribution of pharmaceuticals to more than 30 countries in Central and Eastern Europe as well as Asia acting as a hub in the company's network. (Boehringer Ingelheim GmbH 2018)

In 2017 RCV (Regional Center Vienna) could achieve an operational performance of 1,544.4 million euros which is equivalent to a growth of plus 25 percent compared to previous fiscal year. The net sales of the core business, prescription medicines and animal health, rose by plus 20.8 percent to 837.5 million euros. The most successful markets remain Russia, Poland and Austria itself. In order to keep up with the growth in bio pharmaceutical business, Boehringer Ingelheim invested almost 700 million euros to construct a brand new biopharmaceutical production facility. Once the production plant is fully constructed and validated, the plant, located in the heart of Vienna, will start its operations in 2021. (Boehringer Ingelheim GmbH 2018) As a growing manufacturer for bio pharmaceuticals also the supply chain network will have to grow hence it is an interesting project to look at.

"Creating value through innovation" is one of the guiding principles of Boehringer Ingelheim. This does not only apply to the research and development but to all divisions of Boehringer Ingelheim.

Evaluating the potentials of blockchains in the pharmaceutical supply chain is an approach to keep up with technologies that helps to improve the life of any patient by continuously enhancing its supply chain.

5.2 Recommendations for Blockchain Application

After detailed discussions about possible areas of blockchain application in the pharmaceutical supply chain, the focus of this paragraph lays on the concrete implementation of blockchain technology using the example of the Boehringer Ingelheim RCV GmbH & Co. KG supply chain organization.

When determining which processes could be subject to any blockchain pilots, the interview with Mr. Patrik Ziman, Head of Regional Supply Chain Management at the Boehringer Ingelheim RCV GmbH & Co. KG reveals that the main focus lays on logistical processes, in particular those where 3rd parties are involved and sensitive data must be shared although the partners hardly know each other and hence almost no trust-base is applicable. In the course of the interview, especially the process of document handling during cross-border shipments was mentioned. Currently, companies like BI RCV must provide plenty of paperwork with each shipment in order to custom clear goods at country borders including standard papers such as the packaging list of a truck and respective invoices stating the value of commodities and the insurance note. But, in case of drugs being shipped, also the quality certificates of each batch that is included in the packaging list must be shipped with the goods. In some cases even multiple document sets, in different languages, must be handed out in order to clear goods.[27] From ecological point of view, it is an enormous waste of paper resources, however, it is also understandable that in order to avoid counterfeits entering local markets the documents are of utmost importance. Another problem companies are facing during the long transportations is that the document sets can get lost, either by the freight forwarder or at the customs office. In case the papers get lost on their way, the truck is prevented from driving further, as the documents are not available anymore for the next border crossing. In those cases, a new set of documents must be prepared and shipped by courier that does not only take more time but also creates additional costs. (DHL Trend Research 2018) Speaking for the whole industry, Mr. Ziman claims any solution that would be able to allow sharing confidential documents and information in a secure environment would be interesting for the industry. It would be interesting as well, if the technology

[27] Interview: see also Appendix 1: Interview Protocol 1.

could support a higher level of automatization of processes by reducing human interfering. Last but not least, in the long-run, the technology must simplify processes and increase efficiency.[28]

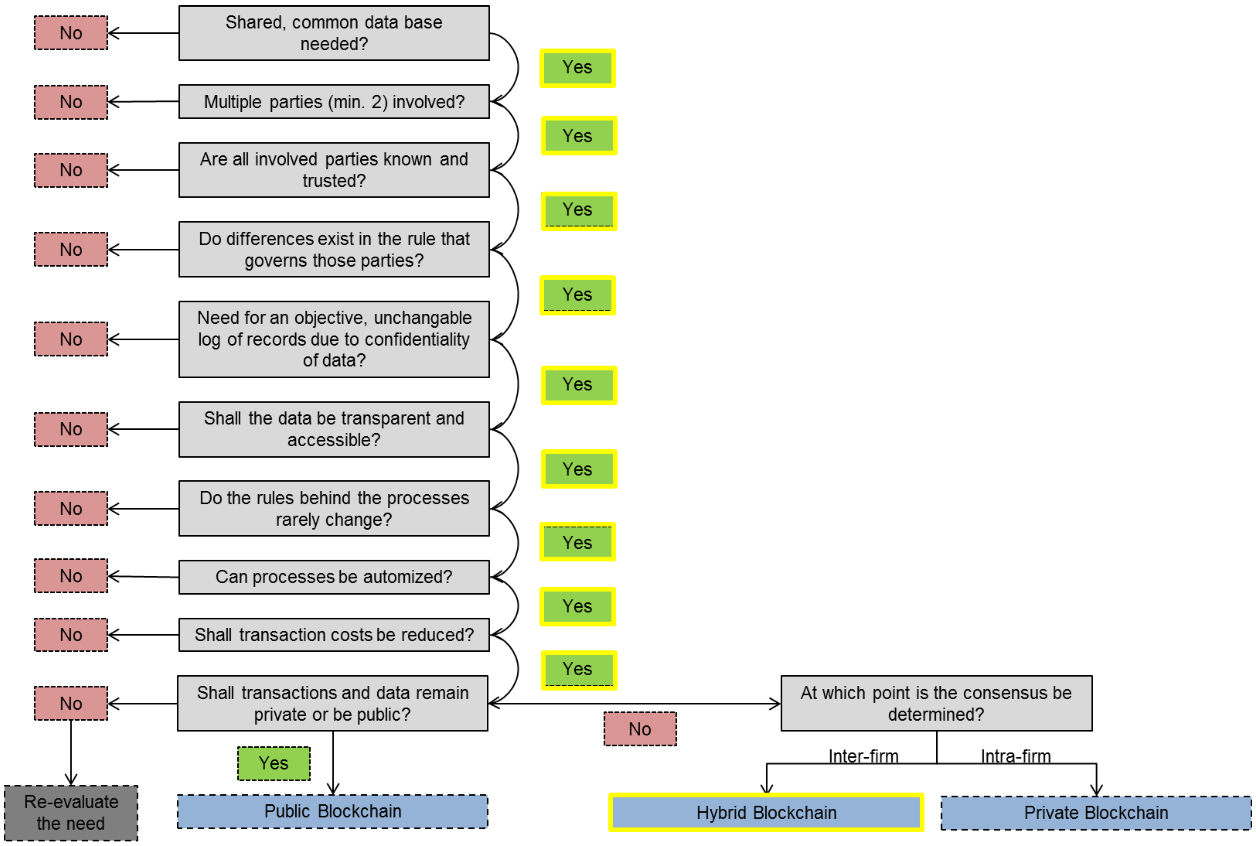

Figure 23 Decision Tree BI RCV

Condensing the input of the interview, one potential, comparably simple but promising process crystalizes out, that could be suitable to create a proof-of-concept; the document handling during cross boarder shipments. Transferring the results of the interview and the information about the process itself, described in 4.2.2.1 Logistical Processes in SCM, into the previously introduced blockchain decision tree, the above Figure 23 Decision Tree BI RCV develops.

All answers in the decision tree could be answered with "yes", which means in general the process of document handling during cross-border shipments would be suitable to be run on blockchain. When it comes to the question, whether a private, public or hybrid blockchain would be best, in case of this particular process, the decision falls on a hybrid blockchain as the data e.g. certificates must be shared with 3rd parties for instance customs authorities or freight forwarders.

[28] Interview: see also Appendix 1: Interview Protocol 1.

In case BI RCV decides to establish a concrete proof-of-concept for the mentioned process, the process itself could be designed as shown below in Figure 24 Integrated Supply Chain with BCT.

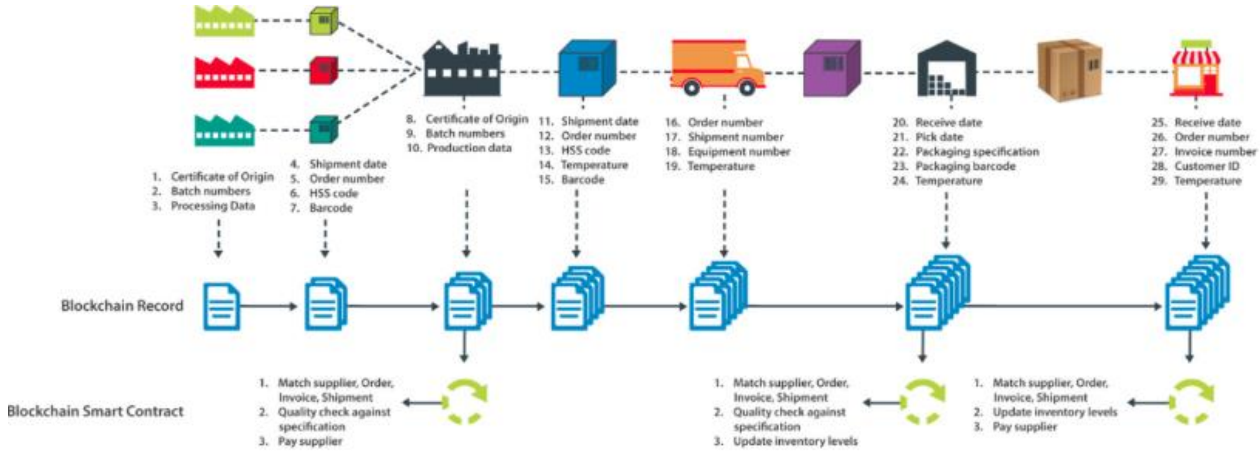

Figure 24 Integrated Supply Chain with BCT (IRC Group 2018)

In the future, the manufacturing site uploads product related data e.g. batch numbers as well as all quality certificates to a hybrid blockchain. Once the products are ready to be shipped, the shipment related data for instance transportation temperature profiles, delivery dates and respective purchase orders are broadcasted to the blockchain as well and matched. The freight forwarder picks up the goods and delivers it according to the terms of contract. During the transport, the position of the truck as well as humidity and temperature data is automatically uploaded and stored on the blockchain. Once the truck has reached its final destination, the receiving site e.g. the wholesaler confirms the goods-receipt back via the blockchain. The shipped goods are verified by matching the data provided from the supplier and uploaded to the blockchain. In addition, in a fully-integrated supply chain, the stock levels could be updated and transmitted to the manufacturing site as well, taking over a completely automated disposition of commodities. In a subsequent step, a local pharmacy could place an order at the wholesaler for certain products. The wholesaler picks and packs the goods and sends the drugs in a temperature-controlled truck to the pharmacy. Upon arrival, the pharmacy verifies the correctness of goods by matching the product related data with the ones initially uploaded by the manufacturer to the blockchain again. In addition, a record of the temperature and humidity during the transport is uploaded to the blockchain. By applying smart contracts as well, as illustrated in Figure 24 Integrated Supply Chain with BCT, even payment processes upon goods receipt could be run automatically. Once the recipient confirms the goods-receipt, the uploaded information to the blockchain would trigger a payment according to contractual terms. It would be possible as well, to trigger penalties in case of late delay, transportation damage or loss. The blockchain stores the relevant data and smart contract execute processes that are aligned upfront with all parties. (DHL Trend Research 2018)

Over all, using blockchain technology to process shipments and documentation of cross-border shipments could reduce human workload, increase the efficiency by right in time actions, could accelerate certain steps due to reduced “black-out periods” by having real-time data accessible in a secure environment. Moreover, BI RCV would not need to send original, paper-based documents with the goods that could get lost or falsified during transport. Whenever a certain party within the supply chain needs access to product or shipment related data, the documents are withdrawn from the blockchain. This does not only reduce the paperwork but also increases transparency in a controlled manner. Overall, due to the increased efficiency, in the long-run blockchain technology shows the potential to save costs.

However, before establishing a proof-of-concept or during the pilot phase, certain obstacles must be overcome. Asking for the most challenging aspects of switching to blockchains, Mr. Ziman mentions the “readiness” for blockchain on all involved sides. The potential of blockchain is limited when it is only used in an internal supply chain. Blockchain reveals its full potential in an integrated supply with connected 3rd parties. Without fostering the idea of blockchain being an added value to pharmaceutical supply chains by increasing drug safety on national or even EU level it will become tough to drive forward the idea. Additionally, Mr. Ziman mentions that switching to blockchain technology would require big ERP system providers to offer interesting solutions to connect existing “base software” with blockchain. Last but not least the missing experience and lack in transparency with regards to the cost structure and development of blockchain solutions is another obstacle. Due to missing, concrete, published pilot projects in the pharmaceutical supply chain, there is a certain vacuum in terms of experience and hence convincement. The concern with regards to missing transparency in terms of costs can be confirmed by two additional interviews, conducted with consultants offering blockchain solutions. Neither throughout the interview nor later on in research it would possible to gain a satisfactory inside into cost structures. Therefore it would be advisable to BI RCV and any other company at the same stage to highlight the topic costs in project meetings with potential blockchain providers that could take over the lead in transforming the paper-based, cross-border logistical chain into an integrated, blockchain-based supply chain.[29]

Besides all obstacles, Mr. Ziman is convinced that blockchains are a promising technology for the pharmaceutical supply chain. As a manager in supply chain he particularly sees the added

[29] Interview: see also Appendix 1: Interview Protocol 1.

value of blockchains when exchanging information and data with “remote” partners in a secure environment. The possibility to automate certain processes, using blockchain based smart contracts is another opportunity for the pharmaceutical supply chain. The increased throughput time due to accelerated decision making and availability of required data is another advantage of blockchains. Last but not least, an added-value that has only been mentioned by Mr. Ziman, presenting a supply chain manager in the pharmaceutical industry, is the increased flexibility and independence from common ERP platform that blockchain technology would bring to companies.[30] The question, whether blockchain technology indeed increases the independency of standard ERP systems to a significant level, is not scope of this thesis however it could be taken up in further research.

[30] Interview: see also Appendix 1: Interview Protocol 1.

6. Analysis

6.1 Research Question 1

“Which parameters influence the applicability of blockchain technology in major internal and/or external supply chain processes in the pharmaceutical industry?”

This research question mainly refers to the chapters 3.3.3 Characteristics of Blockchains in which the general advantages and disadvantages of blockchain technology are described based on literature review as well as chapters 4.3 Outlook and 5. Case Study, in which a decision tree model based on the main influence parameters for the applicability of blockchain technology in business processes, is developed.

The base for the decision tree builds a series of interviews, aiming to identify the most important features of any technology in the pharmaceutical supply chain. During the series of interviews, different people with either an academic or business background were asked to rate the most important characteristics of software in the pharmaceutical supply chain environment, reflected in the white-shaded columns in Table 4 Important Characteristics of Technologies. The interview series was completed with two additional interviews adding the perspective of experts from different industries, more concrete from the chemical and finance sector, shown in the grey shaded columns in Table 4 Important Characteristics of Technologies in order to be able to draw a comparison between different branches.

Table 4 Important Characteristics of Technologies

Characteristic	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6	Ø Average (columns 1-4)
Costs	3	4	1	4	5	5	3,0
Privacy	3	5	5	5	5	4	4,5
Transparency (Internally)	3	5	3	5	3	4	4,0
Reliability	5	5	4	4	3	5	4,5
Security	5	5	5	5	4	5	5,0
Scalability	4	3	2	3	3	2	3,0
Latency	5	3	3	4	2	3	3,75
User-friendliness	3	1	1	4	2	5	2,25

The rating is based on importance 1 means not important at all and 5 means very important. The last column shows the average rating per characteristic. The results are very homogenous and similar; not only with regards to the pharmaceutical supply chain management but also across industries. The only inhomogeneity lies within the user-friendliness. Whilst the two interviewed blockchain consultants claim that this aspect does not play an important role, the experts from business, and potential customers of applications, lay more weight on this aspect. The discordant value in the cost sections results from a very different approach of the interviewee. In his opinion, the costs for the implementation of a new technology do not play a big role as long as the cost savings later on are realized. The other interviewees have a different opinion and attach more weight to the cost aspect. The average results of the answers that refer to the requirements of the pharmaceutical industry are very similar to those from the chemical sector. It can therefore be assumed that the results, obtained in this thesis, can largely be transferred to the chemical industry. In contrast, the finance industry differs from the pharmaceutical sector. The results reveal that blockchain technology certainly is an interesting technology here as well, however, the importance of the single characteristic deviates.[31]

This table clearly states, supply chain managers from business, consultants and also an academic voice see the highest requirements on any technology in the area of privacy, security and internal reliability; basically three characteristics that are also frequently used to describe the advantages of blockchain technology. To sum up, generally the advantages of blockchain technology and the requirements of (pharmaceutical) supply chain organizations match.

After identifying blockchain technology generally as a promising and valuable innovation for pharmaceutical supply chains, in a second step the evaluation must be broken down into single processes. Speaking on a high level all processes that fulfill one of the following conditions have a high potential to be used with blockchain technology in the future:

- All processes currently involving intermediates that shall be bypassed in the future because the intermediate step is either causing additional (interface) costs or the function of the intermediate can be taken over by blockchain based smart contracts in the future for instance credibility or ID checks. It also makes sense when the interim stage slows down the whole process and blockchain technology could accelerate the execution of certain tasks.

[31] Interview: see also Appendix 1-6.

- Processes that require a very high data and process integrity are as well promising candidates for the application of blockchains.
- Blockchain technology is interesting for all processes that involve new, constantly changing or unknown cooperation partners without a trust-base. In those cases blockchain technology can guarantee network integrity by drawing on a decentralized system model.
- All processes that deal with the proof of origin or transfer of rights are suitable as well since blockchains allow the secure transport of values and unforgeable storage of data and rights.

In order to simplify and reify the whole evaluation process, a decision tree was developed. This allows following a standardized approach capturing all relevant aspects that need to be considered. It is a simple model that can even be used by people that are not too familiar with the blockchain matter. Figure 25 BCT Evaluation Model shows the result.

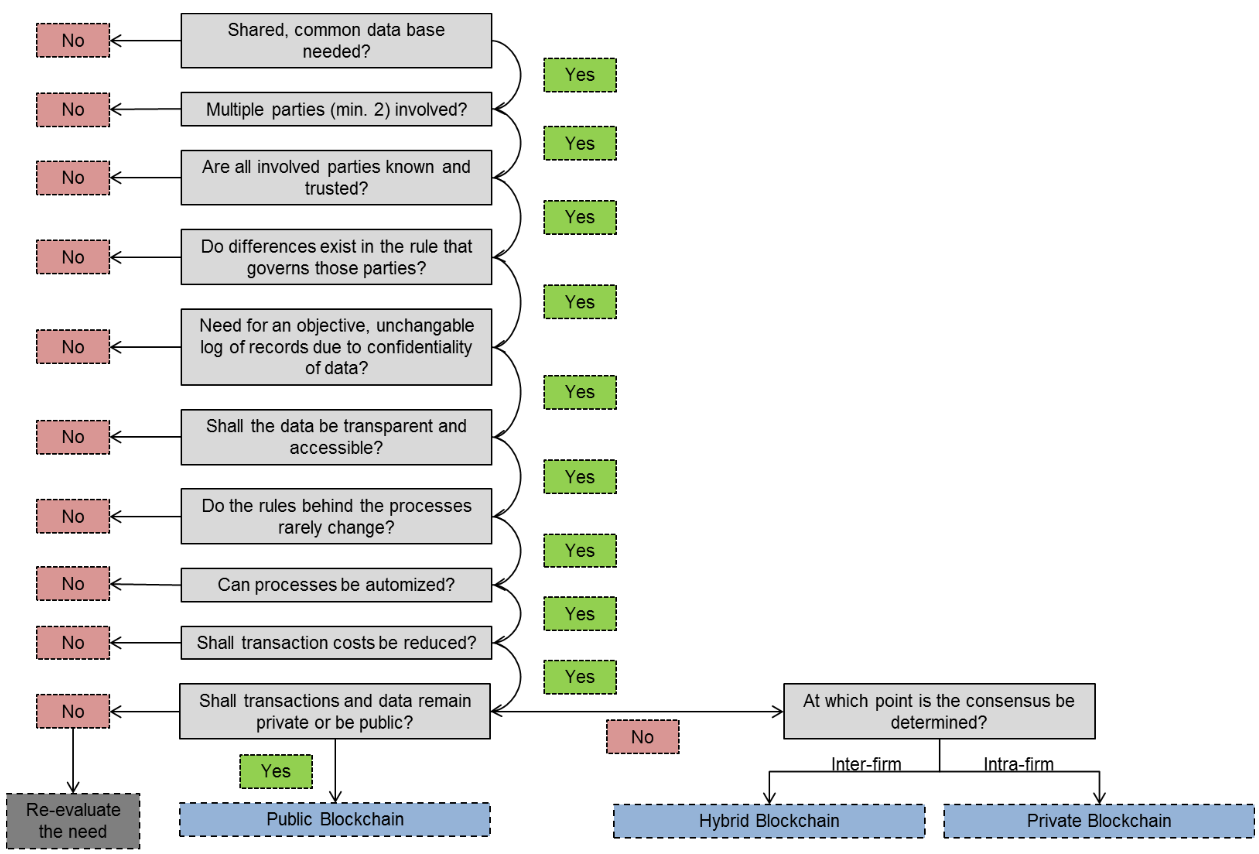

Figure 25 BCT Evaluation Model

6.2 Research Question 2

"What are the main processes in the pharmaceutical supply chain that would be subject of the evaluation?"

This question aims to identify the core processes within supply chain organizations in the pharmaceutical industry that could be part of any pilot project, testing the potential of blockchains and mainly refers to chapter 4.2.2 Usage in Supply Chain Management. Since in every company resources are limited, it makes sense, to identify, cluster and prioritize processes beforehand using the decision tree that was introduced in the previous section. Based on the results it can be further evaluated in which cases the demands and needs of processes and blockchain technology meet. Generally, the pharmaceutical supply chain offers a broad variety of processes that could be subject of blockchain applications. The thesis revealed that during the evaluation supply chain processes must be subdivided into those that deal with the flow of materials and information and others that focus on the financial streams. Additionally taking into consideration the presented future outlooks, challenges and anticipated developments, the following supply chain processes are worth and suitable to run blockchain pilots on:

(1) Logistical Processes

a. Cross-border shipments by digitalizing transport papers and quality certification records.
b. Track and trace initiatives by broadcasting relevant location, humidity and temperature data during shipments.
c. Identification and prevention of drug counterfeits by offering a secure but still transparent environment to store unique serial numbers and safety features. During each step of the supply chain, starting with the manufacturing to the sale of pharmaceuticals, the product is checked against the data in the blockchain.
d. "Material Passports" that allow a retrace of origins and foster an establishment of more ethical and sustainable supply chains

(2) Financial Processes

a. Automated execution of payments after goods receipt.
b. Automated execution of penalty payments in case of breaches of contracts.
c. Automated replenishment along an integrated supply chain.

6.3 Research Question 3

"How will processes be changed by applying blockchain technology and what is the added value for companies?

The answer about the added value of blockchains was partially captured in chapter 3.3.3.1 Advantages of Blockchains focusing on general advantages of the technology as well as in chapter 4.2 Blockchain Technology in the Pharmaceutical Industry where the focus lays on concrete examples in the pharmaceutical industry and supply chain organizations. The topic of how processes could be changed adopting blockchains and which added value it creates to organizations was deepened in chapter 5. Case Study, dealing with the cooperation partner Boehringer Ingelheim RCV GmbH & Co. KG.

How processes will be changed applying blockchain technology strongly depends on the process itself. In the previous section, processes were listed that are promising candidates to run on blockchain in the future. If the question is broken down to the lowest common denominator all processes have in common after BCT is applied to it the following changes can be summarized in a nutshell:

- The transparency and traceability within processes will be increased: using blockchain all steps during the lifecycle of a product and throughout its journey can be reflected in a blockchain. This allows tracing back the origin of a product and its raw materials and a high level of integrity can be ensured. Any touchpoint of a product in the supply chain is known, which will simplify for instance recalls in the future.
- The logistical paperwork will be decreased. Instead of shipping original papers with the physical product, the documents can be uploaded and accessed by all involved parties via a blockchain. This reduces the consumption of paper resources, lowers the risk of document loss and increases the cross-border shipments.
- It allows linking physical goods to serial numbers and verifying the data at any point of the supply chain.
- It allows sharing information even with remote partners in a controlled and secure environment which most likely leads to more horizontally, integrated supply chains and allows cooperation between partners that do not (yet) have a trust-base.
- It increases the automatization level of various supply chain processes by using smart contracts.

The question of the added value to supply chain organization is difficult to answer and certainly one of the biggest obstacles of blockchain technology. The available data in literature is vague and predictions about monetary impacts of blockchain technology on supply chain organizations must be treated with caution as it is difficult to quantify the added value of companies based on the available information. In order to close this gap in research literature the question of the added value for pharmaceutical companies was discussed in detail during the interview sessions. The first-hand information from the interview studies in combination with the available literature allows to come up with certain added values to pharmaceutical companies even though not directly of monetary nature.

- Enhanced transparency and traceability leading to leaner logistics.
- Reduction of counterfeits and falsified drugs as well as inhibition of thefts.
- Higher level of automatization in supply chain processes and subsequently an increase of operational efficiency.
- Contract enforcement and management using smart contracts.
    - Automated execution of payments, penalties for damage and credibility checks.
- Higher level of collaboration along the supply chain and creation of new “eco-systems”.

6.4 Research Question 4

“What are the most significant obstacles and risks for applying blockchains in the pharmaceutical supply chain management and how can they be removed?”

This question was particularly difficult to answer as the responses differ depending on the perspective of the author. The literature review as well the interview series revealed multiple potential obstacles that impact the implementation of blockchain discussed in chapters 3.3.3.2 Disadvantages of Blockchains and during the interviews which protocols are attached in the appendix. Condensing the results into four major clusters, the following threats for blockchain technology can be summarized; technical obstacles, insufficient legal framework and a high inhibition level to switch to new technologies as well as missing proof of concepts.

Currently, the throughput times of blockchain for instance the Bitcoin blockchain is limited and comparably slow which is a disadvantage to other technologies. Additionally, in order to execute all transactions, blockchains consume a huge amount of energy that is gained through mining. This process eats up a big amount of energy and depicts another limitation of blockchain. The major **technical obstacles** are the lower scalability and latency of blockchains. This problem could be solved by using hardware with more computing power and of course further development of blockchain technology. At the moment there is a high demand of blockchain engineers but only a short supply. (Mearian 2018) In order to further develop blockchain technology, blockchain experts are needed. This problem cannot be solved in one day however it is the responsibility of companies and educational institutions to build up the required human resources in this area so in the future this limitation will not be applicable. Moreover, the technical limitations are not as serious as they sound at the first glance. The current level of scalability is only a problem of very big, usually public blockchains. As it is assumed that the majority of future blockchains will be private or hybrid ones the problem will be partially relativized. Although lacking of resources still a lot of research is done in this space. One of the most noteworthy results that could offer a solution to the scalability problem of blockchain is the 6-stages of Casper-Sharding[32]. It is expected that this solution can increase the capacity of blockchains tremendously and hence erase some of its current problems. (Buterin 2018) Another technical hurdle might be the interoperability. Currently multiple protocols are offered on the market but with various, different protocols also challenges come along. The only solution to this problem is that a clear way of interaction across networks and protocols is found. Here on one hand key stakeholders in technology are in the lead. On the other hand, companies that want to join the blockchain wave must carefully choose the right network and protocol that suits their needs best and rather spend more than less time in research here.

Another potential hurdle for blockchain technology is the **insufficient** support by **local and international law** as well as a **lack of common standards**. The different international, regional and local authority bodies are yet to create a full understanding of blockchain before promoting it for mass-adaption. An international framework is required that solves certain open topics such as the question about the legal force of blockchains and the data protection. In addition, industry standards must be established to secure the integrity of blockchains. The level of support by authorities such as for instance the EMA or FDA can strongly influence the success of blockchain technology in the pharmaceutical industry (Bastin 2018). If those administrative bodies choose blockchain to be the future underlying technology for projects such as the serialization and track and trace concepts, the roll-out of blockchain technology will certainly be accelerated.

The problem with the **industry adaption rate** goes hand in hand with the **missing proof of concept**. At the moment not sufficient data is available that proofs if and how blockchain technology can benefit the pharmaceutical supply chain. The majority of data is of theoretical nature but in order to convince key players in pharmaceutical industry, successful pilots must be run. The question of the added value is omnipresent on business side however only insufficiently answered by research and blockchain provers so far. Besides the question of the added value, the question of the cost of ownership is not completely clear. Before blockchain can be rolled out on a broad level it must be clarified who will hold the ownership of the blockchain, how are costs

[32] Whilst in common blockchains every node must verify and execute all transactions while keeping a local copy, sharding follows a different approach where only a small number of nodes verifies transactions. This allows the network to verify and execute more transactions in parallel and subsequently increases the scalability and latency (Buterin 2018).

shared between different parties in case of hybrid or public blockchains, how much are the implementation and maintenance costs of blockchains and what are the concrete incentives for organizations to get on-boarded on a common blockchain. Those questions can only be answered if the outcomes of privately run blockchain pilots are disclosed or research in this specific area is conducted. For pharmaceutical companies and supply chain organizations the only two options at the moment are either waiting for sufficient proof and step into the shoes of a fast follower or becoming a first mover and investing into pilots such as Boehringer Ingelheim. (SAP 2018b) In order to reduce the inhibition level of pharmaceutical supply chain organizations to invest into pilot project as well as for the future success of BCT it is important that the big technology providers such as SAP or Microsoft offer interesting solutions to companies. If blockchains are compatible with commonly used and trusted software in business it will become easier to convince companies trying something new.

Whilst above mentioned factors are either fully or at least to a high level externally driven, one obstacle is solely to be taken up by supply chain organizations. As stressed in chapter 3.3.3.2 Disadvantages of Blockchains the transformation process can only succeed if it is accompanied by a well-managed change management. On the factual level the obstacles and solutions are comparably clear however the human factor must not be underestimated. Human beings are generally creatures of habit so any change leads to insecurity that must be properly absorbed by managers.

7. Conclusion

7.1 Discussion

Is the hyped blockchain technology an opportunity to business or false friend? Blockchain technology certainly is desirable for multiple processes in the pharmaceutical industry and offers new ways to tackle challenges of the industry as explored in the thesis. However, blockchains are not a jack of all trades device. Despite being an interesting and promising technology, blockchains are still in an early stage and face various obstacles that must be overcome before being rolled out as discussed in this thesis and mentioned during the interview series. One of the strongest objectors is a missing proof of concept about how to turn the benefits of blockchains into revenue and competitive advantages. In order to fully utilize the benefits that blockchains offer, it is important to understand the technology, its strengths and weaknesses and consequently choosing the right processes to run on blockchains in the future. The thesis explores the characteristics of blockchain technology and deals with the current and future requirements in pharmaceutical supply chain organizations. Additionally, it elaborates on processes that would be suitable for blockchain applications. Since this is a strongly business driven thesis, it provides supply chain organizations a concrete decision making model that allows to identify processes benefiting from blockchain technology in the future without being an expert in blockchain technology from a technical point of view. Moreover the thesis challenges the question of the added value of blockchain technology from a monetary perspective but also considering other potential benefits for pharmaceutical supply chain organizations. Last but not least, the thesis discusses potential challenges of blockchains and provides precise recommendations for actions either how to clear hurdles or how to proactively avoid problems for instance when rolling out blockchain technology.

The thesis proves that blockchain technology will most likely gain a considerable impact on pharmaceutical supply chain organizations – and other industries or businesses – and should be considered by respective stakeholders as an opportunity. However, the results of the thesis also show that blockchain technology is still in an early stage and not yet mature enough to be blindly rolled out in all areas without trading off opportunities against limitations. In order to profit from blockchains in the future and gain a competitive advantage, pharmaceutical supply chain organization for instance at the Boehringer Ingelheim RCV GmbH & Co. KG should identify and decide carefully on the applicability of blockchains in certain areas, using the introduced decision tree, and develop a clear strategy about how to roll out blockchains and how to turn the technology into a value adding aspect. It will take another two to five years – in the USA sooner than in Europe[33] – until the first blockchains are live but companies must start now in order to stay competitive in the future. It is expected that success stories e.g. provided by future research studies can significantly propel the adaption rate of blockchains.

7.2 Contribution, Limitations and Future Research

The thesis itself contributes to current research in the blockchain area mostly in a practical area. The thesis explained the characteristics of blockchains in a simple but still detailed way always connecting technical aspects with examples in business. This allows readers who are not yet familiar with the matter to follow and understand advantages and disadvantages of the heavily hyped technology. Additionally, the thesis demonstrated why blockchain technology is much more than just the technology behind cryptocurrencies and a hot topic in the finance sector. Blockchain is a promising technology across many different industries but particularly meeting the demands of pharmaceutical companies and supply chain organizations. With its practical nature, supported by a case study, the thesis provides a valuable input in research of blockchain applications in the pharmaceutical industry that was so far rather blank. The thesis certainly answers all questions regarding the application of blockchains in the pharmaceutical organizations yet it adds some valuable data, helping to close the gaps. For those topics that could not be covered within the scope of the thesis, the thesis provided suggestions on how to approach them in the future.

For the cooperation partner, Boehringer Ingelheim RCV GmbH & Co. KG, the thesis is valuable as well. It provides a base for further investigations into blockchain adaptions and delivered concrete methods e.g. the decision tree helping to identify processes suitable for blockchain pilots. Moreover, the thesis explained how processes can look like in the future when applying blockchain technology and what would be the added value for the company. It provides relevant key information for stakeholders in the upper management and makes this whole topic more tangible for non IT people that are still interested in keeping up with industry developments. Besides all advantages blockchains can bring, the thesis does not hide potential obstacles and limitations of the technology. The opportunities but also threats of the new technology are transparently discussed and underpinned with relevant data from research. This shall prevent any company including Boehringer Ingelheim from blindly jumping onto hype without making a clear evaluation of the status quo, identifying problems that shall be solved with blockchain, running pilots and rolling it out only with a well-prepared communication strategy and project plan. Although the thesis' scope is limited to pharmaceutical supply chain organizations and the case study was

[33] Interview: see also Appendix 2: Interview Protocol 2.

performed with one single company, the results of the thesis are valid for other supply chain organizations with similar environments as well, as indicated when drawing parallels to the chemical industry for instance.

Out of the limitations, suggestions for further research result, so those points go hand in hand. The novelty of this topic and the rapid change of developments in this area create a difficult environment for profound theoretical foundation. Additionally, the amount available empirical data is very limited. Future research would be most beneficial in field research, exploring the added values of blockchains in pilot projects in order to validate the theory. A very interesting possibility to explore the full potential of blockchains provides the drug quality and security act entering into force step by step within the next five years.

7.3 Critical Reflection

As captured in chapter 2.4 Critical Reflection the thesis aims to fulfill three main criteria; validity, objectivity and reliability. Regarding the results of this thesis, the applied mix of methods and chosen research design allowed to come up with reasonable outcomes and contributions. An extensive literature research was conducted, using the latest publications in order to achieve a high level of topicality. Additionally, cross-functional interviews were executed aiming to close the gaps in literature regarding the applicability of blockchains in the pharmaceutical industry in particular and providing concrete answers about the added value of blockchains. The reliability of the consulted literature is limited as the topic itself is subject to rapid development hence the data base is frequently changing. Although explaining in detail how the research of this thesis was conducted, when repeating the studies the outcomes would be different, simply due to the mentioned pace of change in blockchain research. In order to still maintain a high level of reliability for this thesis, the literature review was extended by six interviews with selected experts from business but also academic background. The validity of the thesis is strengthened by the insights and outcomes of the case study, delivering more detailed information about challenges, expectations but also trends. As validity goes hand in hand with the generalizability, the interviews were not only conducted with supply chain experts or partner from the pharmaceutical industry but also with interviewees from a finance and chemical background. This allows fulfilling the aspect of generalizability / external validity. Although the thesis focuses on a very specific research problem, the applicability of blockchains in the pharmaceutical supply chain, the outcomes are partially relevant for other industries as well. The interviews with experts from different industries try to draw a bow and allow a certain level of comparison. Critically reflecting the objectivity of the thesis it must be conceded that a pilot study, to test the outcomes of the thesis, would have been of great use. However, the limited financial resources and particularly given time frame did not allow facilitating extensive primary research in this field. This would be subject of possible further research. In this course especially the aspect of the monetary added value of blockchains in the pharmaceutical industry could be further examined.

Bibliography

Aguirre, D., Neilson, G., Tipping, A. (2004): An overall approach to change management, https://www.strategyand.pwc.com/reports/overall-approach-change-management, Accessed 27.07.2018.

Allen, M. (2018): The Future of Data Centers: Distributed, Grid or Cloud Computing?, https://www.datacenters.com/news/future-data-centers-distributed-grid-or-cloud-computing, Accessed 21.07.2019.

Anastas, J.W. (2000): *Research Design for Social Work and the Human Services,* 2nd Edition, New York, Columbia University Press.

Aussenegg, W. (2018): *Wissenschaftliches Arbeiten,* Vienna, Vienna University of Technology.

B2U (2018): Value Chain Analysis: An Internal Assessment of Competitive Advantage, https://www.business-to-you.com/value-chain/, Accessed 20.08.2018.

Bastin, J. (2018): Blockchain In: The Supply Chain Industry, https://bitshouts.com/blockchain-supply-chain/, Accessed 14.09.2018.

Bell, J. (1999): *Doing Your Research Project: A Guide for First-time Researchers in Education and Social Science,* 3rd Edition, Buckingham, Open University Press.

Bergmann, R., Bungert, M. (2011): *Strategische Unternehmensführung: Perspektiven, Konzepte, Strategien.* 2nd Edition, Berlin / Heidelberg, Springer Gabler.

Biddle, P., England, P., Peinado, M., Willman, B. (2003): *The Darknet and the Future of Content Protection,* Berlin, Heidelberg, Springer.

Bisk (2018): Is Logistics the Same as Supply Chain Management?, https://www.michiganstateuniversityonline.com/resources/supply-chain/is-logistics-the-same-as-supply-chain-management/#.W3w5vs4zbRY, Accessed 21.08.2018.

Björklund, M., Paulsson, U. (2014): *Academic papers and theses: to write and present and to act as an opponent,* Lund, Studenttliteratur.

Blockgeeks (2016): Smart Contracts: The Blockchain Technology That Will Replace Lawyers, https://blockgeeks.com/guides/smart-contracts/, Accessed 25.07.2018.

Boehringer Ingelheim GmbH (2018): Who we are, https://www.boehringer-ingelheim.at/en/about-us/who-we-are, Accessed 14.08.2018.

Boehringer Ingelheim RCV GmbH & Co. KG (2018): Who we are, https://www.boehringer-ingelheim.at/en/about-us, Accessed 14.08.2018.

Bryman, A., Bell, E. (2015): *Business Research Methods,* 4th Edition, Oxford, Oxford University Press.

Burnes, B. (2004): Kurt Lewin and the Planned Approach to Change: A Re-appraisal, *Journal of Management Studies,* 41(6), 977-1002.

Buterin, V. (2018): Ethereum's Sharding for Scalability, https://blog.iqoption.com/en/ethereums-sharding-for-scalability/, Accessed 09.09.2018.

Cefic (2018): *Landscape of the European Chemical Industry 2018,* Brussels, European Chemical Industry Council.

Chaitanya, K. (2012): Public key Infrastructure, https://security.stackexchange.com/questions/24383/public-key-infrastructure?rq=1, Accessed 24.07.2018.

Christel, M. (2017): Pharm Exec's Top 50 Companies 2017, http://www.pharmexec.com/pharm-execs-top-50-companies-2017, Accessed 03.06.2018.

Christel, M. (2018): Pharm Exec's Top 50 Companies 2017, *Pharmaceutical Executive,* 37(6).

Christopher, M. (2011): *Logistics & Supply Chain Management,* 4th Edition, Harlow, Pearson Education.

Croman, K., Decker C., Eya, I., Gencer, A.E:, Juels, A., Miller, A., Saxen, P., Shi, E., Sirer, E.G., Song, D., Wattenhofer, R. (2016): On Sealing Decentralized Blockchains, in: Clark, J., Meiklejohn, S., Ryan, P.Y.A., Wallach, D., Brenner, M., Rohloff, K. (eds.): *Financial Cryptography and Data Security,* Berlin/Heidelberg, Springer-Verlag GmbH, 106-107.

Costa-i-Font, J. (2015): Parallel trade in medical drugs is putting the welfare of EU patients at risk, http://blogs.lse.ac.uk/europpblog/2015/03/20/parallel-trade-in-medicinal-drugs-is-putting-the-welfare-of-eu-patients-at-risk/, Accessed 30.07.2018.

DAXX (2018): How Blockchain Technologies Can Help You Make Your Business Future-Ready: Highlights From the Blockchain Event at Daxx, https://www.daxx.com/article/daxx-blockchain-technology-event-developers, Accessed 14.09.2018.

DeCovny, S. (2018): Blockchain and IoT : hot technologies in the cold chain, https://www.chainbusinessinsights.com/insights-blog/blockchain-and-iot-hot-technologies-in-the-cold-chain, Accessed 25.08.2018.

Deloitte Legal Rechtsanwaltsgesellschaft mbH (2018): Die Blockchain aus Sicht des Datenschutzrechts, https://www2.deloitte.com/dl/de/pages/legal/articles/blockchain-datenschutzrecht.html, Accessed 26.07.2018.

Deloitte (2018): 5 blockchain technology use cases in financial services, https://www2.deloitte.com/nl/nl/pages/financial-services/articles/5-blockchain-use-cases-in-financial-services.html, Accessed 14.08.2018.

DeMuro, J. (2018): 7 ways blockchain will change the legal industry forever, https://www.techradar.com/news/7-ways-blockchain-will-change-the-legal-industry-forever, Accessed 31.07.2018.

DHL Trend Research (2018): *BLOCKCHAIN IN LOGISTICS: Perspectives on the upcoming impact of blockchain,* Troisdorf, DHL Customer Solutions & Innovation.

Dhuri, S. (2013): Social Media in the Pharmaceutical Supply Chain, https://pharmapromotional.wordpress.com/2013/08/02/social-media-in-the-pharma-supply-chain/, Accessed 22.08.2018].

Dobos, L. (2018): Bausteine des Vertrauens, *Logistik Heute,* 3, 24-29.

Drescher, D. (2017): *Blockchain Basics: A Non-Technical Introduction in 25 Steps,* Frankfurt am Main, Apress.

Eager, M. (2017): What is the difference between decentralized and distributed systems?, https://medium.com/distributed-economy/what-is-the-difference-between-decentralized-and-distributed-systems-f4190a5c6462, Accessed 22.07.2018.

Elitech Technology Inc. (2018): Elitech RC-19 Single-use USB Temperature Data Logger 16000 Points, http://www.elitechus.com/product/elitech-temperature-data-logger-single-use-usb-port-16000-points-for-storage-food-pharmaceuticals-rc-19-10-off/, Accessed 25.08.2018.

Ernst & Young Global Limited (2017): Pharma and its customers: the new deal, https://consulting.ey.com/pharma-and-its-customers-the-new-deal/, Accessed 30.07.2018.

European Council and the European Parliament (2011): Falsified Medicines Directive (Directive 2011/62/EU), *Official Journal of the European Union,* 1.

European Medicines Agency (2016): *Measures to help protect patients from falsified medicines,* London, European Medicines Agency.

Eurostat (2008): NACE Rev. 2 - Statistical classification of economic activities, https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF, Accessed 30.07.2018.

Fawcett, S.E., Ellram, L.M., Odgen, J.A. (2013). *Supply Chain Management: From Vision to Implementation,* New Jersey, Pearson Education.

FDA (2017): Drug Supply Chain Security Act (DSCSA), https://www.fda.gov/Drugs/DrugSafety/DrugIntegrityandSupplyChainSecurity/DrugSupplyChainSecurityAct/, Accessed 30.ß7.2018.

Franco, P. (2014): *Understanding Bitcoin: Cryptography, Enignerring, and Economics,* Chichester, John Wiley & Sons Ltd.

Franke, D. (2018): Kryptowährungen, https://www.kreditkarte.net/kryptowaehrungen/, Accessed 30.07.2018.

Hackius, N., Petersen, M. (2017): *Blockchain in Logistics and Supply Chain: Trick or Treat?,* Hamburg, Digitalization in Supply Chain Management and Logistics, 23.

Heinen, D. (2017): *Blockchain in Supply Chain Management: In the future, trust must be earned rather than paid,* Cologne, Capgemini Consulting.

Heinen, D., Borgers, O. (2017): Blockchain in Supply Chain Management in the Future, https://www.capgemini.com/consulting/2017/07/blockchain-in-supply-chain-management-in-the-future/, Accessed 25.07.2018.

Hill, J. (2017): Mit Blockchain gegen die Tachomanipulation, https://www.computerwoche.de/a/mit-blockchain-gegen-die-tachomanipulation,3330385, Accessed 31.07.2018.

Hofstede, G., Hofestede, G.J., Minkov, M. (1999): *Cultures and Organizations: Software of the Mind,* 3rd Edition*,* Helsinki, Hofstede Insights.

Höst, M., Regnell, B., Runeson, P. (2006): *Att genomföra examensarbete.,* Lund, Studentlitteratur AB.

Iansiti, M. & Lakhani, K. R., 2017. The Truth About Blockchain. *Harvard Business Review,* 95(1), pp. 118-127.

IBM (2018): Blockchain for supply chain, https://www.ibm.com/blockchain/industries/supply-chain, Accessed 25.08.2018.

IEEE (2017): *State of Blockchain Adoption on the Pharmaceutical,* Piscataway, IEEE Standards Association.

Indian Pharmaceutical Alliance (2018): Process Validation Guideline, http://www.ipa-india.org/static-files/pdf/event/ipf2018-presentation21.pdf, Accessed 14.09.2018.

International Organization for Standardization (2016): ISO/TC 307 - Blockchain and distributed ledger technologies, https://www.iso.org/committee/6266604.html, Accessed 26.07.2018.

IRC Group (2018): Harnessing Blockchain In The SCM & Logistics Space, http://ircgroupglobal.com/blog/harnessing-blockchain-in-the-scm-logistics-space/, Accessed 25.08.2018.

Jayachandran, P. (2017): The difference between public and private blockchain, https://www.ibm.com/blogs/blockchain/2017/05/the-difference-between-public-and-private-blockchain/, Accessed 24.07.2018.

Jiang, S., Cao, J., Ma, M., Wu, H., Yang, Y., He, J., (2018): *BlockHIE: a BLOCkchain-based platform for Healthcare Information Exchange.* 4th IEEE International Conference on Smart Computing, Taormina, Italy.

Karanjia, B. (2018): Blockchain in Public Sector - Transforming government services through exponential technologies, https://www2.deloitte.com/content/dam/Deloitte/in/Documents/public-sector/in-ps-blockchain-noexp.pdf, Accessed 31.07.2018.

Khan, T. (2018): Investing in a World of Heightened Geopolitical Uncertainty, https://www.capitalgroup.com/pcs/latest-perspectives/investing-in-heightened-geopolitical-uncertainty.html, Accessed 30.07.2018.

Leblanc, R. (2018): How Blockchain Will Transform Supply Chain Sustainability, https://www.thebalancesmb.com/blockchain-and-supply-chain-sustainability-4129740, Accessed 24.08.2018.

Lemieux, V.L. (2016): Trusting records: is Blockchain technology the answer?, *Records Management Journal,* 26(2), 111-139.

Lemieux, V.L. (2017): *Blockchain and Distributed Ledgers as Trusted Recordkeeping Systems: An Archival Theoretic Evaluation Framework,* Vancouver, Researchgate, 1.

Loop, P. (2016): Blockchain: The Next Evolution of Supply Chains, *Material Handling Logistics (MHL),* 71(10), 22-24.

Lopez, E. (2017): *Big Pharma builds blockchain prototype to stop counterfeits,* Washington D.C., Industry Dive.

Lovelock, J.-D., Furlonger, D. (2017): *Three Things CIOs Need to Know About the Blockchain Business Value Forecast,* Stamford, Gartner.

Marett, D. (2012): A Temperature Data logger using the Microchip PIC16F777, http://www.conspiracyoflight.com/temperature/temperature.html, Accessed 25.08.2018.

Maxeiner, L. S. (2017): Blockchain in the chemical industry, https://medium.com/@lukas.maxeiner/blockchain-in-the-chemical-industry-8b0ebb9f8696, Accessed 01.09.2018.

McLeod, S. (2018): Maslow's Hierarchy of Needs, https://www.simplypsychology.org/maslow.html, Accessed 14.08.2018.

Mearian, L. (2018): The blockchain market is hot; here's how to learn the skills for it, https://www.computerworld.com/article/3258848/blockchain/the-blockchain-market-is-hot-heres-how-to-learn-the-skills-for-it.html, Accessed 09.09.2018.

Mey, S., Schiede, S., Halwax, N. (2018): Blockchain: Die Branche im Zwiespalt, *Horizont,* 4.

Nakamoto, S. (2008): Bitcoin, https://bitcoin.org/bitcoin.pdf, Accessed 21.07.2018.

Natarajan, H., Krause, S.K., Gradstein, H.L. (2017): Distributed Ledger Technology (DLT) and Blockchain, *World Bank,* 1, 2.

Nead, N. (2017): Pharmaceutial Industry Overview: Trends, Risks, Opportunities & Deals, https://investmentbank.com/pharma-industry-overview/, Accessed 29.07.2018.

OECD (2010): *Annual Report on the OECD Guidelines for Multinational Enterprises 2010: Corporate responsibility: Reinforcing a unique instrument,* Paris, OECD Publishing.

Pastoor, T. (2016): The Exact Definition of 'Blockchain', https://medium.com/@2W/the-exact-definition-of-blockchain-225b96a5e2b9, Accessed 22.07.2018.

Pastoor, T. (2016): BitCoin-v0.01-ALPHA, https://github.com/livegnik/BitCoin-v0.01-ALPHA/blob/master/src/main.h#L1002, Accessed 22.07.2018.

Pettey, C. (2018): Gartner Top 8 Supply Chain Technology Trends for 2018, https://www.gartner.com/smarterwithgartner/gartner-top-8-supply-chain-technology-trends-for-2018/, Accessed 23.08.2018.

Pilkington, M. (2016): *Blockchain Technology: Principles and Applications,* Cheltenham, Edward Elgar Publishing.

Porter, M.E. (1998): *Competitive Advantage of Nations,* New York City, The Free Press.

Presentationload (2015): The Fundamentals of Change Management, https://blog.presentationload.com/the-fundamentals-of-change-management/, Accessed 02.09.2018.

PwC Deutschland (2017): Blockchain und Smart Contracts, https://www.pwc.de/de/newsletter/it-security-news/blockchain-und-smart-contracts.html, Accessed 20.08.2018.

PwC (2011): Pharma 2020: Supplying the future, https://www.pwc.de/de/gesundheitswesen-und-pharma/assets/pharma_2020_sc_final.pdf, Accessed 20.08.2018.

Quantalysus (2018): Choosing between Centralized, Decentralized, and Distributed Networks, https://steemit.com/cryptocurrency/@quantalysus/choosing-between-centralized-decentralized-and-distributed-networks, Accessed 21.07.2018.

REGISTRAR CORP (2018): U.S. FDA DRUG DEFINITIONS, https://www.registrarcorp.com/fda-drugs/definitions/, Accessed 22.08.2018.

Sanghera, A. (2018): How Adoption Of Blockchain Technology Will Disrupt Agriculture, https://inc42.com/resources/blockchain-technology-agriculture/, Accessed 22.07.2018.

SAP (2018a): Blockchain und Distributed-Ledger-Technologie, https://www.sap.com/austria/products/leonardo/blockchain.html, Accessed 14.08.2018.

SAP (2018b). Verifying Pharmaceutical Products Using Blockchain, https://www.sap.com/assetdetail/2018/05/c48ee5c2-047d-0010-87a3-c30de2ffd8ff.html, Accessed 01.09.2018.

Savage, C.J., Roberts, K.J., Wang, X.Z. (2006): A holistic analysis of pharmaceutical manufacturing and distribution: Are conventional supply chain techniques appropriate?, *Pharmaceutical Engineering,* 26(4), 8-18.

Schrey, D.J., Thalhofe, D.T. (2017): Rechtliche Aspekte der Blockchain, *Neue Juristische Woche,* 20(1), 1425-1504.

Schütte J., (2017): BLOCKCHAIN UND SMART CONTRACTS: Technologien, Forschungsfragen und Anwendungen, *Fraunhofer-Gesellschaft,* 11.

Shah, S. (2018): How blockchain is revolutionising the legal sector, https://www.raconteur.net/business/blockchain-revolutionising-legal-sector, Accessed 30.07.2018.

Shanley, A. (2017): Could Blockchain Improve Pharmaceutical Supply Chain Security?, *Pharmaceutical Technology,* 3, 34-39.

Shirra, D. (2017): *Blockchain: Pharma's Answer To Restoring Trust In Healthcare,* Toronto: Digitalist by SAP SE.

Smartsheet (2018): Integrated Supply Chain Management: Horizontal and Vertical Integration, https://www.smartsheet.com/integrated-supply-chain-management-vertical-and-horizontal, Accessed 21.08.2018.

Statista (2017a): Pharmaceutical Market Worldwide Revenue since 2001, https://www.statista.com/statistics/263102/pharmaceutical-market-worldwide-revenue-since-2001/, Accessed 29.07.2018.

Statista (2017b): Pharmaceutical Sector Growth Forecast Worldwide by Country, https://www.statista.com/statistics/783145/pharmaceutical-sector-growth-forecast-worldwide-by-country/, Accessed 30.07.2018.

Stratfor Worldview (2017): Stratfor's 2018 Annual Forecast: The Big Picture, https://www.forbes.com/sites/stratfor/2017/12/26/stratfors-2018-annual-forecast-the-big-picture/#6a3bb2ecf5d6, Accessed 30.07.2018.

Tapscott, D., Tapscott, A. (2016): *How blockchains could change the world,* New York City: McKinsey & Company.

Tillier, M. (2017): What Is The Stock Market, And How Does It Work?, https://www.nasdaq.com/article/what-is-the-stock-market-and-how-does-it-work-cm895748, Accessed 14.08.2018.

Tondreau, G. (2016): Blockchain: The Future of the Finance Industry?, https://www.rolandberger.com/en/Point-of-View/Blockchain-The-future-of-the-finance-industry.html, Accessed 14.08.2018.

Troy, S. (2018): Notwendig, aber heikel: Proof of Concept für die Blockchain, https://www.searchenterprisesoftware.de/lernprogramm/Notwendig-aber-heikel-Proof-of-Concept-fuer-die-Blockchain, Accessed 26.08.2018.

University of Cambridge (2016): Porter's Value Chain, https://www.ifm.eng.cam.ac.uk/research/dstools/value-chain-/, Accessed 20.08.2018.

Vandevelde, P. (2018): How to make supply chains ethical and sustainable with blockchain, https://www.supplychaindive.com/news/how-to-make-supply-chains-ethical-and-sustainable-with-blockchain/524920/, Accessed 24.08.2018.

WHO (2015): Growing threat from counterfeit medicines, http://www.who.int/trade/glossary/story073/en/, Accessed 28.07.2018.

Wong, R. (2018): Application of Blockchain in Finance, https://medium.com/@wongchiuchun/application-of-blockchain-in-finance-acd011a2180e, Accessed 14.09.2018.

Yin, R.K. (2008): *Case Study Research: Design and Methods,* 4th Edition, Thousand Oaks, Sage Publications Ltd.

Yli-Huumo, J. (2016): Where is Current Research on Blockchain Technology? A Systematic Review, *PLOS ONE,* 11(10), 27.

Zhang, Y., Wen, J. (2017): The IoT electric business model: Using blockchain technology for the internet of things, *Peer-to-Peer Networking and Applications,* 10(4), 983-994.

Appendix 1: Interview Protocol 1

Interviewer	Giulia Zamponi
Interviewee	Patrik Ziman
Date	08.08.2018

I. General Part

What is your profession and role?

- Head of Regional Supply Chain Management at Boehringer Ingelheim RCV GmbH & Co. KG in Vienna, Austria

What is your experience in blockchain technology?

- Project Member in a pilot to evaluate possibilities for blockchains at the regional center Vienna.

II. Blockchains in the Pharmaceutical Supply Chain Management

What are the most important features of any technology in your industry? Please rate:

*1 = not important to 5 = very important

	1	2	3	4	5
Costs			X		
Privacy			X		
Transparency (internally)			X		
Reliability					X
Security					X
Scalability				X	
Latency					X
User-friendliness			X		

Do you think blockchain is a promising technology in general – and in the supply chain management?

Yes, especially in “international trade” related supply chain process.

If yes, in which specific areas or processes can blockchains be used? / If not, why not?

- Providing secure environment between participants/partner who do not now/trust enough each other
- Enabling automatization of certain subsequent process (information/document exchange)
- Interesting options of use of blockchain technologies in "private/business to public sector", when dealing with authorities (e.g. customs, insurance)
- But much more information about costs of running a blockchain based solutions is required to be spread, in order to have relevant data for decision making, whether or not to involve blockchain models

Which obstacles or limitations do you see in the applicability and implementation of blockchains?

- Using blockchain solution requires readiness on both sides of transaction. There is huge opportunity in public sector (citizens/businesses to authorities and vice-versa), especially in international environment (customs, certification authorities, market supervision authorities – pharmaceuticals, veterinary, food supplements), which would be possible only in case the topic gets attention at EU level (or at least national governments).
- Major ERP system providers need to be motivated to enable their products to work with blockchain without difficult customization required.
- Specific cost structure of the blockchain based solution must be communicated wider than currently is. To enable prospect participants/partners to start evaluating blockchain as natural option to existing methods.

Which added value could blockchains bring supply chain organizations?

- Secure environment for information exchange and so enabling transactions with more "remote" partners, new markets, industries, etc.
- Automatization of processes (e.g. when any kind of action or non-action is based on previous act of other party)
- Fast decisions/actions (e.g. when approvals)

Appendix 2: Interview Protocol 2

Interviewer	Giulia Zamponi
Interviewee	Darryl Glover
Date	02.08.2018

I. General Part

What is your profession and role?

- CCO at iSolve LLC

What is your experience in blockchain technology?

- Being the Principal and Chief Clinical Officer (CCO) of iSolve creating connections between the advantages of Advanced Digital Ledger Technology™ (e.g. Blockchains) and the needs of the Biopharma and Healthcare Industries plays an important role → High level of experience with blockchain technology.

II. Blockchains in the Pharmaceutical Supply Chain Management

What are the most important features of any technology in your industry? Please rate:

*1 = not important to 5 = very important

	1	2	3	4	5
Costs				X	
Privacy					X
Transparency					X
Reliability					X
Security					X
Scalability			X		
Latency			X		
User-friendliness	X				

Do you think blockchain is a promising technology in your industry? Which problems could be addressed with blockchain technology?

- Definitely, yes.
- Data silos could be avoided by accessing and using data that was not applicable before on an end-to-end supply chain
- Blockchains could provide a solution to move forward with personalized medicine
- It can support the data management during clinical trials
- Enable to execute recalls in a more efficient way

- Parallel trade
- Increase traceability along the supply chain incl. partners e.g. wholesalers

If yes, in which specific areas or processes can blockchains be used? / If not, why not?

- Every area/process could benefit from blockchain technology to a certain extent

Which added value could blockchains bring to your industry/company?

- Due the increased visibility (knowing where and how goods move), the operational efficiency can be increased and this leads to a decrease of costs
- Increasing transparency of stocks along the supply chain helps better managing inventories
- The monetary added value of blockchain is hard to quantify unless implemented

Which obstacles or limitations do you see in the applicability of blockchains?

- The biggest hurdle is the implementation approach; instead of trying to change and replace all systems with blockchains, a smarter move might be to promote blockchains as a complementary technology
- The implementation itself from a technical point of view; the more variety of interfaces and the more data, the more complex the implementation will be
- Interoperability might be another obstacle: if every company is using its own Blockchains the full potential of Blockchains will not be realized; however, companies like Microsoft's CoCo Framework and others are trying to solve this problem.

Further comments

- Is the missing legal frame an obstacle?
    - No, the underlying technology is not brand new hence it should not be difficult to fit blockchains into a legal framework
- When can we expect to have the first blockchains running in the pharmaceutical supply chain organizations?
    - Approximately in 2019: blockchains would offer a technical solution how to deal with the requirements of the drug supply chain security act
    - In Europe it will most likely need another 5 years until the first blockchains are running

Appendix 3: Interview Protocol 3

Interviewer	Giulia Zamponi
Interviewee	Maneesh Grover
Date	30.08.2018

I. General Part

What is your profession and role?

- Lead Architect in Solutions and Emerging Technologies at Wipro Limited in Bangalore, India

What is your experience in blockchain technology?

- Profound blockchain experience due to profession.

II. Blockchains in the Pharmaceutical Supply Chain Management

What are the most important features of any technology in your industry? Please rate:

*1 = not important to 5 = very important

	1	2	3	4	5
Costs	X				
Privacy					X
Transparency (internally)			X		
Reliability				X	
Security					X
Scalability		X			
Latency			X		
User-friendliness	X				

Do you think blockchain is a promising technology in general – and in the supply chain management?

Blockchain is a strong technology solution and it has not taken too long for the businesses to realize that blockchain can be very effective especially in bringing transparency, enhanced security, efficiency, cost effectiveness and disintermediation. Business believes it will test and push the boundaries of conventional approaches to problem solving.

If yes, in which specific areas or processes can blockchains be used? / If not, why not?

- Pharma is one of the most regulated industries. The challenges of keeping the research / clinical trials very transparent, auditable yet secure is of very high importance. Blockchain can bring transparency, auditability with the right mix of security to the set-up.
- Anti-counterfeit/Product recalls/Returns
- Financial reconciliations: Keeping a complete track of multi-tier invoice reconciliation has traditionally been a challenge. With blockchain, the auto reconciliation as well keeping all financial transactions in an auditable manner provides great benefits to the organization.
- Collaboration: Collaboration has always been a difficult task in any organization. Managing vendors, partners even departments within the organization is a tough task. By having a single source of truth which is distributed in nature across all entities, allowing peer-to-peer verification mechanisms (consensus), the organization can have better and more cost-efficient solutions to conduct their businesses. Blockchain offers a proactive means to engage with the eco-system.
- New business models: Blockchain, through collaboration, has a huge potential to bring down cost, increase optimization in doing business and allow newer business models to evolve. Peer-to-peer insurances, secure data sharing, compatibility across drugs and many such business models have started to show up in the market.

Which obstacles or limitations do you see in the applicability and implementation of blockchains?

- Number 1: how to streamline all different types of blockchains and protocols

Which added value could blockchains bring supply chain organizations?

- By introducing blockchain (working with other technologies such as IoT and AI) can better and transparently track shipment consignment across the value chain.
- Multiple facets of the tracking can be done over blockchain:
    - The same solution can be used to track the actual shipment/consignment across the value chain
    - It can also be used to track any regulatory/compliance related documentation along with the consignment (especially in case of international shipments involving custom clearances etc.)
    - Track actual condition of the consignment – where some of these chemicals and drugs are very environmentally sensitive. Now, instead of verbally relying on the vendor’s system or reports, company can get better and direct access to such sensitive information directly over blockchain.
- Any deviation from the set norms can also help trigger any pin-pointed recalls at any stage of the shipment – instead of incurring additional costs and risks by letting such damaged goods travel till the end of the value chain.
- By having such strong tracking across multiple facets – also inhibits thefts or introduction of counterfeit drugs into the supply chain.
- Blockchain as a common communication channel across the eco-system provides a platform to collaborate and sharing details across parties – be it internal or external entity to the organization, enables trade that is more transparent at lower administrative costs allowing companies to also venture into markets with lower margins.

Further comments

How long will it take till the first blockchains are used in daily business in the pharmaceutical supply chain?

Pharma industry is in the early phase of blockchain adoption. So far early success stories are promising and are expected to propel the adoption into mainstream sooner. For daily business, it might take a while may be another 2-3 years but for business to stay in competition they need to start today. As more companies become aware of blockchain and its capabilities, everyone has started to experiment with it. Many of the current shortcomings are getting identified during these experimentations and huge investments and effort are going into overcoming these challenges. Some of the current roadblocks are:

- Regulatory: Despite blockchain capabilities and advantages – the regulatory authorities are yet to create complete understand and promote it for mass-adoption. One of the key ask of these regulatory authorities (along with the academia) is also to establish industry standards to allow the proper adoption of the technology within the industry.
- Scalability: There are several questions being raised on the scalability and adoption of the blockchain technology due to multiple platforms claiming different benefits against different use cases. However, very few platforms can handle the real production-grade level of transaction volumes. Lot of research is on the way, to make this enterprise grade - One of the most noteworthy research currently being done in this space is the 6-stages of Casper-Sharding introduction – that expects to raise the current capacity of the platforms to minimum of 100x in just the first stage itself. During the subsequent stages, the actual space capacity against each blockchain node will be drastically reduced – a factor which also contributes to the scalability of the network.
- Interoperability: Yet another research topic in progress to blockchain adoption is interoperability. With multiple protocols comes challenge of interoperability, without any clear way to allow interaction across varying networks and protocols. It is one of the critical factor for the organization to choose the best possible platform to suit their needs and often go with few protocols for initial implementations.
- Cost of Ownership: Below are some of the questions which needs to be answered for wider adoption.
    - Who will hold the ownership of the entire solution?
    - Who will pay for it and how much?
    - How will the network entities divide the implementation cost?
    - What are the incentives for each of the entities to get on-boarded on a common network?
    - What are the ROI of this technology?

  However, despite all these challenges, blockchain is fast getting the industry attention with global pilots in progress and the number of willing participants to this adoption are fast rising. These engagements are leading to better and newer discoveries that will make it the common choice for a day-to-day use for the technology.

Appendix 4: Interview Protocol 4

Interviewer	Giulia Zamponi
Interviewee	Prof. Dr. Lydia Bals
Date	24.08.2018

I. General Part

What is your profession and role?

- Professor of Supply Chain & Operations Management at Mainz University of Applied Sciences and affiliated with the Department of Strategic Management & Globalization, Copenhagen Business School.
- Main Research Areas: Sustainable Supply Chain Management, Offshoring and Reshoring, Purchasing & Supply Management Organization

What is your experience in blockchain technology?

- Blockchain experience from an academic research point of view.

II. Blockchains in the Supply Chain Management

What are the most important features of any technology in supply chain? Please rate:

*1 = not important to 5 = very important

	1	2	3	4	5
Costs				X	
Privacy					X
Transparency (internally)					X
Reliability				X	
Security					X
Scalability			X		
Latency				X	
User-friendliness				X	

Do you think blockchain is a promising technology in general – and in the supply chain management?

- Yes.

If yes, in which specific areas or processes can blockchains be used? / If not, why not?

- Execution of payments without intermediates e.g. banks
- Creation of digital “material passports” storing relevant data throughout a product lifecycle in a blockchain for instance country of origin, ownership.
- Blockchains could foster recycling markets → sustainability aspect & circular economy

  Tate, Wendy/Bals, Lydia/ Bals, Cristof/ Foerstl, Kai (2018): Seeing the Forest and Not the Trees: Learning from Nature’s Circular Economy, presented at Academy of Management Annual Meeting (AOM), Chicago, USA.

Which obstacles or limitations do you see in the applicability and implementation of blockchains?

- Alignment on standards missing
- Uncontrolled growth of different blockchain solutions that misses the ability to “communicate” with each other
- Missing use-cases

Which added value could blockchains bring supply chain organizations?

In order to measure the added value, different approaches are applicable:

- Comparison of process costs: before and after the implementation of blockchains
- Comparison of the level of transparency
  - Due to the increased transparency for instance where used materials are purchased from or under which conditions the finished goods are produced, the image could be improved → image change could be measured
- Due to the transparency and accessibility of data, companies could learn how their products are used which could lead to product enhancements or changed interaction with customers. The gained insights from markets could be used to develop new products that meet the demands of potential customers.

Further comments

n.a.

Appendix 5: Interview Protocol 5

Interviewer	Giulia Zamponi
Interviewee	Alexander Tscherteu
Date	29.08.2018

I. General Part

What is your profession and role?

- CEO of Heta AG in Vienna, Austria

What is your experience in blockchain technology?

- No professional experience with blockchain technology so far.

II. Blockchains in the Finance Sector

What are the most important features of any technology in your industry? Please rate:

*1 = not important to 5 = very important

	1	2	3	4	5
Costs					X
Privacy					X
Transparency (internally)			X		
Reliability			X		
Security				X	
Scalability			X		
Latency		X			
User-friendliness		X			

Do you think blockchain is a promising technology in your industry? Which problems could be addressed with blockchain technology?

- Yes, in specific areas.

If yes, in which specific areas or processes can blockchains be used? / If not, why not?

- Any type of basic services as it allows continuous servicing of payments / transactions due to the removal of cost disadvantages (traditional banks compared to providers of basic services) → Cost reduction

Which added value could blockchains bring to your industry/company?

- Goes hand in hand with above mentioned areas of potential blockchain applications. Due to the removal of cost disadvantages, banks could continue participating in the "basic services market".

Which obstacles or limitations do you see in the applicability of blockchains?

- Apparently the technology is not yet ready to execute as many transactions as needed in an adequate time since the more information is stored in blockchains, the longer the chains become. This problem must be tackled from technical point of view first.

Further comments

Finance is driven by significant cost pressure and new entrants offering similar services for much lower fees. Blockchain might help banks in cutting costs and being competitive in the future.

Appendix 6: Interview Protocol 6

Interviewer	Giulia Zamponi
Interviewee	Sebastian Dencker
Date	03.09.2018

I. General Part

What is your profession?

- Director Compliance Europe at Ecolab in Vienna, Austria & CEO of Ecolab Austria until December 2017.

What is your experience in blockchain technology?

- No professional experience with blockchains so far but the technology itself is known in combination with cryptocurrencies e.g. Bitcoins

II. Blockchains in the Chemical Industry

What are the most important features of any technology in your industry? Please rate:

*1 = not important to 5 = very important

	1	2	3	4	5
Costs					X
Privacy				X	
Transparency (internally)				X	
Reliability					X
Security					X
Scalability		X			
Latency			X		
User-friendliness					X

Do you think blockchain is a promising technology in the chemical industry?

- Generally it remains to be seen how the technology develops especially taking into consideration the limitations
- It is an interesting technology but a proof of concept is missing
- Too early to mention clear areas

If yes, in which specific areas or processes can blockchains be used? / If not, why not?

- Digital identities of assets or persons
- Protection of intellectual rights in 3D manufacturing

Which obstacles or limitations do you see in the applicability and implementation of blockchains?

- Speed of adaption; more reserved tendencies in the industry expected
- Regulations and data is changing frequently, it is questionable whether blockchain offers a superior solution in those cases
- Technology is not yet ready to process the high amount of data

Which added value could blockchains bring to any company busy in the chemical sector?

- Data Storage and any kind of cloud solution
    - In case common software providers such as Microsoft or SAP would offer suitable Blockchain solutions, the chance that pilots are started would increase.

Further comments

n.a.