

Don't be fooled by the blocks that it got.

Blockchain, a revolution or not?

W.R. van Nes
321311

ERASMUS UNIVERSITY ROTTERDAM

Erasmus School of Economics

Urban, Port & Transport Economics

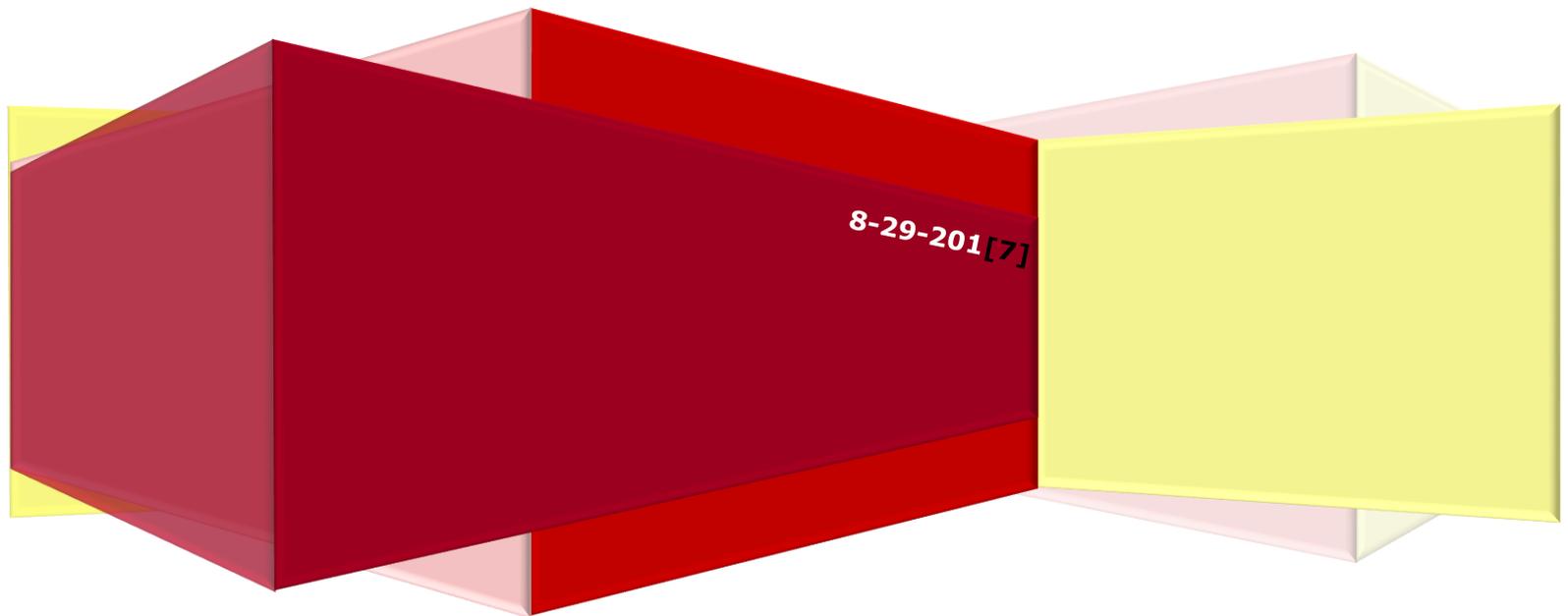
Master thesis written at CARU containers

Supervisor

Dr. B. Kuipers

Second assessor

O. de Jong MSc



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Preface

Well, here I am. Sitting at CARU containers Rotterdam at the Seattleweg, working on the final pieces of my thesis. This was all quite unexpected to say the least. I would like to thank Siebren Hoekstra for putting me in the spotlight at CARU containers and Merijn Zondag for inviting me for a talk at the company. Because I definitely wanted to know the company better but I could not do a full-time internship, I got offered every kind of flexibility that was possible.

I would like to thank Rob Tromp and Rob Feenstra for this fantastic opportunity. I have learnt a lot during this internship about CARU containers and the people that work here. The atmosphere is very pleasant and generous. I could ask anyone about anything. What I noticed later on is that some of the employees were also honestly interested in my thesis subject.

My topic arose during a brainstorm session with both Merijn Zondag and my supervisor from the Erasmus University Bart Kuipers, who I would both like to thank for the guidance that was offered during the entire thesis process but also for some tips that might be useful for the rest of my life.

During my research I got into contact with several blockchain experts in the field. Sander van Loosbroek, Aljosja Beije, Arthur Janse and Gerard Bottemanne: thank you for taking your time to answer all my (maybe sometimes stupid) questions about blockchain, bitcoin and the supply chain. I really got the idea that it took my thesis to a higher level. Furthermore a thank you to all the employees of CARU containers for the warm welcome and the official and less official conversations that we had about almost every topic that can be thought of.

Last but certainly not least I would like to thank my parents for the support that they have given in my entire life. Always, no matter what did or did not happen.

- Wesley -

Abstract

This paper tries to offer a non-exhaustive overview on blockchain. It is presented as being a management rather than a technical topic. With the help of the fathers of economics, the history of transactions and institutions are described accompanied by the current status of the economy. The blockchain protocol of Satoshi Nakamoto solves the problem of digital double spending. The whole protocol of hashing, blocking, chaining and mining is described together with the issues of limited computer power and computer memory, next to the general subjects such as the security of the assets and the publicity of information. The applications of the cryptocurrency bitcoin and the smart contracts basis of ethereum are reviewed. In the supply chain, blockchain can be used for more transparency regarding the origin of products, cargo shipment tracking and cargo shipment weight. Currently, IBM and Maersk are working together on a new blockchain solution in the shipping and logistics industry. As this thesis is written at CARU containers, the implications in the container sector for this company specifically will be debated and recommendations are given for different scenarios in the future. The developments need to be followed closely as the impact of blockchain could be very disadvantageous.

The blockchain protocol is able to make one big ledger that is distributed, synchronized and cryptographically secured. It can make trusted third parties largely obsolete. Blockchain is still in its infancy, therefore a lot of issues need to be solved and more applications can still be developed but slowly and steadily it acquires the potential to improve the entire economy and to replace a part of the activities of the current actors in the supply chain.

Content

Introduction	7
Technological developments	7
The supply chain	7
Transactions	8
Blockchain in short	8
Problem statement	9
Academic relevance	9
Practical relevance	10
Design and method	10
Chapter one - history	12
1.1 The Wealth of Nations	12
1.2 Institutions	13
1.3 Costs of trading	13
1.3.1 Transaction costs by Coase	14
1.3.2 Transaction costs by Williamson	15
1.4 Global developments	17
1.4.1 Credit crunch	17
1.4.2 Economic rates	18
1.4.3 Political factors	20
1.4.4 Ecological factors	21
1.5 Current status	22
Chapter two - blockchain	24
2.1 In the middle of the crisis	24
2.2 The problem of double spending	24
2.3 The blockchain protocol	25
2.3.1 Requirements	25
2.3.2 Hashing	27
2.3.3 Blocking	28
2.3.4 Chaining	29
2.3.5 Mining	31
2.3.6 Smart contracts	31
2.4 Blockchain bottlenecks	32
2.4.1 Multiple blockchains	32
2.4.2 Privacy	32
2.4.3 Speed, size and security	33
2.4.3.1 The mini-blockchain	34
2.4.3.2 The blocktree	34
2.4.3.3 The bigchain	34
2.4.3.4 The DAG-structure	35
2.4.3.5 Finding a balance	35

2.4.4	Cryptographic puzzle alternatives.....	35
2.4.4.1	Proof-of-stake.....	36
2.4.4.2	Proof-of-activity.....	37
2.4.4.3	Other proofs.....	37
2.4.4.4	Verification and validation of information.....	37
2.4.5	Legal implications.....	38
2.4.6	The Paxos anomaly.....	39
2.4.7	Longlisting problems.....	39
2.5	Different views on blockchain.....	40
2.6	Blockchain in a political setting.....	41
2.7	An (un)limited applicability.....	41
2.8	Standardization of the system.....	43
2.9	Bank versus blockchain.....	44
Chapter three - applications.....		46
3.1	Bitcoin.....	46
3.1.1	Digital money.....	46
3.1.2	Bitcoin wallet.....	47
3.1.3	Bitcoin bottlenecks.....	48
3.1.4	Bitcoin as the backbone of the financial market.....	50
3.2	Ethereum.....	51
3.3	Scheme.....	53
3.4	Other applications than cryptocurrencies and smart contracts.....	54
3.4.1	Money tracking.....	55
3.4.2	Insurance world.....	55
3.4.3	Health care.....	55
3.4.4	Governments.....	56
3.4.5	Identification.....	56
3.4.6	Media industry.....	56
3.4.7	Software.....	56
3.4.8	Storage.....	57
3.4.9	Multi-functionality.....	57
3.5	Application in the supply chain.....	58
3.5.1	The current supply chain.....	59
3.5.2	Blockchain experience lab PWC.....	60
3.5.3	Start-ups regarding origin of products.....	61
3.5.4	Walmart.....	61
3.5.5	Cargo shipment tracking.....	62
3.5.6	Cargo shipment weight.....	62
3.5.7	Blockchain platform IBM Watson.....	62
3.5.8	Blockchain cooperation IBM and Maersk.....	63
3.5.8.1	The research.....	64
3.5.8.2	The problem.....	64
3.5.8.3	The solution.....	65
3.5.8.4	The cooperation.....	65

3.5.8.5	The consequences	65
3.6	A simpler supply chain.....	66
Chapter four - scenarios	67
4.1	Introduction to CARU containers	67
4.2	Sales process	67
4.3	Why blockchain and why CARU containers	70
4.4	Scenario planning	71
4.4.1	Scenario 1 - blockchain fully implemented.....	71
4.4.2	Implications of scenario 1 for CARU containers	72
4.4.3	Scenario 2 - blockchain has disappeared	73
4.4.4	Implications of scenario 2 for CARU containers	73
4.4.5	Scenario 3 - gradual introduction of blockchain.....	74
4.4.6	Implications of scenario 3 for CARU containers	74
4.4.7	Scenario probability and overlap	75
4.5	Blockchain and CARU containers.....	76
Chapter five - conclusion	78
5.1	Blockchain through time	78
5.2	A new revolution.....	78
5.3	Recommendation for further research	79
5.4	Implications for CARU containers	80
5.5	The future.....	81
Bibliography	82
	Cited start-ups working with blockchain	93
Appendix	94
	Interviews employees CARU containers.....	94
	Account management, Allard Langenhuijsen	94
	Credit management, Simone Ewijk	94
	Zeecontainer.nl, Lennart de Bruin	95
	Financial administration, Dennis Paantjens	96

Introduction

To start with, in this part some technological developments will be discussed very succinctly in the context of the supply chain. After that the subject of this thesis will be introduced together with the rest of the design of this paper.

Technological developments

The Internet of Things, Big Data and the Cloud seem to become the buzzwords of the century. If the technological developments of the past years keep going at the same pace in the future, almost everything seems possible. We might be able to create our own virtual reality, 3D-print most of the products that we need and our cars can bring us to the destination without any interference of the human being anymore. Products and applications might be introduced that we cannot even think of right now. As Henry Ford said, when introducing the Ford model T: 'if I had asked people what they wanted, they would have said faster horses.'¹

The mentioned developments also have their influence on transport and the entire supply chain. If 3D-printing indeed will become the new way of buying products, chances are that the amount of goods that needs to be transported will decrease or that a shift will be taking place from transporting end-products to transporting raw materials. The commercialization of the autonomous car can have a big impact on truck transport and the application of Big Data can give a lot of clarity at every stage of the entire supply chain.

The supply chain

At the moment, most of the times this clarity in the supply chain is lacking. There is no good overview when transporting products. Research by Maersk Line (2015) was done about the transport of flowers from Nairobi in Kenia to Europe. For this transport, almost 200 communications between parties were needed. The journey lasted 34 days of which the flowers were standing still for 10 days in total, waiting for another document or approval.

According to Maersk (2015), the physical side of the supply chain is actually arranged pretty well. The problems can mostly be found in the paper trail. The communication is going from one stage to the next and often people in a further or

¹ Although it has to be admitted that there is no evidence that Henry Ford indeed used this exact phrasing and therefore people are having doubts about the veracity of this statement (Harvard Business Review, 2011).

previous phase of the chain are not aware of the previous or subsequent steps. In fact the entire communication structure is difficult and with the current technological possibilities this seems unnecessary. Next to that the question is if indeed the physical side of the supply chain can hardly be improved as Maersk states, when taking into account the delays of the ships on a regular basis due to all kinds of circumstances that are not always under the control of the shipping company (Vernimmen, Dullaert and Engelen, 2007).

Transactions

Another problem can be found in the transactions in the broadest meaning of the word. When paying any bill or when transferring property from one party to another, a third central institution is necessary most of the times such as a bank. We need trust in these administrators to make the system work and pay the administrators for this work; empirical research done in the USA from 1963 to 1990 pointed out that in trading transaction costs are 1.2% of the market value for large decile firms and 10.3% for small decile firms (Lesmond, Ogden & Trzcinka, 1999). International official remittances to developing countries can even take up to 20% of the total amount; this is also the reason why money is still send in an envelope (Tapscott, 2016). These informal remittances are estimated at 35% to 75% of the official remittances to developing countries (Freund & Spatafora, 2005).

These are only a few examples of the transaction costs that companies and individuals are facing. If trust would not be a criterion anymore, these costs can be eliminated for a big part as well. With all discoveries in the technological sector, a system in the supply chain would be desirable that is easier to use, cheaper and more transparent. It may sound too good to be true, but this system - although still in its infancy, but growing - is there. It is called blockchain.

Blockchain in short

Blockchain is the underlying protocol of for example bitcoin and has the potential to disrupt entire industries because it makes the trusted third party obsolete; the trust is in fact digitalized. The communication is directly peer-to-peer and the contributors are distributed. Every transaction that is made needs to be linked to previous transactions and every participant got real-time access to the same data.

Because of this, trust is the result of the system instead of being the prerequisite. The risks are lower, doing transactions takes less effort and the transparency will increase significantly (PWC, 2017). Moreover, the system can find its application in all kinds of sectors, for example the insurance world and the healthcare industry

(Blockgeeks, 2017). Because it is still in its infancy, there are some start-up problems as well for instance with regard to the trade-off between speed and security (Kiayias & Panagiotakos, 2015).

Problem statement

People may have heard before of the concept of blockchain and at first glance the phenomenon might sound vague and woolly. This paper tries to offer a comprehensible description of how blockchain works, what the possible problems can be and how this system can find its application in the economy and more specifically within the supply chain and the container industry. The central problem statement therefore is:

Is blockchain with its applications able to create a revolution within the economy as a whole and specifically within the supply chain and the container sub-chain or are the capabilities of the system overrated?

To come to an answer, the central problem statement can be split up into multiple sub-questions, which are:

- 1. Why do institutions exist in transactions and what are transaction costs?**
- 2. What is blockchain and how does it work?**
- 3. How can blockchain be used in the economy, the supply chain and the container industry?**
- 4. What are the possible consequences of the rise of blockchain for CARU containers and how does the company need to act upon it?**

Although the nature of blockchain is very technical, the explanation of the exact coding and programming will be kept to a minimum. The aim of this thesis is to be as clear and comprehensible as possible while discussing the working of blockchain in-depth. So this contribution can also be worth reading for people that have no educational background or working experience in Information Technology as the author of this piece is in the exact same position.

Academic relevance

This thesis gives, among other things, an overview of a substantial amount of problems that are encountered when using blockchain both in theory and in practice. No novel crypto-technicalities will be presented as the goal of this thesis is to give an overview of the available current solutions rather than focusing on one specific problem. In the last

part, there will be some recommendations about which fields or parts of blockchain need further research and whether or not there are still any 'gaps' in the whole system of blockchain that need to be filled.

Moreover, it might give researchers new suggestions about applications in practice that can be developed. Since a blueprint of activities of one specific company will extensively come forward, it can be imagined that this one company is not the only one that is experiencing problems of this nature. In addition, blockchain projects of other businesses will be reviewed which gives an idea of the issues that still need to be dealt with on an academic level.

Practical relevance

There is a lot of practical relevance in this contribution. Blockchain is explained with a management rather than a technical perspective. Companies can profit from this information to get a better understanding of the possibilities of blockchain. In a later chapter some projects in different phases of the supply chain are discussed and a glance into the future is given. The relevance is evident. Similar projects might be implemented in that particular company. Both time and costs gains can be made. Successful blockchain use can result in more efficient and effective activities within any company because of its broad usability.

The relevance for CARU containers will even be bigger if possible. Because there is an opportunity to experience the business activities as close as possible, very concrete applications can be shown. This can help the employees of the company to do their work easier, better or faster. Next to that this thesis may also give the employees a better and coherent insight into the whole phenomenon of blockchain, regardless of their current function or daily activities, especially when the fact is taken into account that shipping company Maersk is already working together with IBM on concrete blockchain implementation within the supply chain (Maersk, 2017). Maersk is involved in a 2M-alliance with MSC (Flexport, 2017) and MSC is one of the most important business partners of CARU containers. Chances are that if the blockchain implementation of Maersk is indeed successful, this will affect CARU containers via MSC as well. In that case it is better for the company to be prepared for rather than surprised by this phenomenon, that is also why different recommendations are given to this company.

Design and method

Every sub-question will be discussed in a separate chapter after this introduction. The first chapter will be about the relevant history with regard to doing transactions. As will turn out, a certain trend can be discovered. This trend continues in the present and can

possibly be extended into the future. The current characteristics of the economy will be described together with the problems. The next chapter will be fully dedicated to blockchain and how the system works. The paper of Satoshi Nakamoto (2008) will be the basis of this chapter. Blockchain is relatively new, so there still is a significant amount of problems which will also be debated. In chapter three the applications will play a central role and they are funneled down from the whole economy to the supply chain and container sector. Blockchain can be applied in a lot of industries and at the moment different companies are busy with several pilots.

The first three chapters and main part of this thesis will consist of a review of the available literature. This literature is mainly found via Google Scholar in scientific journals, however due to the novelty of the subject sometimes there will also be referred to less known websites or videos on Tedx (www.ted.com) or YouTube (www.youtube.com). The credibility of the information and source is always considered before using it or crosschecked whenever possible or necessary.

For the last sub-question the method will be slightly different. As the thesis is written at CARU containers, there is also access to both employees and databases of the company. Through research of the databases and interviews with several workers of for example the finance department the last sub-question will be answered, illustrated with different scenarios.

The paper will close with a conclusion and discussion of everything that has been reviewed before. Both recommendations for further research will be given as well as practical advice considering the emerging trend of blockchain.

Chapter one - history

This chapter will give a relatively short history about doing transactions and describe the current characteristics of the economy accompanied with its challenges.

1.1 The Wealth of Nations

In his *Wealth of Nations*, Adam Smith (1776) describes how people used to live in small villages and were reliable on the hunt of animals in order to survive. Because some individuals were for example better in hunting dears than hunting beavers, the trend of *specialization* and the *division of labor* arises. In order to obtain all the products that were necessary or wanted by a person, one had to trade products against another on the 'market' with a ratio that was based on for example the amount of effort that it takes to hunt a deer compared to hunting a beaver.

The rise of completely other crafts is also related to specialization. For example the production of crossbows can make the hunt easier which will result in more hunted animals in the same period of time. A bigger surplus can be created and this will be beneficial for the revenue of the whole village. Other than that it gives the producer of the crossbow the occasion to 'buy' meat without being involved in hunting at all. An additional problem of the increasing variety of goods is that for every two products a new ratio had to be established or calculated based on the amount of time and effort required.

Adam Smith is considered as one of the fathers of modern economy (Kennedy, 2016). In this chapter also other fathers will be mentioned. The *Wealth of Nations* consists of in total five books and two parts. In the first book, Smith gives his example of hunting deer and beavers. In this book he also talks about the use and origin of money; a butcher that has more meat available than he can ever consume but does not want to trade with the baker that actually needs meat, because the butcher has a sufficient amount of bread as well. This is the big problem of an economy that is based on barter.

Eventually, people started trading against durable, precious metals that were non-perishable such as gold, which later got stamps to indicate some of the characteristics. The stamps were made by mints. Mints are companies that ascertained the information that was displayed on the stamps. This is where the origin of coined money and *institutions* lies, the only difference is that in the current economy the intrinsic value of the money is near null. In relation to institutions Smith also talks about legislature and the sovereign that has the 'duty of superintending'. In this thesis I will get back to both

money as tender and institutions multiple times as both of the subjects play a central role. The modern version of the sovereign will also be mentioned.

1.2 Institutions

In the work of Adam Smith the institutions are definitely present but their existence is not really of a decisive matter. Their significance starts when the trading does not stay within the borders of the small village where there is a dense social network of informal constraints. Trading goes from the village to the region and from the region to basically the rest of the world. Gradually the borders are fading and we do not know anymore who we are dealing with.² With the distances between trading partners getting longer and longer, the problem becomes twofold:

- An agency problem, in which the agent should act on behalf of his merchant but also has other interests that are conflicting with those of the merchant. He might be keeping a part of the trade or the money for himself. As the trading distances were getting bigger and bigger, so was this problem. The control of the merchant on the negotiations only decreased.
- The other problem is related to the enforcement of the contract and the protection of the goods. Even if the agent was acting in the best interest of the merchant, the other party could still be a swindler or the goods could be stolen by highwaymen during the trip. This problem could be solved by sending armed forces to accompany the goods making the trade only more expensive for both parties.

The emergence of what later were called notaries, law courts and other bodies - next to standardized measures - were able to provide a lower uncertainty and a more efficient trade over long distances (North, 1991).

Over history we can see a shift from informal constraints such as norms of behavior and self-imposed codes of conduct to formal constraints such as rules and laws accompanied by their enforcement characteristics in institutions (North, 1994).

1.3 Costs of trading

Of course, a part of the costs of trading is the amount of money or other goods that is paid for the products that you want to get. Other indirect costs in the past were for example the wage of the agent and the armed forces that needed to protect the goods

² The story of this development in phases from local autarky to the situation that is described here is based on the German historical school, although history most of the times does not let itself classify into these phases (North, 1955). However, for clarity reasons it is assumed that these phases are the usual course of events.

and needed to make sure that the contract that was agreed upon was executed in the right way.

Later, the armed forces might have become (partially) obsolete but instead we now pay a notary or a bank for doing transactions. For the enforcement of a contract in case things do not work out as agreed upon beforehand we can ask a mediator, collection agency or the court for help and clearance. Plainly seen, all of these actors exist to compensate for the fact that often we do not know our trading partner very well nor what his intentions are. For all these actors we pay a fee when making use of their services because we do know that we can trust them, in contrast to the trading partner.

1.3.1 Transaction costs by Coase

These indirect costs of trading were first used and described by Ronald Coase (1937). He called this the 'costs of using the price mechanism'. Later, Coase (1960) referred to these costs as the 'costs of market transactions' of which the general term of *transaction costs* is derived. With these transaction costs, Coase expressed his critique on three key assumptions of the neoclassical economics (Weintraub, 2008):

1. People have rational preferences among outcomes.
2. Individuals maximize utility and firms maximize profits.
3. People act independently on the basis of full and relevant information.

Especially the lack of truthfulness of the third assumption led to these transaction costs according to Coase (1960); the consumer had no access to every piece of relevant information and even if he did, this would cost him at least some time and effort. The famous Coase-theorem is derived from these statements. Given the situation that there are no transaction costs applicable in any way, individuals will be able to maximize aggregate income and thereby create a Pareto-efficient³ outcome, regardless of the presence of institutions and regardless of the initial allocation of products. However, when transaction costs are involved, the institutional arrangements matter as well. Institutions are the rules of the game and entrepreneurs are their players. During a long time the wrong assumption was made that institutions do not matter. Another wrong assumption that was made to this regard is that time is not of any influence. In this context with 'time' is meant the learning embodied in individuals, groups, and societies that is cumulative through time. The worldview and mindset of individuals and groups have a lot of influence on the way that institutions evolve (North, 1994).

³ An outcome is Pareto-efficient when there is no reallocation of products possible to make one individual better off without making at least one other individual worse off (Cirillo, 2012).

1.3.2 Transaction costs by Williamson

Where Coase laid the foundation on the nature of transaction costs, Oliver Williamson elaborated a lot on this concept. With regard to the actors also Williamson (1979) expressed some critique on the three assumptions of the neoclassical economics mentioned before:

- Although it is true that people intend to behave on a rational basis, they can often not calculate every possible outcome and decide what the best option is in the end. This is associated with the fact that they do not have access to every piece of relevant information. Therefore we can better speak of bounded rationality instead of full rationality of individuals.
- Related to the bounded rationality is opportunism. Opportunism is an effort to realize individual gains through a lack of candor or honesty in transactions. This can take shape in two ways (Williamson, 1975):
 - Before any transaction by disclosing information purposefully, for example knowing that the car you want to sell is a wreck without the buyer being able to see it at that moment. This is a direct consequence of parties not having access to all information and some knowing more than others.
 - During the execution of the contract. To stick to the same example, quickly changing the tires of the car that was just sold in that state because the quality is still good and there are some old tires available that barely pass the legal requirements.

Opportunism is some kind of egocentric behavior at the cost of the trading partner. In terms of Pareto it comes down to reallocation of the products so that somebody is better off while making at least one other individual worse off.

Considering the transaction itself, Williamson tried to make a distinction for the choice of governance. This is depicted in Figure 1.



Figure 1 - The sliding scale from hierarchies to market solutions (Fink, 2013 (edited)).

At the one end of the spectrum is the company itself that can make all products itself or do the necessary services in-house, which Williamson calls hierarchy. At the other end is the market where products and services are bought and sold. Of course all kinds of

hybrid versions can be thought of such as long-term contracts, alliances and joint ventures. According to Williamson (1979) the determinants for the choice of governance are as follows:

- Asset specificity. The more specific the asset needs to be, the higher the transaction costs will become. Think of it as the difference between ordering a standard lease car versus ordering a bolts-making machine that will only fit in the Cessna 425 Conquest I. For the lease car it is fairly easy to find another customer while for the machine this seems almost impossible.
- Uncertainty of the transaction, which can be interpreted very wide. We can never predict the future with regard to economic phases, ecological disasters or human interventions (think of activists or terrorists) in any way. Complexity also falls under uncertainty of the transaction, one can imagine that the transaction costs increase with the difficulty of the transaction. There are differences in time, effort and agreements between buying a stamp for an envelope and building an all-in site with 30 apartments.
- Frequency of the transaction. If this is low, it does not seem such a good idea to implement that activity into the company. If a product or service is needed on a regular basis, the consideration can be made to do that in-house as well.

In short, when there is a high degree of asset specificity, a lot of uncertainty about the transaction (for example because of a high complexity) and a low frequency, according to Williamson (1979) it is better to have a type of governance that is more aimed at the market side of the spectrum in Figure 1. *Mutatis mutandis* is the same applicable for hierarchy. Different hybrid versions are available for the middle ground.

Finally, Williamson (1979) divided the kind of transaction costs into three broad categories that can be illustrated with the example that was already given:

- Information costs. These are all the costs related to the searching of for example a construction company that is able to build 30 apartments on a site.
- Negotiation costs. After contact with the construction company, agreements need to be made into detail about what the apartments will look like, which materials are going to be used and if maybe one can get a quantity discount or a lower price in another way.
- Monitoring costs, which are related to the execution of the contract, supervision on the activities and compliance with the conditions. Even after all the apartments are built, when the whole sum is paid and the work seems to be done, it can be that the structure is not sound after all and some rework has to be done.

After having discussed this short history on institutions and transaction costs with the help of the fathers of modern economics, it is now clear where they come from and why we need them. Their role is still significant in the current society, next to some other developments in the world that will be reviewed below.

1.4 Global developments

If we fast forward to the year 2017, we can see a lot of different (and maybe threatening) developments in different parts of the world, some technological possibilities were already mentioned in the introduction. Other developments that are relevant in this context will be reviewed now; most of them will sound familiar and are mentioned in a lot of articles. Often their origination has an economical motive.

1.4.1 Credit crunch

In 2007 a credit crunch started. For a detailed explanation of the causes and consequences is referred to Foster and Magdoff (2009). In essence the primary cause was the bursting of the housing bubble, but in the period before there were low mortgage interest rates, low short-term interest rates, relaxed standards for mortgage loans and there was an irrational exuberance going on. These were the perfect ingredients for a storm (Holt, 2009). Apparently when Lehman Brothers announced on 15 September 2008 that it intended to file for a chapter 11 bankruptcy, we were very close to a catastrophe of unprecedented proportions (Friedman & Posner, 2011). The banks certainly were not too big to fail.

The transport sector took the first hits of the economic crisis, since that sector is very volatile and follows the economic cycles quite accurately (Abayasiri-Silva & Horridge, 1998). This is also important for CARU containers to take into account, as the transport sector and supply chain is closely related to the demand and supply of containers, irrespective of the containers being sold, leased or rented.

After Lehman Brothers followed Washington Mutual, General Motors, CIT Group, Chrysler, Thornburg Mortgage, Capmark Financial and many, many other companies (Forbes, 2011). Although the worst part of the storm seems to have passed and the damages have become somewhat clear, the question is if the world learnt from what occurred (The Guardian, 2011). Have changes been made in the whole financial sector and - more important - can these changes prevent happening the same all over again?

1.4.2 Economic rates

Related to the credit crunch are the different economic rates such as the federal funds rate, exchange rates and interest rates.

The federal funds rate is the interest rate that banks use to lend money to each other. This is determined by the Federal Open Market Committee, a department of the United States Federal Reserve Bank. An overview of the target rate from the year 2000 to 2015 can be found in Figure 2. It can be seen that as from around 2009, the federal funds rate is set at the very low number of around 0.25%.

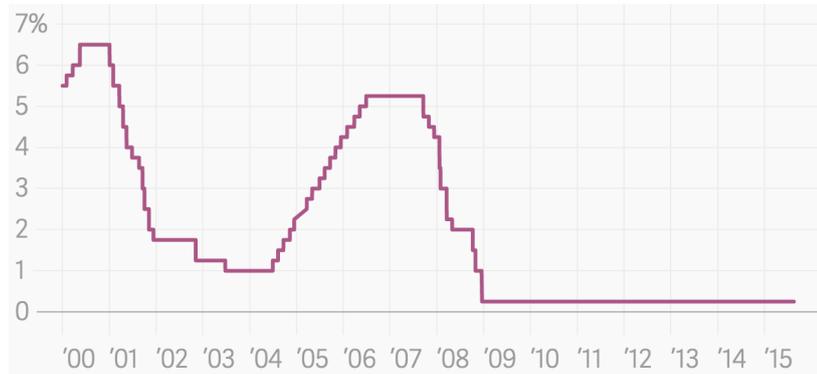


Figure 2 - An overview of the US federal funds target rate (The Atlas, 2016).

Of course with this low target rate, the Federal Reserve Bank wanted to facilitate and stimulate that banks lend money to each other in order to keep the economy going. The Federal Reserve Bank expects to raise the rates eventually to 3% in 2019 (The Balance, 2017).

The interest rates for example on mortgage loans in the USA are related to the federal funds rate. It can be imagined that the interest rate will never be lower or equal to the federal funds rate, as banks also need to make a profit margin. In Figure 3 the mortgage rate in the USA of the past 50 years is depicted.

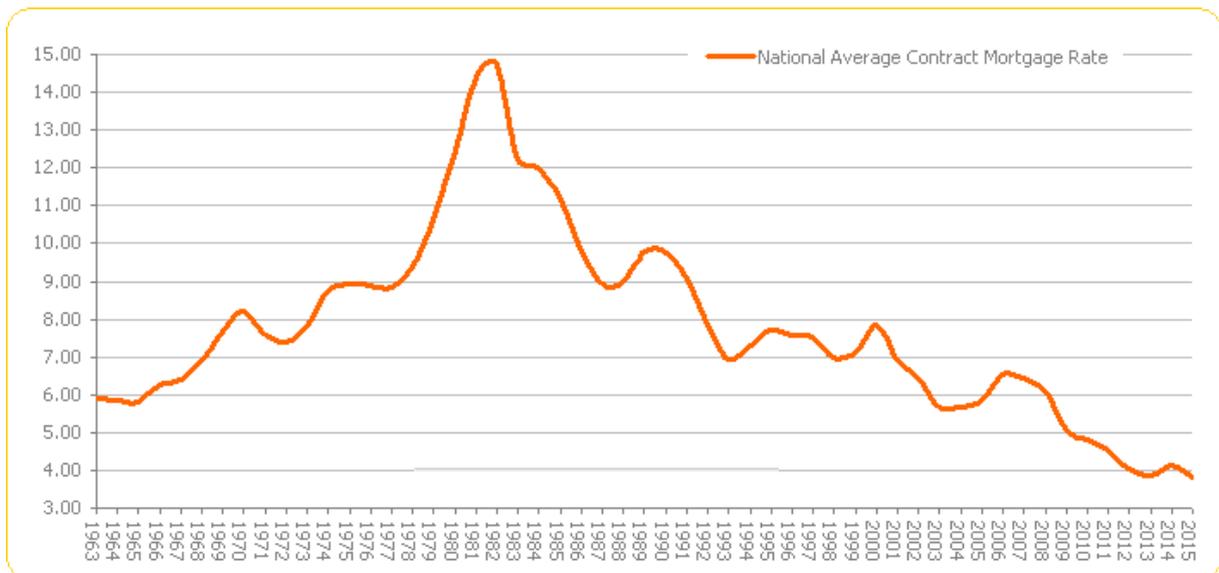


Figure 3 - The national average contract mortgage rate in percentages in the USA over the years (Mortgage-X, 2015 (edited)).

Again we can see a drop in the rate as from 2008. Since 2012 it sticks to around 4%, but this is nothing compared to 1982. Lately, this mortgage rate is getting higher as well again (USA Today, 2017).

The last rate that will shortly be considered is the exchange rate. As the previous rates that were discussed were all in dollars, so will the exchange rate be. Instead of using one other

currency to express the US dollar in, a basket of other currencies is used to correct for possible accidental differences. This is called an effective exchange rate (OECD, 2001). The basis index of 100 in 1990 is used, see Figure 4.

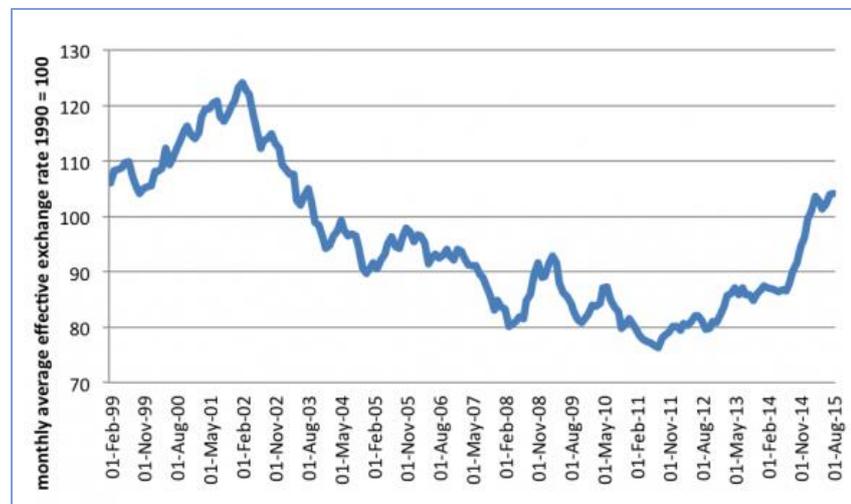


Figure 4 - An overview of the dollar exchange rate index (Economicshelp, 2015).

Now that an overview of the different rates is given, there are some characteristics that can be discovered. First, both the federal funds rate and the mortgage rate decrease as from 2008. This is related to the fact that when these rates are low it becomes appealing to attract money. It does not make any difference whether it is about a bank wanting to

lend money from another bank or a consumer wanting a loan to buy a house. By making it easy to lend money from other parties, governments and other bodies want to encourage doing investments and trading; in this way hopefully the economy can grow again. Lately, these two rates are increasing again, which might indicate that the worst part of the credit crunch is behind us. At the other hand nothing is sure, not even this. With the exchange rate things are slightly different, as this rate is dependent upon the laws of supply and demand; no intervention from any public entities takes place here.

Another trend is the volatility of the federal funds rate and the interest rate on the mortgage loans. The latter is on its turn positively related to the volatility in the bond market. When there is high interest volatility, households tend to disinvest in government securities and invest in real assets for which loans are necessary (Hillebrand & Koray, 2008). The same volatility trend is applicable to the exchange rates, but for another reason. Here, the reason is the divide between the Federal Reserve Bank and the Bank of Japan with

regard to quantitative easing⁴ and the volatility in commodity prices of the last years (The Economist, 2015). This volatility of futures prices⁵ of five different basic commodities can be seen in Figure 5.

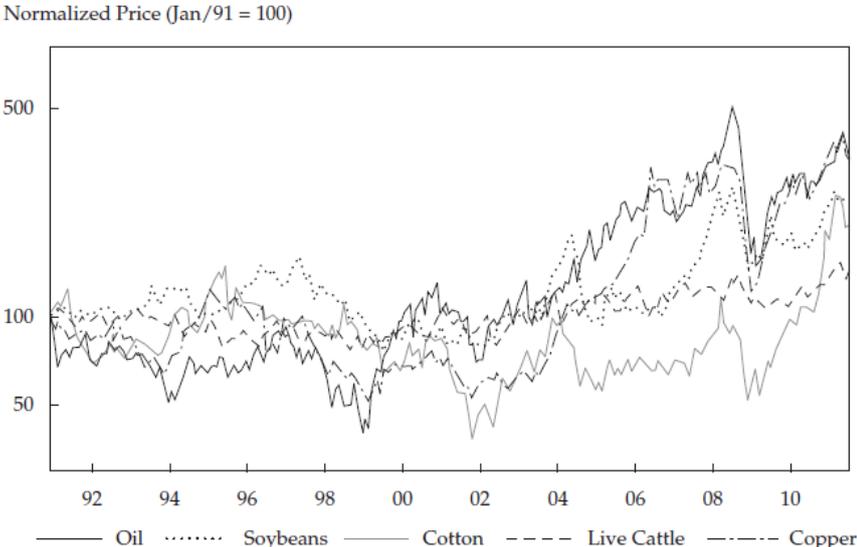


Figure 5 - Five commodity future prices over the years 1991-2011 (Tang & Xiong, 2012).

Already starting in 2002 the ranges become bigger and bigger. This volatility will be discussed again in the subsequent chapters when talking about for example bitcoin. It will turn out to be more relevant than it seems now.

1.4.3 Political factors

At the moment of writing this thesis attempts are made to create a new Dutch parliament. The negotiations are not going really well: some political parties do not want

⁴ Quantitative easing is a policy of any Central Bank to create money by buying assets like government bonds. This is a quite unusual way to try to boost the economy (Bank of England, 2017).
⁵ A futures contract is an agreement between two parties to trade a commodity or other type of product on a specific date in the future at a predetermined price (IG, 2017). One can imagine that 'futures' also give a good indication of the (expected) underlying price of the commodity or product.

to be in a coalition with others. Because every party has different preferences for and different objections against other parties, every potential composition is more or less ruled out in advance.

On a more global scale we see the same, politicians are creating a lot of stir, among which are the leaders of the bigger countries. People are having a range of thoughts about Trump being chosen as the president of the United States. Meanwhile the European Union takes action against Russia because of the illegal annexation of Crimea in the shape of freezing assets and banning visa of people, next to bans on the import of goods from that region and a ban on the provision of tourism services. Russian countermeasures were (partly) a prohibition on the import of materials and food from the countries that have imposed the sanctions in the first place (European Parliament, 2015). In Turkey recently a referendum had been held about in short giving more power to president Erdogan. The question is whether or not the whole voting process went completely according to the usual fair and honest practice (NY Times, 2017). North Korea keeps performing nuclear tests and does not seem to be concerned about the warnings of the rest of the world (CNBC, 2017).

Next to these movements - or maybe accompanied by them - there seems so be a tendency towards extremism. We can see actions that have a lot of similarities with a cold war and the amount of terroristic attacks all over the world increases (CNN, 2016). The political performances might be getting more fierce. Because countries are bonding (think about the European Union), when there is a dispute chances are high that more partners become involved at a rapid pace. Actions provoke reactions which evoke counteractions while there is a lot at stake.

1.4.4 Ecological factors

The biggest environmental changes always happen because of human interventions. This is not different when it comes to global warming. Over the past 100 years, the average temperature has increased by approximately 0.6 °C and is projected to continue to rise at a rapid rate (Root e.a., 2003). The impacts on the flora and fauna will be very big, a few of these can be found in Figure 6.

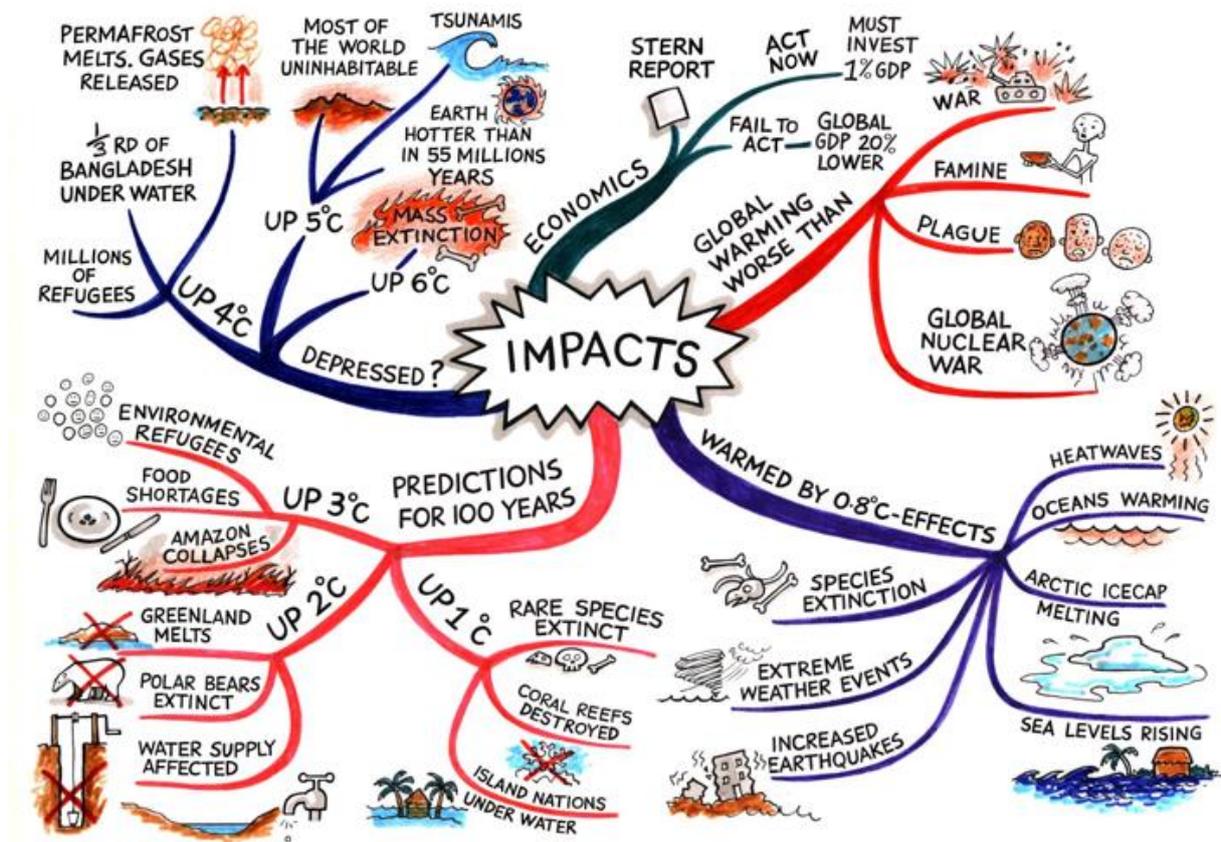


Figure 6 - The impacts of global warming (The British Geographer, 2017).

The emissions of greenhouse gasses must be reduced, companies are strongly recommended to diminish their environmental footprint. However, in the transport sector for example the emissions were still growing (EU Observer, 2017). Action needs to be taken rather sooner than later, before it may be too late.

1.5 Current status

After reading the previous paragraph, one might get the impression that the future does not look too rosy. This is not necessarily true. Yes indeed both the economic, political and ecological circumstances are exciting and tumultuous. In that perspective we can speak of a VUCA-world in which the environment is volatile, uncertain, complex and ambiguous (Bennett & Lemoine, 2014). When looking back not too far we can see a credit crisis with a big volatility of various rates, when looking into the future the whole global warming concept can cause a serious diversity of problems. In the present we can speak of political tensions without exaggerating the situation in any way. The issues are challenging to say the least.

Meanwhile politicians are still necessary to run regions, countries and unions. We cannot ignore nature and just go on with the activities like always. Likewise, although often bankers and regulators are blamed for what happened - whereby the question is if

indeed they are the only one who should feel responsible (The Economist, 2013) - in 2008 and afterwards, it is not possible to exclude these middlemen from the transactions that need to be carried out.

Or is it? Maybe it is. As already stated in the beginning of the introduction, with the current technological developments almost everything seems possible. One of these possibilities will be reviewed in-depth in the following chapters: blockchain. After knowing the relevant history and present status of the economy, now a part of the future can be presented. Also the side note is made that from here on the thesis is going to get a little more complicated, a little more refreshing and a little more optimistic.

Chapter two - blockchain

In this chapter the whole concept of blockchain will be explained. There will be a review of what blockchain is and how it works including some possible bottlenecks to overcome.

2.1 In the middle of the crisis

Seven weeks after Lehman Brothers filed for the bankruptcy, a paper of in total nine pages appeared on The Cryptography Mailing List under the pseudonym Satoshi Nakamoto (2008). In this paper Nakamoto introduces a complete new concept of a digital currency that could and still can change the entire financial sector and everything related to it. The name of this cryptocurrency is bitcoin, although we can only deduct that from the title since he does not mention it anywhere else in the paper.

The author describes the processing of transactions by financial institutions and therefore the trust in these institutions that is required. Byproducts are transaction costs, mediating costs and necessary provisions for 'accounts receivable' on the balance sheet (as far as they are not all the same), that are increasing. An electronic payment system without the need of intermediaries seems to be attainable, but the big problem is that of double spending. That is, up until that moment as Nakamoto (2008) found a solution and claims to present a safe and revolutionary system as long as the majority of the computer power is in the hands of honest owners, reducing fraud and every kind of transaction costs to a minimum. The system beyond bitcoin is called blockchain, even though Nakamoto nowhere in his paper uses this specific word but he is talking about a 'chain of blocks'.

2.2 The problem of double spending

If a letter is written, put in an envelope and sent via the postman, in a couple of days this letter will arrive at the consignee. At that moment the consignee is in the possession of the original letter. When an e-mail is sent, this works slightly different. Not only does the consignee almost instantly receive the letter after it is digitally sent, also he is not in the possession of the original. The consignee has got an identical copy. In most of the cases this is not problematic at all when e-mailing with the exception of some cases in which people were accused of 'stealing' data.⁶

⁶ It can be argued that the data are not stolen at the moment that the original owner still possesses them. As a matter of fact the original is not even gone but only copied. For more information (in Dutch) about how Dutch courts dealt with the characteristics of data is referred to van Nes (2012).

Things become more difficult when somebody wants to send money or stock. If one wants to send \$100 to somebody it is important that it is sent to that one person only and that it is prevented that the same money is sent again at a later time to somebody else. Cryptographers call this the problem of double spending and this is also a reason why we need to rely on intermediaries (Tapscott, 2016). With the blockchain protocol of Nakamoto, this problem of double spending is solved without any need for a middleman.

2.3 The blockchain protocol

In the article of Nakamoto, the blockchain protocol is mainly explained in the light of the new digital currency bitcoin. As will turn out later this protocol can be used not only for transferring digital money but for all kinds of applications.

Because bitcoin takes place in the digital world, the character of the currency is pretty abstract. Unlike a dollar, there is nothing that can be touched with bitcoin. To that respect it can be compared with transferring dollars or euros at home via internet through a bank. The difference is that bitcoin is not transferred via the bank but directly peer-to-peer and therefore that it is not possible to withdraw bitcoins from a bank, they only exist in a digital form. With blockchain being the underlying layer of bitcoin, one can imagine that explaining this protocol is even a little more difficult and abstract. Others compare it with holding a slippery soap in your hand (Management Events, 2016). Below the protocol will be presented as simple as possible, but not any simpler.

2.3.1 Requirements

For blockchain, there are a few basic requirements that have to be met (PWC, 2017). These are:

- Contributors. A contributor can be anybody with a computer and access to the internet. With multiple contributors the network becomes distributed instead of the usual centralized or decentralized network. This is depicted in Figure 7. In a centralized network every kind of communication is transmitted via the central node to the one you actually want to reach. A modern example is the instant messaging application Whatsapp. Every message that is sent actually goes through

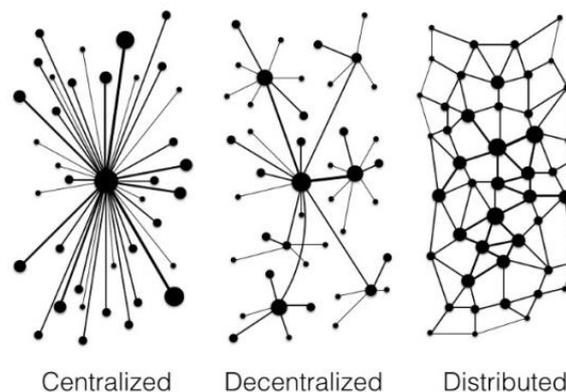


Figure 7 - The centralized, decentralized and distributed network in a graphical representation (Medium, 2015).

the node of the company of Whatsapp and then reaches the recipient. The decentralized network more or less works the same, but now there are a couple of nodes available through which a message can be delivered. The weaknesses of both of these types of network are obvious. If the node crashes for whatever reason either the entire or a part of the system goes down.

The odd one out here is the distributed network, with which blockchain works. Any transaction or any message does not have to go through another node to reach the consignee, it is directly sent from a peer to another peer. Every contributor can be a node on his own. An intermediary is obsolete for this exact reason and a crash of one node has no consequences for the other users.

- Rule-set of the system. New transactions have to be approved in order to be able to execute them. When person A wants to transfer 25 bitcoins to person B, this transaction is put into a block. To implement this block into the existing blockchain, it needs to be mined. The exact details of the mining process will be explained later. Once a block is mined, this is communicated to the other users who can also check whether or not the mining is done in the correct way and if the transaction is valid. Of course this can only be the case if person A indeed had 25 bitcoins in his wallet.

Because new blocks are implemented into the existing blockchain, any discrepancies will immediately become clear, also because it can be revealed who the validators are (Sammantics, 2016). So new blocks are always connected to old blocks and new transactions are always connected to old transactions. Once a block is mined and implemented, this cannot be changed anymore. The only way that a block can be altered is by adding a new transaction, discarding fraud with transactions that were already closed in the past.

- System itself. The contributors are participating in a network that is distributed. Every dot in the system can do a transaction, be a validator or a miner. In principle every node has got the same rights and obligations. As long as the majority of the miners act on an honest basis, basically no fraud can be committed with the mining. Every node acts on itself, so one rotten apple does not spoil the whole barrel. Chances are even high that the rotten apple can be pinpointed and excluded. In this way the network becomes incredibly flexible and any additional host or facilitator is redundant.

Because of these requirements trust in a middleman or in the transaction partner is not a prerequisite anymore, as committing fraud is almost impossible. Trust is the end of the protocol of blockchain instead of the beginning. In this context a transaction can be

interpreted in the broadest way possible. It is not specifically or exclusively related to transferring money.

2.3.2 Hashing

Whenever a letter is written, it can be signed to give some guarantee that this message is indeed coming from a specific person. This can be done with every letter that is sent and the same signature can be used every time. Once somebody can copy the signature, he can pretend that messages are coming from that specific person. To make things more secure different signatures can be used for every day of the week, not only does the forger now needs to imitate in total seven signatures, he also needs to know on which day which signature is used. This story can be extended to using a different signature for every day of the year or for different messages, making it harder and harder to become a copycat.

Before the digital age coming up with a range of different signatures is a wearisome task. With the current level of technology, digital signatures⁷ can be made and they can even be fabricated for different messages. An example of these signatures is a secure hash algorithm. This is abbreviated with SHA after which a number is put to indicate the output size in bits. A SHA-256 is a secured hash algorithm with an output of 256 bits. SHA-512 has an output that is twice as big and is much more than twice as safe. The secured hash can be compared with guessing a pin. The odds of guessing a pin of 4 numbers correct is 1 out of 10,000. When guessing a pin of eight digits, the chance that somebody is right is only 1 out of 100,000,000. At the other hand it also requires a lot more space and computational power, to which will be come back later. For bitcoin

SHA256 Hash



The image shows a web-based interface for generating a SHA256 hash. It consists of two main sections: 'Data:' and 'Hash:'. The 'Data:' section has a text input field containing the word 'container'. The 'Hash:' section has a text output field displaying the resulting 64-character hexadecimal hash: 'a42d519714d616e9411dbceec4b52808bd6b1ee53e6f6497a281d655357d8b71'.

Figure 8 - An example of a message with the accompanying hash (Anders, 2017).

⁷ The situation becomes even more complicated in the case that either paper or digital forms need to be verified with the help of a signature but the content should stay confidential, for example in a voting process. With paper votes this situation can be accomplished when making use of the voting paper, a carbon envelope and multiple regular envelopes (Chaum, 1983).

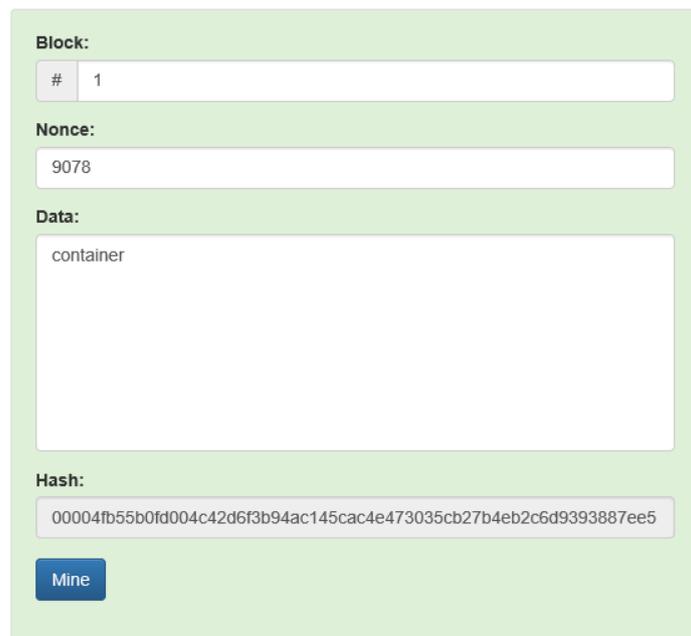
For electronic banking, more or less the same idea is applied (Chaum, 1985). Later, Chaum, Fiat and Naor (1990) also found a solution to the problem of double spending a long time before Nakamoto did, but in case of the work of the three authors still a central server in the form of a bank was required.

SHA-256 is used (Godsiff, 2015) and this type of hashing will be taken as the basis for the rest of the explanation.

For hashing the text 'container', somebody can go to several hashing or encrypting sites. In this case the hash is 'a42d519714d616e9411dbceec4b52808bd6b1ee53e6f6497a281d655357d8b71', see Figure 8. This is not only an online signature; it is actually a digital fingerprint. The code is unique for this message and not only will it appear every time that the text 'container' is typed in into any SHA-256 hashing system, it also works the other way around. If the hash is put into an unhashing or decrypting site, the message 'container' appears. To every message - no matter how big or how small - another unique hash gets attached that always has the same length.

2.3.3 Blocking

Now that hashing is made clear, we can go one step further into putting the message into a block. Except for the text that can be put in and the associated hash, also a number of the block in the chain and a nonce appears. A nonce is another number that makes sure that the first four digits of the hash are zero. Things are illustrated in Figure 9 and again 'container' is the text. Because it is the first block, the number of the block is one and the nonce is constructed in a way that the first four digits of the hash are zero. The hash is different than in Figure 8 for the reason that also a block number and nonce is added.



The screenshot shows a web interface for creating a block. It has a light green background. The form is divided into sections: 'Block:' with a '# 1' input field; 'Nonce:' with a '9078' input field; 'Data:' with a text area containing 'container'; and 'Hash:' with a read-only field showing '00004fb55b0fd004c42d6f3b94ac145cac4e473035cb27b4eb2c6d9393887ee5'. A blue 'Mine' button is located at the bottom left of the form.

Figure 9 - The text 'container' put in a block (Anders, 2017).

If now all of a sudden the text is changed to plural, so from 'container' to 'containers', what happens can be seen in Figure 10. The number and the nonce did not change, however the data has indeed changed and so did the hash. On top of that the block turned red, this is actually an analogy of the figurative red flag. Apparently something is not right. The hash for these data is correct but with the old nonce the first four digits are not all zero. Some of the readers might already have noticed the button

that says 'mine'. If this button is clicked the computer searches for a nonce that will make the hash starting with four zeros again through trial and error. If it has found one, it will both change the nonce and the hash and the block will turn green again. Of course, both the block number and the data itself will not be edited due to the mining. If all of the content is restored to the original information, the block will also turn green again. Mining for a second time is in that case not necessary.

The screenshot shows a mining interface with the following fields:

- Block:** # 1
- Nonce:** 9078
- Data:** containers
- Hash:** 74dbabe575351d6db508b552125882fff5282fc74a3ec432b367c3251c2e155a
- Mine** button

Figure 10 - The text 'container' of the previous figure changed to plural (Anders, 2017).

2.3.4 Chaining

Quite intuitively, a blockchain is a chain of the blocks that are mentioned in the previous paragraph. An example of such a chain can be found in Figure 11. Again the same kind of blocks as in Figure 9 appear, but now they are linked to each other and another box is added, which is called 'Prev:'. This stands for previous and with this is meant the hash of the previous block.

The figure shows three mining blocks in a chain, each with a 'Prev' field containing the hash of the previous block:

- Block 1:**
 - Block: # 1
 - Nonce: 71970
 - Data: Hey, I saw your message about containers. You want to buy one?
 - Prev: 00000000000000000000000000000000
 - Hash: 0000f47c8937b1b7af2b2b6d415e45eb539e
- Block 2:**
 - Block: # 2
 - Nonce: 77534
 - Data: Yes, three please.
 - Prev: 0000f47c8937b1b7af2b2b6d415e45eb539e
 - Hash: 0000e0fc805af22245d16e26c415fe512937f
- Block 3:**
 - Block: # 3
 - Nonce: 31452
 - Data: I will arrange it.
 - Prev: 0000e0fc805af22245d16e26c415fe512937f
 - Hash: 0000840a16dca0b81c0d3b2cd3cf1066629f

Figure 11 - A conversation between two parties in a blockchain (Anders, 2017).

In the first block the hash of the previous is '000000...' because of the fact that the first block naturally does not have a previous block or hash. The previous hash of the second block starts with '0000f47...' and it can be seen that indeed this is the hash of the first block. The same goes for the third block.

If all of a sudden the content of the second block is changed, the following in Figure 12 happens. The current hash of the second block has changed and so did the color. This is similar to Figure 9 and Figure 10, the nonce stays the same but the result is that the hash does not start with four zeros anymore. Although nothing in the content of the third block has been changed, the third block is red as well. This is because the third block is linked to the second block via the hashes and these do not add up anymore. The chain is actually broken in block two. Every additional block in the blockchain will therefore turn red.

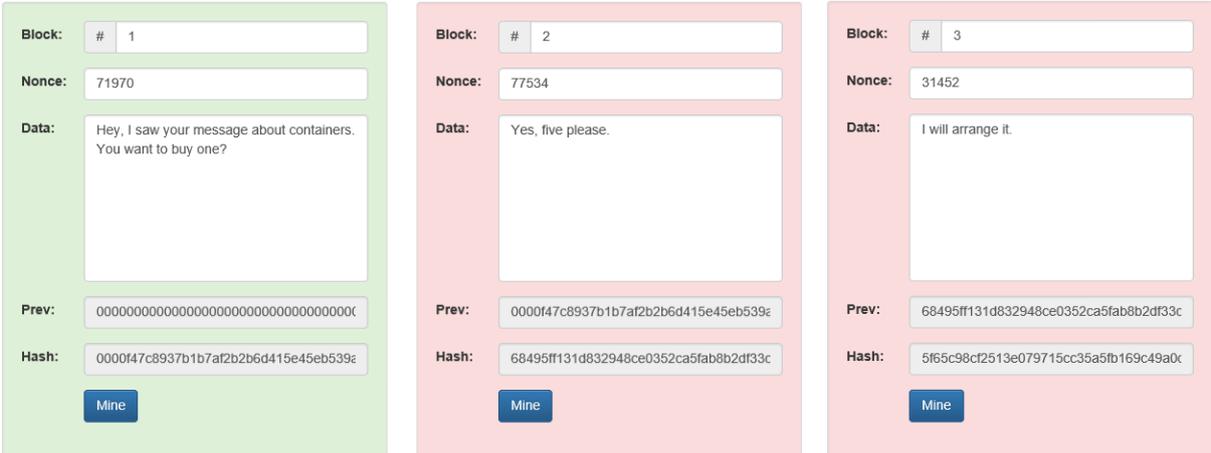


Figure 12 - Consequences of a change of the content in a blockchain (Anders, 2017).

This problem can be solved by mining all the red blocks again, starting with the first one. In this chain that does not cost too much time or effort but it can be imagined that when block number two is broken in a chain of 200 blocks, mining everything all alone is impracticable.

The content in this chain can indeed be changed and the blocks can be mined again, only two blocks need to be remined. But the fact that only two blocks need to be remined, also proves that this blockchain is accessible for one individual. Things again require more effort and become more complicated when the chain is for example accessible for five people. Imagine first the blockchain of Figure 11 times five, so five chains of three blocks, which indicates that there are indeed five participants in this blockchain. If a forger now wants to change the content as in Figure 12, he has to do that in five chains and then he has to remine ten blocks. The moment that either the blocks or the number of participants are of a significant amount, it becomes practically impossible to commit

fraud, as long as the majority of the computer mining power acts in good faith (Pass & Shi, 2016).

2.3.5 Mining

In real the mining is a little more difficult than explained in the previous paragraph. The idea is the same, but it is mainly related to the fact that blockchains are introduced on a much bigger scale than presented before. Therefore the mining is not just a matter of pushing a button and finding a solution after several seconds. The nonce in combination with the hash is a cryptographic, mathematical puzzle. In case of bitcoin this puzzle is difficult and the solution is hard to find. However, once found the correctness can be checked easily. It can be compared with cracking a safe. It is hard to find the correct numbers, but when somebody pretends to have them, putting them in and checking is easy (Bitcoin Magazine, 2013). Adding a transaction to an existing blockchain in reality will work as follows (Nakamoto, 2008):

1. New transactions are broadcast to all nodes in the distributed network as depicted in Figure 7.
2. Each node collects new transactions into a block.
3. Each node works on finding a difficult so called proof-of-work (mining with the help of the hash and nonce) for the block.
4. When a node finds the proof-of-work, it broadcasts the block together with the solution to all nodes.
5. Nodes accept the block only if all transactions in it are valid and if the coins were not already spent.
6. Nodes express their acceptance of the block by creating the next block in the chain and using the hash of the accepted block as the previous hash just like in Figure 11.

When the block indeed is approved, the miner who found the solution will receive 25 bitcoins as a reward, but only after 99 blocks have been added to stimulate the entire mining process (The Economist, 2015). The mining takes place with the help of a lot of computational power. It is possible to be a solo miner, but often miners unite their forces in a mining pool with which they are connected either through installed software or through the cloud (Bitcoin Worldwide, 2017).

2.3.6 Smart contracts

Almost all concrete applications of blockchain in various fields will be discussed in the next chapter. However, the idea of smart contracts will already be explained in this paragraph. With the current system it is possible to make smart contracts that operate

on the basis of blockchain. These contracts are smart for the reason that the rules of the contract can be translated into computer code, replicated and executed across the nodes of the blockchain. In this way, the contract can become self-enforcing, monitoring external inputs from trusted sources in order to settle according to the stipulations of the contract (Peters & Panayi, 2016).

Once the conditions of the contract are put in, it will execute itself as soon as all these conditions get fulfilled. For example, ten barrels of light sweet crude oil will be transferred from A to B at the moment that the dollar to euro exchange rate gets above \$1.20 and when the oil price gets below \$40 per barrel. When these conditions are met, the transfer will automatically take place. No intervention of any party is necessary anymore. The consequences can be revolutionary.

2.4 Blockchain bottlenecks

As both the idea of blockchain and bitcoin became bigger and more accepted, some bottlenecks were found on the way. For most of the rising problems a (temporary) solution is found. The most prominent and important matters are discussed below.

2.4.1 Multiple blockchains

On itself multiple blockchains are no problem at all and they can exist next to each other. Some small problems do arise when transactions need to be done between different blockchains, for example regarding the transfer of assets. For this the pegged sidechain is invented. Pegged sidechains allow the user to transfer assets between multiple blockchains. Sidechains can easily interoperate but they remain separate systems. As a result, malicious designs will be confined to that specific sidechain (Back e.a., 2014). The sidechain developed by Back e.a. has a two-way peg which means that assets can be transferred between chains and can be returned if necessary.

2.4.2 Privacy

In a blockchain as presented in Figure 11, every piece of information is fully public. This would also be the case for personal and sensitive data that preferably should be kept private. In the contribution of Zyskind and Nathan (2015) the blockchain is combined with an off-blockchain storage solution. The users of it still do not have to have trust in any third party for protecting their data and at the same time companies do not have to be continuously worrying about securing and compartmentalizing them. Whenever a company wants to use the data, the original owner is being notified.

The Hawk-system of Kosba e.a. (2016) has the same kind of application, but then specifically focused on financial transactions to retain from the eye of the public how

much money is transferred to which person. Just like with the storage solution of Zyskind and Nathan, the system keeps being involved in interactions with the blockchain.

Heilman, Baldimtsi and Goldberg (2016) discovered that within the financial transactions although often claimed otherwise bitcoin is not a fully anonymous currency. By using a third party - that does not have to be trusted - who issues vouchers, this state of fully anonymous transactions can be achieved. The solution to ensure privacy can be desirable for people with both good and less good intentions.

2.4.3 Speed, size and security

If blockchain is really going to be introduced on a massive scale, the earlier mentioned mining process seizes a lot of time, maybe even too much. The creation of a new block with bitcoin currently takes around ten minutes. The amount of transactions within one block is limited to 500. Therefore the throughput in the bitcoin network is maximized to 7 transactions per second (tps) at the moment (Kiayias & Panagiotakos, 2015). If we compare this to for example VISA, which has 2000 tps, the throughput is way too small and currently there are discussions about how to increase it. This is possible with SegWit, an extension that doubles the size of the blocks. For some of the investors and developers this is not enough; they introduced the alternative 'bitcoin cash' that can handle blocks that are 8 times the size of a current bitcoin block (The Next Web, 2017). Earlier, Kraft (2016) already presented a model to predict the time it will take to create a new block in the long-term future, given that the mining power either grows with a constant rate or exponentially. Taking Moore's Law⁸ into account the latter seems the most plausible, but finding an estimator for the block times does not solve the underlying problem for bitcoin. The question also is whether or not bitcoin cash is the solution and if its bigger blocks are big and safe enough for worldwide scaling; as it is only introduced a few weeks ago there still is a lot unclear about this new cryptocurrency.

So, in any case latency can become a big issue here and the same goes for the size and bandwidth. In February 2016 the size of a blockchain in the bitcoin network was over 50,000 MB. If the throughput increases, blockchain could grow with 214 Petabyte each year (which is more than 220 billion MB). This is related to the fact that everybody has got a full copy of the same data; the consequence is a lot of redundancy (Ammous, 2016). Meanwhile, mining bitcoin transactions costs a lot of energy because of all the computing power that is necessary to solve the cryptographic puzzles. This is estimated at 15 million dollar a day (Yli-Huumo, 2016). For these problems of speed, size and security, a few systems are in development as well and reviewed below.

⁸ This law was a prediction in 1965 of Gordon Moore, one of the founders of Intel, that the amount of transistors in a circuit doubles about every two years.

2.4.3.1 The mini-blockchain

A mini-blockchain has the same characteristics as the 'normal' blockchain, the only difference is that the amount of blocks within the blockchain is going to stay stable. The moment a new block is implemented at the end of the blockchain, one block at the beginning of the blockchain gets eliminated. This process is called trimming. While solving some sizing problems, new problems will arise in the area of the security and coin ownership that could be solved with a coin ownership database, which is called an account tree (Bruce, 2013). The author also suggests a situation in which it becomes possible to remine lost coins after for example 100 years to prevent that only a small number of coins will circulate in the network.

2.4.3.2 The blocktree

Instead of the blockchain protocol that uses the basis of a chain, now the basis of a tree is used, which is illustrated in Figure 13. Kiayias and Panagiotakos (2016) call this protocol the GHOST-protocol.

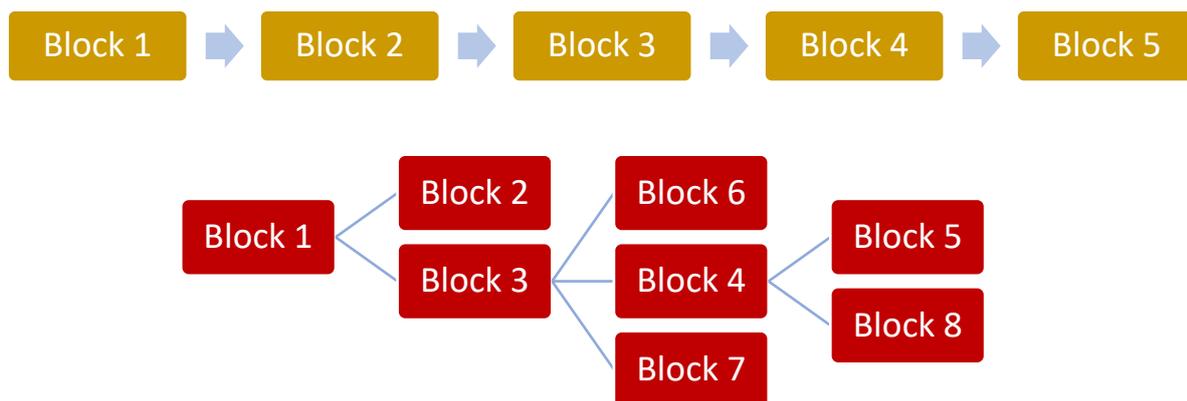


Figure 13 - Blockchain application with the protocol of a chain (above) and with the protocol of a tree (below).

This protocol is also proposed in other blockchain-based systems. Different kinds of attacks are done at both the traditional and the GHOST-protocol and the latter one seems to be the weaker one. Just as with the mini-blockchain, some speed issues can be solved but additional security issues arise.

2.4.3.3 The bigchain

McConaghy e.a. (2016) introduced BigchainDB. Also this application is a solution to the size and latency problem and in essence it works the same as the contribution of Zyskind and Nathan (2015) and the Hawk-system of Kosba e.a. (2016). Apparently BigchainDB fills a gap in the decentralization ecosystem. It can perform one million writes per second

throughput, starting with a decentralized database - hence, DB - in combination with blockchain aspects.

Downsides are the same as well, it still works with decentralized platforms and consequently not everything can be visible on the blockchain. The authors also emphasize this, but they laid the accent on scalability. The most important paperwork such as contracts and certificates will be put on a blockchain, trying to find a balance between in this case speed and security instead of privacy and security.

2.4.3.4 The DAG-structure

Another reason that it takes a substantial amount of time to create a new block is that when blocks can be created with the blink of an eye a lot of conflicting blocks will arise and consequently this will influence the performance negatively as well. Because the throughput is limited and the security requirements are high, the system stays within safe parameters and a complete crash with hundreds of conflicting blocks is impossible.

DAG is invented by Lewenberg, Sompolinsky and Zohar (2015) and stands for 'directed acyclic graph'. In essence the system allows more than 500 transactions in one block and relaxes the required safety standards. The disadvantage here is a higher vulnerability for malicious attacks.

2.4.3.5 Finding a balance

With the presentation of new solutions to current problems of speed, size and security around blockchain it becomes clear that trade-offs have to be made. Decreasing the size of the blockchain is possible but the cost will be a piece of security. The same goes for the increase of the amount of transactions within a block or reducing block times. By not putting everything on the blockchain, (parts of) transactions can remain private but this was exactly the reason why blockchain was introduced in the first place: transparency.

We have to keep an eye on the underlying issues that we are trying to solve with new contributions. The new problems definitely do not need to be worse than the current ones and therefore we might consider not introducing some of these novel inventions that are trying to support the existing - and so far flawless - blockchain. We have to prevent robbing Peter to pay Paul.

2.4.4 Cryptographic puzzle alternatives

The mining of the new blocks goes together with solving a difficult cryptographic puzzle that cost a lot of time, computer power and energy. The way of mining described with the nonce and hash is how new blocks in for example bitcoin need to be created, which is called proof-of-work. This 'proof' shows that the miner is acting in good faith and deters frivolous and malicious use (Investopedia, 2017).

The only downside of this method is that the majority of the miners need to act in honest faith. The moment that this is not the case, the system becomes vulnerable for a so called 51%-attack. If 51% of the miners or more are able to get on the same malicious page, they are able to change the majority of information on the blockchain, which then automatically becomes the 'truth'. With the proof-of-work protocol and the increasing size of the blockchains, mining demands more and more computer power. For this reason people increasingly participate in mining pools.⁹ Once that one mining pool possesses more than half of the computing power, things can get somewhat tricky. Currently, with bitcoin, the top-three mining pools in fact own more than 50% of the computer power (Gervais, 2014). With that they do have the power to do a lot of harm. On top of it, because of the increasing required computer performance and steady mining fees it is possible that in the future mining is not lucrative at all anymore. This depends on a lot of parameters such as the development of the IT-sector, Moore's Law and the growth and maturation of blockchain in general.

Especially the method of proof-of-work requires a lot of effort in every meaning of the word, but at the other hand it matches the most safety conditions compared to other proofs (Beigel, 2014). Some alternative proofs will be mentioned below.

2.4.4.1 Proof-of-stake

In the proof-of-stake the miner does not have to solve a cryptographic puzzle. Proving ownership of a certain amount of cryptocurrency such as bitcoin is sufficient. For example, if some person owns 2 out of the 100 bitcoins that are available, in total this person is allowed to mine 2% of all the possible transactions. The advantage is that everybody is invited to mine a certain amount of the transactions compared to proof-of-work because not a lot of computational power is necessary. Moreover, no energy is wasted because ownership is easily shown. Other than that are proof-of-stake protocols less vulnerable to 51% attacks than proof-of-work protocols (Bitcoin Magazine, 2013). Houy (2014) shows that the vulnerability to a 51%-attack of the proof-of-stake is equal to the proof-of-work protocol as long as the motivation of the attacker is large enough. Recently, Kiayias e.a. (2016) introduced a proof-of-stake protocol that can provide almost the same security guarantees as the proof-of-work. The authors also present possible different types of attacks and how they are undermined. So this negative side of the proof-of-stake might have been tackled already.

Another disadvantage is that the person is required to have an amount of cryptocurrency in order to be able to engage in the mining activities. So ownership of

⁹ To prevent disputes about the division of the fruits of mining in those pools, Pass and Shi (2016) present fruitchain. Fruitchain is a protocol that always divides the rewards and transaction fees in the most honest way.

bitcoin is required to mine bitcoin transactions but next to this cryptocurrency also other cryptocurrencies are starting to be introduced such as Dash (www.dash.org), Safecoin (www.maidsafe.net) and Litecoin (www.litecoin.org). If one needs to possess all of these cryptocurrencies in order to mine transactions of them, the job of mining might become somewhat costly before having even properly started.

2.4.4.2 Proof-of-activity

This version is a hybrid of both the proof-of-work and the proof-of-stake protocol. It starts with the first protocol where miners are trying to solve the cryptographic puzzle. Afterwards, the blocks that need to be mined are randomly assigned to the miners that were able to solve the puzzle, but the more coins the miner owns, the greater the chances of assignment to that specific miner (Bentov e.a., 2014).

At this point it is not completely clear what the advantages are of this proof-of-activity. The authors mention that it offers good security against possible future attacks on for example bitcoin. Intuitively this makes sense since two 'proofs' are combined, although except for the 51%-attack there does not seem to be a lot of security issues with the proof-of-work protocol alone. Furthermore it is understandable that the proof-of-activity will not solve the problem of energy waste at all.

2.4.4.3 Other proofs

Other type of 'proofs' are proof-of-burn, the proof-of-capacity and the proof-of-elapsed-time. The proof-of-burn requires the burning of coins. The only way to accomplish this is by sending an amount to an address from which they are irretrievable (Coindesk, 2017).

The proof-of-capacity more or less works the same as the proof-of-burn. The difference is that now not an amount of cryptocurrency needs to be burned, but an amount of space on the hard disk (Coindesk, 2017).

Intel (2017) developed the proof-of-elapsed-time. This protocol roughly works the same as the proof-of-work, but it consumes far less electricity. The only problem is that this type of proof is only made available by Intel. Again it would be then a third party in which we have to have trust.

2.4.4.4 Verification and validation of information

In the end the different proofs are only necessary for a miner to show that he is acting in good faith. Rather than just stating that his intentions are sincere he has to give some kind of evidence that indeed he is, ranging from solving puzzles to giving up cryptocurrency or hard disk space.

Of all the proofs presented here, the proof-of-work still seems to be the best for the job of verification and validation of information but the proof-of-stake is catching up.

The proof-of-stake is the best alternative and will probably also be introduced on a big scale in the not so far future. Besides, the proof-of-elapsed-time that belongs to Intel looks promising but the question is how this will develop over time and whether or not the public really wants to trust a third party again while this is not completely necessary. Of the other mentioned types of proof is not that much information available and thus so far they do not look like they are going to improve blockchain considerably.

2.4.5 Legal implications

As Steve Jobs said: technology either needs to be beautiful or invisible (Entrepreneur, 2016). Hopefully at this point blockchain is a little more demystified. It can still be hard to understand how it really works in terms of computer code. Since the author of this piece also does not have any experience in this field, it is tried to keep away from the specific coding and encrypting as much as possible. This does certainly not imply that both businesses and consumers should stay far away from blockchain in general. How many people really know how internet works? In order to use it effectively it is not necessary to know exactly how it works and the same goes for blockchain. It is not only a technical, but also a business and management topic.

Nonetheless, similar to the internet we might have to come up with novel legal mechanisms because of this new set of technology. No parties need to interfere in the transactions of other people anymore, but this also means that supervision and control of authorities can be a lot harder. To that respect Wright and De Filippi (2015) speak of the evolution from the *Lex Mercatoria*, that during medieval times emerged organically from the interactions of merchants analogous to the story in chapter one, to the *Lex Informatica*, which are contractual agreements between internet service providers and online operators due to the lack of appropriate (inter)national regulation, to the *Lex Cryptographia*, where again parties have to agree about the set of rules themselves because a higher suitable authority is missing. This authority might have serious issues with regulating blockchain in any way because of for example the application of smart contracts.

Kiviat (2015) recognizes these problems, next to his posed questions about jurisdiction, which activities to regulate and to what extent. At the moment of writing his contribution, the author stated that bitcoin was not only easy to use for the average consumer, but also for the less ordinary part of society considering black-market transactions, tax evasion, money laundering and terrorist financing.

Without a doubt, implementing one-size-fits-all rules for every application with blockchain as a basis is impossible. It has to go through trial and error. Law will always be one step behind compared to technology, but this seems to make sense as first the

technology needs to be introduced to the public. One needs to know what it is, how it works and where the growing pains are before any guidelines can be made.

Equal to the internet, we should not stay far away of blockchain for this reason. When it is used in practice slowly but steadily the gaps will appear and the rules will crystallize during time.

2.4.6 The Paxos anomaly

Paxos is a decentralized protocol that guarantees agreement and validity in a system with a couple of unreliable nodes (Lamport, 1998). It makes sure that every node is working with the same information despite little crashes in the meantime, as long as the majority of nodes are working correctly. In blockchain, the same kind of protocol as that of Paxos is used, but unfortunately also the Paxos anomaly is applicable.

In essence, the Paxos anomaly comes down to the fact that transactions cannot be made dependent of other transactions because of the nature of the system regarding verification and validation. For blockchain and the earlier mentioned smart contracts this means that the condition 'B transfers money to C after he has received another amount of money from A' is invalid (Natoli & Gramoli, 2016). Contrary to other, external conditions like exchange rates or oil prices, transactions cannot be made dependent of other transactions in this protocol. This undermines a part of the usability.

2.4.7 Longlisting problems

When looking at the enumeration of the main problems - the real practical issues will follow in the next chapter - the list looks impressive and infinite. Other questions are how bugs in the system are going to be repaired and if somebody can reverse transactions in case something goes wrong without a middleman or anybody responsible. The answer to the first question is that in bitcoin for example a few administrators exist that can do bitcoin operations like protocol updates and resolution of incidents. These administrators do not need any computer power at all (Gervais, 2014). The answer to the last question is basically no, but transactions can be done in the same but exact opposite way. With blockchain, mutual transactions can be executed when and only when both parties are able to do so. The benefit is that money does not need to be transferred before or after ownership of an asset, it can happen at the same time if that is what parties wish. In case that transactions happen subsequently instead of synchronously and the other party refuses to honor his part of the deal, intuitively they can go to court to legally reverse the contract but in terms of blockchain transfer the asset back to the original owner. This will not yield problems of any significance.

In the end it probably all looks worse than it really is. The most important matter is that of privacy and security and the balance between them. But this is no different

than when introducing databases for insurance companies and in the healthcare sector, for Facebook and with the introduction of public surveillance cameras.

Taking fingerprints, making pictures and storing information about individuals will always be a precarious matter. This is rooted in the nature of saving data and it does not only hold for blockchain. We may need some time to get used to new ideas, doubtlessly mistakes will be made during further development but in the end it might help with the daily activities in life and businesses. Giving it a try cannot do a lot of harm.

2.5 Different views on blockchain

After a meticulous explanation on how blockchain exactly works now some alternative views will be given. As will turn out, considering history this development also completely makes sense.

On closer examination, blockchain is nothing more than a big database (Gasteiger, 2016). To that extent it can be compared with Google Sheets on the internet; all relevant parties have access to these sheets, the information that is available is real-time and updates can be made by anybody that will be more or less immediately visible to everybody. New rows can be added but only under the already existing rows, to which they have to be connected in some way. The rules of the games can be changed, but only from the new row further down (What is Blockchain, 2017). Additionally, every participant has a copy of the sheet, so the moment that there are two individuals with a copy saying one thing and 98 copies indicating another thing it becomes clear quite fast who is right and who is not.

Another way to look at blockchain is that of one big ledger. Where usually in the past there were multiple separate ledgers that were managed by a few administrators, now blockchain offers the opportunity of one big ledger for everybody (What is Blockchain, 2017). This so-called mutual distributed ledger can become a single source of truth in a very cheap and robust way (Mainelli & Smith, 2015).

Being fraudulent with this big ledger is harder as well. This activity is compared with stealing a cookie; it is easier to steal a cookie out of a jar in a room where often nobody is than when this jar is standing on the middle of a market place with a big amount of people passing by every minute (Crosby e.a., 2016).

Considering the history that was given in the first chapter from North (1994) that we were going from informal rules in the time that everybody knew each other, to the need of formal institutions because distances between trading partners were increasing and trust could not be taken for granted anymore, now the third paradigm may have arrived.

Actually already for a while, with the internet we try to put these formal institutions online. Platforms like Amazon and eBay were built to facilitate human

economic activity (Warburg, 2016). Blockchain can then be the next step within this paradigm of online institutions. While still online we can now suffice with technology alone, without the platforms.

2.6 Blockchain in a political setting

In the same line as the online institutions as mentioned in the previous paragraph, blockchain can also be considered in a governmental dimension. Atzori (2015) researched the blockchain applications from a political perspective and states that blockchain can be seen as a hyper-political tool with which central authorities can be dismissed as the state was often seen as single point of failure on the long term. This on its turn can lead to a stateless global society as the ultimate stage of globalization.

However, the author recognizes problems and does not think that any authority can be completely absent. The role of the State is a necessary central point of coordination in society that cannot be replaced by algorithms only, but those algorithms can definitely help with the execution of that role. To that respect blockchain and its platforms can better be seen as a pre-political tool instead of a hyper-political tool. By utilizing this information infrastructure governments can become much smarter and a lot less expensive (Øines, 2016).

2.7 An (un)limited applicability

Up until today the real identity of the inventor of blockchain and bitcoin, the person behind Satoshi Nakamoto, is still unknown. Last year, Australian computer scientist and business man Craig Wright claimed to be him backed up by cryptographic proof and other information (The Economist, 2016), but later it turned out to be a scam (Cryptocoins News, 2016). Earlier Dorian Satoshi Nakamoto was wrongfully identified as the inventor (BBC, 2016). The question also is whether or not the real Satoshi Nakamoto will ever be revealed; the pseudonym was created for a reason. Not every individual and company will appreciate a revolutionary system that makes a portion of activities superfluous.

The system can come in very handy, but the applicability should also not be overestimated. During my research I came across a video on YouTube, which was a compilation of various videos about bitcoin. In that video people are calling Wall Street a fraud, hosts are yelling that banks are financial terrorists that are here to kill us and kill themselves and a person is crying because he thinks that bitcoin can save children in the Middle-East (Winmouth, 2016). Personally I think this is going a couple of steps too far. It is not that blockchain is beatific and going to ensure world peace.

Swan (2015) suggests an idea of blockchain thinking, in which the brain is acting as a decentralized autonomous organization. Blockchain thinking is proposed as a computational system of input-processing-output, which can be beneficial for both human enhancement and artificial intelligence. Naturally this paper is very forward looking and speculative. It is aimed at the discovery of explorative concepts with no immediate feasibility. Swan is speaking about mind cloning and multispecies intelligence and although blockchain can help in this development, it will not be the breakthrough that is decisive for the feasibility of those concepts.

Others are sceptic about the general usability of blockchain. Taking into account the already mentioned barriers of scaling and regulation, blockchain is good at removing third parties but unlikely to offer economic advantages for any commercial problem other than the one for which it was specifically engineered to solve. With bitcoin in existence for eight years, no other application than digital cash have been found (Ammous, 2016). The last statement of the author - even in 2016 - seems to be untrue; this will become clear in the next chapter. Besides the introduction of the cryptocurrency, a lot of other functions are being explored. Where the YouTube video was at the too positive side of the spectrum, in my opinion Ammous is at the too negative side regarding blockchain. I think the truth will be somewhere in the middle.

The upside is that some of the negative characteristics of blockchain can be removed by choosing for another architectural structure. The architecture can be created in such a way that a new entry must be approved by one specific person (node) in the system or by all nodes. The architectural choices are given in Figure 14, together with the benefits and risks.

Option	How it works	Potential benefits	Potential risks
Master	Specific node must approve all entries	<ul style="list-style-type: none"> ▶ Central ability to control ledger ▶ Straightforward to update approval rules ▶ Increased speed of entry to ledger as no need to wait for other nodes to be live ▶ Simple to implement 	<ul style="list-style-type: none"> ▶ Single point of failure – ledgers cannot function without it ▶ Remain reliant on single trusted third party
Supervisor	A number of specific nodes must approve all entries	<ul style="list-style-type: none"> ▶ Relatively straightforward to update approval rules ▶ Moderate speed of entry as only waiting for specific nodes 	<ul style="list-style-type: none"> ▶ Remain reliant on specific nodes being live ▶ More complex implementation – need to agree supervisors and fallbacks
Majority	51% or more of nodes must approve all entries	<ul style="list-style-type: none"> ▶ Not dependent on specific nodes to be available 	<ul style="list-style-type: none"> ▶ More complex to implement – e.g., to calculate how many nodes are live at any time
Collective	All nodes must approve all entries	<ul style="list-style-type: none"> ▶ Increased certainty over entries – no partial approval allowed 	<ul style="list-style-type: none"> ▶ Requires all nodes to be live at all times ▶ Likely to impact performance while waiting for 100% approval
Free for all	Any member of network can add to chain	<ul style="list-style-type: none"> ▶ Simple to maintain and implement ▶ Relatively high performance ▶ Does not require specific nodes to be live 	<ul style="list-style-type: none"> ▶ Lack of control over data entry

Figure 14 - Different architectural choices with a blockchain basis (Mainelli & Smith, 2015 (edited)).

The architectural options all have their own strengths and weaknesses. The master option exhibits a lot of similarities with a bank that needs to approve the transactions while the option of free for all looks very accessible and easy, but here there is a risk of disorder.

2.8 Standardization of the system

As blockchain is a relatively new invention, an innovation race to the bottom is going on regarding all kinds of aspects within this system. The race is characterized by (Liebenau & Elaluf-Calderwood, 2016):

- High levels of investment. During the first years of blockchain, the spending on research and development was low and cautious. Since 2014 investments are getting higher and are not only done by start-ups, but also by large established companies and governments. Businesses are starting to break the mold.
- A standards race. Also in this thesis a lot of improvements and modifications are presented. At the other hand the basic standards are not set either. The most lucrative applications still need to be picked out.

- An effort to control the directions of the diffusion, in which the problem of a lack of standards so far is rooted. There is a diversity of developments to be found in which every party hopes to introduce the decisive platform for businesses. Potential market leaders are on the way. Another effect now is fragmentation which threatens a uniform development of blockchain.

The fact that there is a lot of turbulence around blockchain can be a sign. A lot of parties are getting involved in different developments for several reasons and this amount only keeps increasing.

Once in a while, individual enthusiasts of blockchain are coming together in so-called hackathons. There are different kinds of hackathons; with or without specific goals and often sponsored by software companies. Other than that there are embassies, centers, conferences, workshops and hackerspaces in relation to blockchain. Embassies provide coordinating information flows for people that are positive about blockchain. Hackerspaces are physical places where the necessary tools are offered to explore technology and to work on projects. The hackathons and hackerspaces are not exclusively focused on blockchain, but also here the interest in this system is growing (Allen, 2016). One example of a Hackerspace is Pixelbar (www.pixelbar.nl), which is situated in the west of Rotterdam.

2.9 Bank versus blockchain

After having discussed blockchain extensively, it can definitely be concluded that this new system can cause a revolution in various industries and in several ways although it has to be admitted that it is still in its infancy (Warburg, 2016). So far, banks have executed their tasks quite well but there are a few problems (Tapscott, 2016):

- Banks are centralized and can be hacked. Especially with the apparent rise of hackers this should be taken into serious consideration. Recently hackers are focused on shutting down the supply of electricity and so far this seems an achievable goal (Bloomberg, 2016), next to the various ransomware attacks that only seem the beginning of a lot more (The Guardian, 2017).
- Banks exclude billions of people as not everybody has access to a bank that easily. Furthermore, if there is any access, banks take up a relatively big part of the whole. International official remittances to developing countries can take up to 20% of the total amount and the money takes quite a while to get there (Tapscott, 2016). A fairly old research showed that in the USA 45% of the GDP was devoted to this transactions sector (Wallis & North, 1986). The work of Wallis and North is considered as one of the most prominent efforts in quantifying transaction costs (Wang, 2003).

- Banks are the only one that have access to the whole picture and this might undermine our privacy. At the other hand the consumers only have access to their own account.

Blockchain can make a change in these banking problems. In essence it is nothing more than a big database in which all the information is public, distributed, synchronized and cryptographically secured (Gasteiger, 2016). It disintermediates, does not need any trust and can provide transparency and reliability at low costs. However, new issues arise around privacy, security and scaling.

The possibilities should definitely not be embellished but in general the benefits outweigh the costs. With a solid blockchain fundament a lot of practical applications - of which bitcoin is often briefly mentioned - can be further developed. What these applications look like and what they can do, will be discussed in the next chapter.

Chapter three - applications

This chapter will be about blockchain in practice. It will start with some general applications and during the chapter this is funneled down to the supply chain, transport and logistics sector and container sector.

3.1 Bitcoin

As the subject of the contribution of Satoshi Nakamoto is mainly bitcoin with the underlying system of blockchain, bitcoin has already been reviewed a lot in the previous chapter. The new coin has been used as an example and for a discussion of the negative sides such as the latency and the 51%-attack. However, there still is some more that can be written about this cryptocurrency.

3.1.1 Digital money

The history described in chapter one about coined money and institutions leads to fiat currencies. First, stamps were put by these institutions on gold 'coins' to indicate the value of the coin. This value was an intrinsic value: the gold itself was valuable and worth its indication. Later on, the metal of the coins was changed and bills were introduced. A bill of \$100 is worth 100 dollar because that is indicated on the bill and not because the cotton of which it is made is worth 100 dollar. This is the whole idea behind a fiat currency. The European Central Bank (2015) defines fiat money as money that is declared legal tender and issued by a central bank.

This tender can both exist in a physical and a digital form which can be called electronic money. According to Halpin and Moore (2009) electronic money is 'electronically, including magnetically, stored monetary value as represented by a claim on the issuer which is issued on receipt of funds for the purpose of making payment transactions [...], and which is accepted by a natural or legal person other than the electronic money issuer.' Although this definition may sound quite hard, it is very familiar and most of us use it on a regular basis. Money can be transferred at home through the internet directly via the bank, with a smartphone or through the use of Paypal. All of this would be digital money, in the UK for example this is 97,9% of the total money supply (Lipsey & Chrystal, 2011).

Next to this there is also a currency for in virtual environments that are used to buy assets in for example the online game World Of Warcraft (www.worldofwarcraft.com). These currencies are used in an online virtual economy and are somewhat comparable with fiat currencies: they are used for the purchase of virtual

assets and have a central authority that can regulate the supply (Peters, Panayi & Chapelle, 2015).

Bitcoin can be seen as a combination of the trends above. On one side the currency does not exist in a physical form and therefore the price is not related to the intrinsic value of the metal or fabric, neither matches it exactly the definition of Halpin and Moore (2009) of electronic money as there is no claim on a third party as issuer. On the other side the coin can be used in the non-virtual community to buy for example video games, books and Alpaca socks (Blockchain, 2017).

3.1.2 Bitcoin wallet

In order to be able to pay with bitcoins, they need to be send to somebody else. For this a bitcoin wallet is needed. Wallet may sound a little misleading. The wallet does not contain any bitcoins since those are stored on the blockchain. Instead, the wallet contains the private keys that give access to the bitcoins and enable the owner to transfer them to other addresses. The similarity with the normal wallet is that once the private keys are lost, also all the bitcoins are lost to which someone had access via those keys. The five main types of wallets are desktop, mobile, web, paper and hardware wallets. All of the wallets serve the same purpose and it can be imagined that a paper wallet is more susceptible for theft than other wallets (Coindesk, 2015)

Within a wallet the distinction can be made between a hot and a cold wallet. The hot wallet can send bitcoins directly to hot wallets of other users. Via the cold wallet bitcoins can be stored (The Merkle, 2017). At this point the comparison can be made with a savings account and a checking account. The cold wallet is the savings account for the bitcoins, although no interest can be received. The hot wallet is the checking account; transferring bitcoins is directly possible but this comes with a slightly higher chance of malicious use.

The rest of the process is the same as the 'regular' blockchain protocol that was demonstrated in the previous chapter. Party A wants to transfer bitcoins to party B and therefore accesses his hot wallet. The steps that are taken after that can be seen in Figure 15.

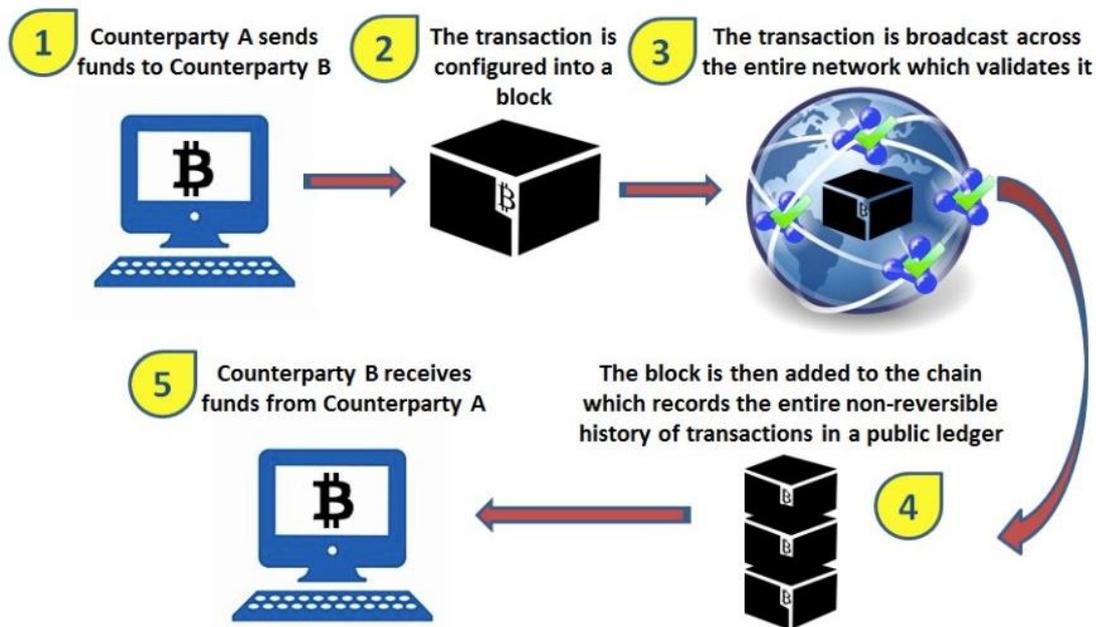


Figure 15 - The simplified example of a bitcoin transaction (Business Insider, 2015).

At step 5, when party B has received the money in his hot wallet, he can spend it on his turn. There is even a bitcoin exchange rate, so currently one bitcoin can be traded against around \$4,400 (Coindesk, 2017). The maximum amount of bitcoins that are released into the world will be 21,000,000 (Coinbuzz, 2015).¹⁰

3.1.3 Bitcoin bottlenecks

Additional to the general problems, there are also some bottlenecks that are specifically related to bitcoin. An example is the use of the hot wallet. Once somebody can get access to this hot wallet and the private keys, the bitcoins can easily be stolen. The equivalent is stealing a pin-number; if somebody is careful it is not too easy but once they are in the wrong hands it can do a lot of damage. In the past years actually a lot of bitcoin disasters happened, varying from individuals losing their private keys to entire companies that suffered security breaches and that vanished from one day to another (Bitcointalk, 2014). Important remark is that the thieves were able to crack the hot wallets or break into the security systems of bitcoin but not into the underlying blockchain protocol. Other than the teething problems, so far blockchain is infallible.

¹⁰ At the one hand this can mean that the price of bitcoin will only increase in the future because of the scarcity. At the other hand, with the rising exchange rate another problem is created. If this amount of 21,000,000 is reached, how are the transactions going to be mined from that moment on? The miners will certainly not be rewarded with new bitcoins as a mining fee.

This maximum of 21,000,000 is an algebraic maximum that is valid under some conditions. It is too technical to debate it on this place, for both the mathematical proof and the conditions is referred to a discussion on Bitcoin Stackexchange (2017).

Regarding bitcoin one of the more known scandals is that of MtGox. MtGox was the biggest trader in bitcoins and handling about 70% of the total transactions (Stanford Review, 2014) up until the company went bankrupt in 2014 for unclear reasons. Of the 2.4 trillion dollars that was lost allegedly back then, only 91 million dollar has been tracked down. The rest was gone all of a sudden. Not much later, the leader of the company Mark Karpeles was arrested in Tokyo for reasons that could not directly be related to all the bitcoins that were missing. Lawsuits for getting the money back are still pending (NY Times, 2016).

The amount of money that was claimed in total at MtGox, cannot only be related to the loss of bitcoins. If the maximum amount of bitcoins is multiplied with the current rate of around \$4,400 per bitcoin, which is the highest so far (Coindesk, 2017), the outcome does not get any higher than 92.4 billion dollar.

Examples of other cryptocurrencies are Litecoin, Darkcoin and Citicoin. Litecoin comes from former employee of Google Charles Lee, that requires a different procedure regarding the mining and has a shorter average block time compared to bitcoin (Coindesk, 2014). Darkcoin is part of Darksend, which can make transactions even more anonymous than bitcoin. Other than that users do not have any risk of losing their coins because of a special collateral-protocol (Duffield & Hagan, 2014). Since 2015 the name of Darkcoin is changed into Dash (2017). Citicoin is coming from Citibank and looks a lot like bitcoin (Techcrunch, 2015). The coin being invented by a bank is a paradox to some degree, the whole idea beyond a cryptocurrency is that it just makes the bank obsolete. In this way it looks like the Citibank is tearing down itself. However, other banks are also no longer ignoring the upcoming trend of blockchain. Although not specifically developing their own coin, UBS has set up a blockchain research lab in London, Goldman Sachs has invested in bitcoin start-up Circle and Santander is investigating how to use blockchain in the scene of traditional banking (Business Insider, 2015). From this point of view with these efforts banks are trying to stay updated and rise along with the trend. There are loads of other cryptocurrencies being introduced such as Primecoin, Peercoin and Namecoin. Each of these types of coins has its own characteristics but they all have in common that they are built on a blockchain basis. Because of that fact they also have the same sort of problems with regard to security, maximum amount of coins and latency. Of all the cryptocurrencies that are available to buy at the moment, with a current market capitalization of almost 60 billion dollar (Cryptolization, 2017), bitcoin still is the market leader.

3.1.4 Bitcoin as the backbone of the financial market

After the negative stories of bitcoin in the previous paragraph of people losing their private keys or coins disappearing all of a sudden for unclear reasons, Pieter Wuille is now focusing on making bitcoin more user-friendly, so that it can be prevented that individuals are transferring coins to the wrong address and are not able to retrieve them (Coindesk, 2017).¹¹ The new system is able to highlight possible errors.

Despite the attempts of making bitcoin easier to use on a big scale, the question is whether or not bitcoin in general could serve as the backbone of the financial market. Walch (2015) recognizes this problem and first researches the principles that financial regulators have adopted to maintain global financial stability, which can be divided into governance, risk management and operational risk. Especially with the exchange rate of bitcoin being very volatile, illustrated in Figure 16. As one can see, the price of bitcoin has varied in seven years from almost zero to over \$4,000 and except for the time before July 2010 it has not been stable ever since, although that cannot be seen at first sight in the figure. For this reason alone it may be hard to maintain financial stability.



Figure 16 - An overview of the price of one bitcoin in dollars from July 2010 until August 2017 (Coindesk, 2017).

Another problem with bitcoin being decentralized and open-source is rooted in its protocol; no one is responsible for a crisis with the software, accounts cannot be frozen and repair can be delayed or imperfect. Of course there are a few administrators that can do protocol updates and incident resolution, but nobody serves as 'the voice' of the

¹¹ The question rises whether or not it is really impossible to retrieve the coins that were accidentally sent to the wrong person. Setting aside the difficulties of tracking, identities and proof, I would say that the coins can be recovered through a similar legal procedure as that of an undue payment, in Dutch law this is embedded in article 6:203 of the Civil Code.

software. On top of that, who watches these watchmen? Being able to operate the buttons backstage without any control gives a lot of power with such a high overall value of bitcoin. This all strongly undermines the suitability to serve as financial market infrastructure. These problems come on top of the bottlenecks about blockchain in general and bitcoin specifically that were summed in the previous chapter.

At the other hand, the current financial system also is far from perfect as turned out in 2007 with the credit crunch that was explained in the first chapter. The measures taken by the Federal Open Market Committee amongst other measures were barely enough to avoid a complete financial implosion. On top of that the mortgage rates, commodity prices such as oil and partly related to this also the exchange rates are very volatile ever since. Admittedly the amplitude is not as big as that of bitcoin, but because of the novelty of bitcoin one can imagine that this will stabilize a lot over time and get the same proportions as the current exchange rates.

All in all, it looks like bitcoin is not going to rule out banks completely and going to be the financial hub in the world, what it maybe can do is provide support in transactions and make banks less prominent.

3.2 Ethereum

The possibility of smart contracts has been discussed shortly in the previous chapter. One of the applications that facilitates the creation of smart contracts is ethereum. Ethereum was created by the then 20 years old Russian programmer Vitalik Buterin. After first doing his research and making tracks in bitcoin, he developed ethereum on the basis of blockchain (Triantafyllidis & van Deventer, 2016).

In the contribution of Delmolino e.a. (2015) the technical aspect of ethereum is explained, from the requirement and installment of the user addresses that are necessary to the programming of the smart contracts and the addresses that those contracts need to be sent to.

Basically it comes down to the fact that ethereum offers a relatively easy to learn programming language similar to Javascript with which smart contracts can be created, once somebody got some basic understanding of coding. The programming language Solidity is quite well-known to this respect, the Ethereum Virtual Machine (EVM) will automatically check the conditions of the contract and when those are fulfilled, the contract will be executed (Blockgeeks, 2017). The EVM is so-called Turing complete. This means that in principle it can solve any computational problem if enough memory is available (Ethereum Stackexchange, 2016). At the moment for the mining still the protocol of proof-of-work is used, but Buterin is planning on making a gradual switch to the proof-of-stake protocol (Coindesk, 2017). Also for the mining a fee has to be paid but this is based on the amount of work that it takes to perform certain actions, which is

slightly different than the mining of bitcoin that is based on the size of a transaction in kilobytes. The mining needs to be paid with gas and that can be bought with ethereum. There is also an exchange rate from ether to gas and this is introduced to discourage overconsumption and to encourage miners to keep mining. The composers of the contract also determine a maximum amount of gas they are willing to pay for the mining job (Ethereum Stackexchange, 2016).

Other differences compared to bitcoin are that the maximum amount of ethereum is 18,000,000 per year; there is no all-time maximum. This also means that inflation can take place for ethereum and that some 'monetary policy' needs to be pursued to this extent (Egbertsen e.a., 2016). The average block time for ethereum is only 15 seconds compared to an average of ten minutes for bitcoin. Also because of a special additional protocol in the bitcoin system, the engagement in mining pools is discouraged which prevents a 51%-attack (Cryptocompare, 2017) that should not be worried about anymore in the near future because of a transition to proof-of-stake.

The draft of paper contracts with all the necessary clauses is a legal profession on its own. The same is partly applicable when creating smart contracts on a blockchain.¹² Delmolino e.a. (2015) created a lab to design numerous smart contracts. Students were invited to participate and the common pitfalls were discovered. Most of them are too technical to discuss but in short there were a lot of issues centered around third parties that wanted to participate in a contract in a later moment for example to make a payment. Ways to fix or avoid these mistakes are suggested and therefore the best practices for creating contracts become clear and were later given in open online course materials (Delmolino, 2017).

In the contribution of Delmolino e.a. both the general drawbacks and the specific problems for ethereum were exposed. Later Atzei, Bartoletti and Cimoli (2017) made a complete overview of the security vulnerabilities of ethereum that were known up until that point. Different series of attacks are done and apparently it is possible to steal money or cause other damage. It is definitely recommended to incorporate some additional security measurements.

Just like with bitcoin, while blockchain still looks infallible the protocol of ethereum that is built on the system of blockchain has its weaknesses. However, that does not withhold people from using both bitcoin and ethereum. The opportunities with ethereum even look a lot more promising than bitcoin because of the option of smart contracts. Smart

¹² With ethereum it is also possible to just upload the paper contract. However the system is not able to read the conditions of the paper contract and to take action accordingly. Moreover, some clauses cannot be translated into smart contracts (yet), making it hard to simply replace one for another (Egbertsen, 2016).

contracts can even help in the development of artificial intelligence and with the translation of information (Omohundro, 2014). Of course ethereum can also merely be used as a digital currency.

At the moment of writing this thesis there are 645 decentralized applications running on ethereum (Dapps ethercasts, 2017) and this number is increasing quickly. The same goes for the price of ethereum, see Figure 17. Just like with bitcoin, the first period after the introduction the price stays relatively stable after which it gets pretty volatile.

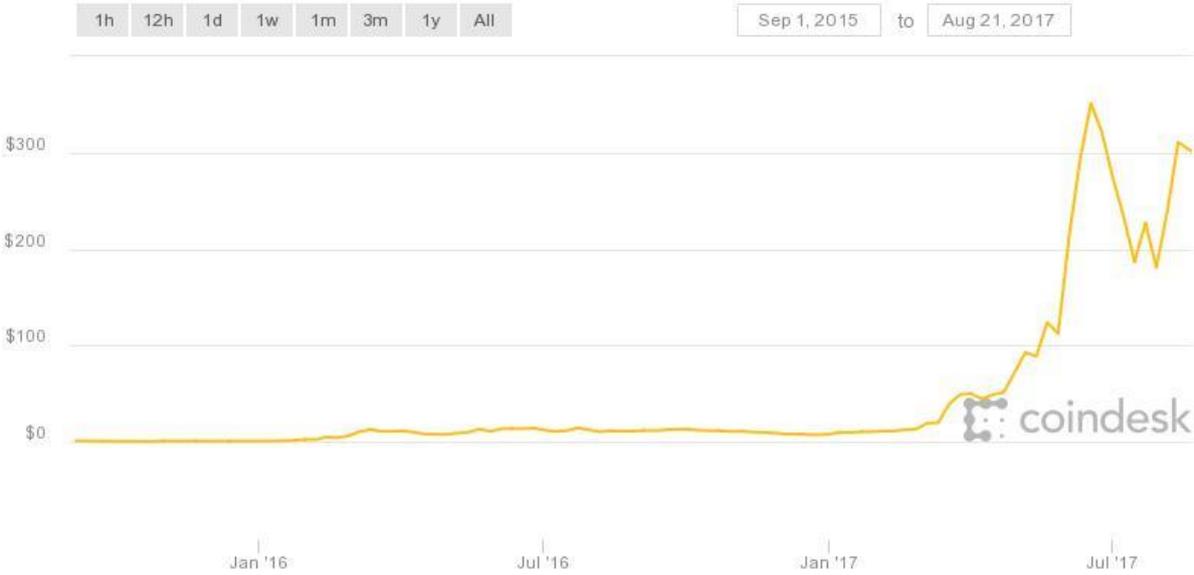


Figure 17 - An overview of the price of ethereum in dollars from September 2015 until August 2017 (Coindesk, 2017).

Recently the prices of bitcoin and ethereum are increasing a lot. The same is applicable to other cryptocurrencies like Dash (\$290) and Litecoin (\$47) or to Monero (\$89) that is more focused on privacy, decentralization and scalability (Coin market cap, 2017). The increasing rates are also causing alternative, opaque stories about the cryptocurrencies.

3.3 Scheme

In an in my opinion doubtful article in the Financial Times (2017), the bitcoin is called too volatile to become useful as a medium of exchange. The author also compares the cryptocurrency with a pyramid scheme, he therefore thinks that only one value for bitcoin is right and that is zero.

Indeed, bitcoin is volatile. Maybe this will stabilize over time, maybe it will not. We also have exchange rates with the dollar and the euro that change over time, next to the inflation. Money in any way is prone to inflation and it is not remarkable that the value of a currency changes over time. An exceptional example is that of the Zimbabwean dollar

that at one point reached an inflation of 500,000,000,000% (The Guardian, 2015). Indeed with this spectacular decrease - and for similar increases as well - it will not be very useful as an exchange medium. Unlike the Zimbabwean dollar, with no intermediary to control the bitcoin, neither the values can be influenced or stabilized in any way. In the end the paradox of money is that everybody wants to have it while nobody wants to have it. We want to buy the goods and services that we actually desire. We need money to not have all kind of exchange rates for one deer in beavers, crossbows and all other goods. It is just a medium of exchange but nobody needs the money itself and we attach a relatively stable value to the coins and papers because we have agreed on that. For bitcoins, we can agree on similar conditions in the future.

The story about bitcoin being a pyramid scheme sounds unlikely. In a pyramid scheme new investors are attracted to 'pay' the return of the old investors. This story can go on and on until ultimately not enough new investors can be attracted anymore to pay the already settled investors and the system will collapse (Schneiderman, 2017). One of the more famous examples is the Ponzi scheme of Bernie Madoff. However, with bitcoin this is not the case. The new acquirers do not pay for the people that already own bitcoin. I think that the author is trying to say that by promoting bitcoin very fiercely, the price will be pushed upwards. This makes perfect sense since it is one of the basic laws of supply and demand of the Wealth of Nations of Adam Smith in chapter one. Whether it is a hype or not; if the demand increases, the price will, *ceteris paribus*, increase as well.

This does not take away the fact that it is hard to imagine that something that cannot even be touched is of such a high value. However, regular software - to which ethereum actually comes really close - also is more or less untouchable but we pay for that as well. The value is reflected in the program that we can use on a computer. Alternatively, diamonds for example are expensive as well but we cannot do anything with them except for using them to trade. Therefore this whole new phenomenon of cryptocurrencies is maybe just a combination of characteristics that we already know and might only take some time to get used to. Although that is quite risky, we do not need to fully understand it to be able to use it.

3.4 Other applications than cryptocurrencies and smart contracts

Bitcoin and other coins can be used as a tender. Next to that, ethereum can be used for the use of smart contracts. This is only a small selection. Without trying to be exhaustive, below will follow a list of other systems that are built on blockchain and that can be used in completely different kinds of settings. The specific application within the supply chain will follow later.

3.4.1 Money tracking

Better tracking of money can prevent money laundering and the financing of terrorism (Deloitte, 2016). With regard to loans, banks might become partially obsolete. A private stranger can also lend money while taking collateral of the borrower, all via the blockchain (Blockgeeks, 2017). Another way for companies to attract capital is via an initial public offering. Executing such an IPO usually costs a lot of effort and money. Likewise, here is a possibility to directly put it on a blockchain, reducing administrative burdens (Crosby e.a., 2016). However, also after the IPO blockchain can be used. It can even be introduced as of today in the stock and trading market, including high frequency trading and short sales (Lee, 2016) and the trading of energy (Deloitte, 2016).

As Mainelli and Milne (2016) point out in the market of securities, we have to be careful to not to get too unrealistic expectations. The whole idea of data sharing is absolutely not new. Moreover the authors state that distributed ledgers do not remove the need of third parties entirely. We might still need them for the confirmation of identities and asset existence, dispute resolution and enforcement of legal obligations.

Indeed most probably even with blockchain and every application built on it perfectly functioning, we cannot do completely without any third party. It will appear below however that also blockchain solutions are created regarding identity checks and asset registration. With the help of the mentioned smart contracts, execution can be enforced which makes lawsuits less likely. Are third parties still necessary in the future? In my humble opinion they are, but even to a lesser extent than Mainelli and Milne (2016) state.

3.4.2 Insurance world

In the world of insurances, payments of premiums and claims can be streamlined. The smart contracts can help a lot in this field. Because claims are a lot more transparent by putting it on a blockchain, fraud can be prevented or detected and countered (Deloitte, 2016). Furthermore with this system it can easily be checked whether or not the property really belongs to the one who is filing the claim (Shrier, Wu & Pentland, 2016).

3.4.3 Health care

In medical scientific research sometimes a temptation arises to slightly adjust some kind of information to get better outcomes, especially when taking into account the amount of money that is involved and the fact that lives may be at stake. The pressure in this field can be high. In blockchain the protocols get timestamped so the research can easily be verified (Irving & Holden, 2016). The data cannot be manipulated afterwards and therefore the results will be more reliable.

Furthermore, apps are developed with the help of blockchain that enable patients to own, control and share their own data easily and securely without violating privacy regulations (Yue e.a., 2016). This development comes on top of the electronic medical record, which is the digital version of the paper-based medical record for an individual (Techtarget, 2012).

3.4.4 Governments

Public services by the government can be offered in a much more efficient way (Deloitte, 2016). With regard to the registration of land and property, things can also become more straight-forward. Just like with the insurance industry ownership can easily be shown or transferred.

3.4.5 Identification

Passports, wedding and death certificates on a blockchain can prove who you are, who you are related to and whether or not somebody is still alive (Blockgeeks, 2017). It can be imagined that even more information regarding an identity can be stored. One can think of DNA, fingerprints or scans of the iris which can be very helpful for investigative services. But also shoe sizes and other measurements of the body can be stored and/or updated, so that a custom tailored suit can be made with a few mouse clicks.

3.4.6 Media industry

The Pirate Bay, Spotify and YouTube are very familiar platforms. They are created to stream or download music, sometimes legal, sometimes less legal. Authors and owners of music rights have a lot of nuisance of these internet applications. In the past with the sales of singles and albums in the format of a CD a lot of money was earned and now this source of income is reduced substantially. With the help of blockchain, legal copies and distribution of (streaming) content against a payment can be facilitated while preventing the same activities in an illegal way. The royalties will end up at those to whom it belongs (Crosby e.a., 2016).

3.4.7 Software

The current problem with software is that validation can easily be circumvented by reverse engineering, removing certain mechanisms or copying the license keys. Now, one unique license key can be generated which cannot be copied or used multiple times in any way (Herbert & Litchfield, 2015).

3.4.8 Storage

In whatever field or industry, blockchain offers the possibility to store documents both on the chain that is accessible to anybody or on a sidechain that is only accessible to for example only that person that created it. With this option in general proof of existence, authenticity or signatures can be checked by the relevant parties (Crosby e.a., 2016).

Again, this is not really new. For a long time there already is something such as storage in the cloud. As every party needs to rely on this cloud, the chances are higher that this type of information disappears due to malfunctioning of the central system.

3.4.9 Multi-functionality

There are loads of different applications in several industries with blockchain as a basis. The list above is definitely not complete and can be seen as only the beginning of a lot more in the future. Both bigger and smaller companies are starting to discover this new revolution. IBM has opened a blockchain innovation center in Singapore (IBM, 2016). Microsoft is offering a free testing environment for blockchain as a service via Microsoft Azure and Deloitte is doing the same with the program Rubix (Microsoft Developer, 2016). Airbus (2017) is putting teams on blockchain to learn how to deploy the technology with regard to smart contracts and big (immutable) data. Meanwhile different start-ups are trying to jump into this pool of opportunities. Blockstream (2017) is offering sidechains that can process micro-payments which can be useful for the media and software industry. Blockverify (2017) has solutions to verify companies, detect counterfeits and discover fraud and stolen goods that can come in handy with insurances and identification. Factom (2017) is specialized in documentation management and can help with the execution of smart contracts.

Recently, the PortXL shakedown has taken place in the Maassilo in Rotterdam. During this event, different new applications based on the latest technology such as virtual reality and blockchain were presented while trying to accrue the interest of big companies such as Van Oord and EY. Just like IBM in Singapore, possibly in Rotterdam also a blockchain fieldlab is going to be constructed (Beije & Jullens, 2016). Additionally, the University of Delft, ABN-AMRO, the Port of Rotterdam and 13 other companies are going to participate in a big TKI Dinalog project that focusses on the blockchain technology in logistics. A collaboration of this size on a concrete blockchain project has been unique so far (TKI Dinalog, 2016). What blockchain can imply for the logistics sector will become clear in the next paragraph.

3.5 Application in the supply chain

In 1963, Anthony 'Tino' De Angelis, who has been involved in a swindle before, was a trader in vegetable oil. Again this time he was engaged in doubtful activities. He wanted to expand his business and needed capital for that. So he went to the American Express for a loan, for which collateral was needed. De Angelis had a substantial amount of vegetable oil in its inventory which he decided to increase artificially. When the inspectors of the American Express came to check the inventory, De Angelis had filled the tanks with water and made sure that only the top layer consisted of the required oil. Next to that the different tanks were secretly connected to each other with pipelines. After the inspector was done checking the first tank the content was quickly pumped into the next tank that the inspector was going to see. When the forge was discovered, it turned out that he only had 6 million dollars of vegetable oil instead of the alleged 150 million dollar. If American Express had done more research they had discovered earlier that this inventory was more than the entire inventory of the United States as reported by the Department of Agriculture in that year. The scam got detected and the vegetable oil market collapsed. This was the start of the salad oil crisis in 1963 that not many people heard of (Business Insider, 2013).

In 2006 there was an outbreak of the harmful bacteria e.coli due to contaminated spinach. The vegetable was pulled in the entire United States and it took the food and drug administration two weeks to find out that it was only one lot on one day at one farm that was contaminated. During those two weeks not a single piece of spinach was served nationwide (Freightwaves, 2017).

In both of the mentioned cases the consequences are very big, a collapse of a market and a block on a vegetable. If there would have been more transparency in the whole supply chain this could have been prevented. Fairly easy it could have been found out that this amount of vegetable oil was impossible and had no origin and which specific spinach crops were bad and transported to which companies. Currently the supply chain is unnecessarily vague but from a business perspective this can be understood. Of course a company does not want to disclose all the information about where it got its raw products and materials from. Companies purposely do not want to give away their entire supply chain as it may be a competitive advantage.

Perhaps a better balance can be found on this scale of at the one hand transparency and at the other hand the secrets of the company. With blockchain this is possible. First, the regular supply chain will be described, after which different applications within the supply chain will follow. A lot of start-ups and long established companies are working on solutions.

3.5.1 The current supply chain

In Figure 18 is depicted very basically what a regular supply chain can look like. Of course, a lot of variations or extra stages are possible.



Figure 18 - A very simplified example of the supply chain (Maersk, 2017).

This figure can be interpreted in multiple ways. On the left for example we can see a truck transporting raw materials in a container to a port. At one side of the ocean the container gets loaded and is brought to the other side by a shipping line. There, the container with raw materials gets transported by another company to the factory where the raw materials are processed into end-products and need to be transported again to their users.

Another view would be that in which raw materials are picked up in the woods, brought to the factory which is situated near the blue crane on the left. After production the goods are transported in containers to for example the consumers or retailers. As will later turn out in the research of Maersk, every stage in the supply chain is a part on its own. In the entire chain a lot of documents need to be arranged such as contracts for the (truck) transports, bills of lading that transfer the ownership of the content and all kinds of customs documents that indicate or guarantee a sound state of the (tank)container or the product(s) in it. Other than that an agreement needs to be reached about who arranges the insurance and when the risk of loss transfers from the consigner to the consignee.¹³ The supply chain can be extended with warehouses for temporary storage or centers where (re)packing or assembly takes place. Except for trucks and deep-sea ships transport can also be done by train or barge. Figure 19 gives an overview of a somewhat more difficult supply chain.

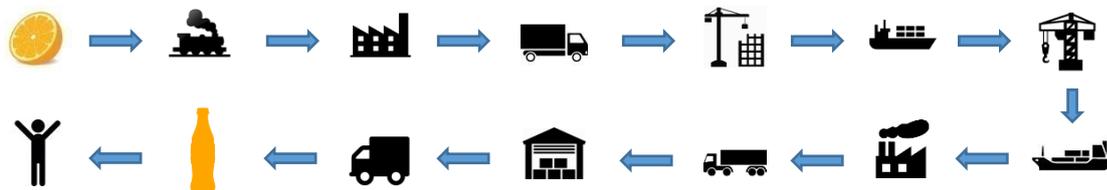


Figure 19 – A little more difficult supply chain compared to the previous figure, including an assembly center and a warehouse.

¹³ There are standard Incoterms that can be used, varying from 'ex works (EXW)' in which the consignee basically needs to plan everything, to 'delivered, duty paid (DDP)' where the sender arranges all additional items such as transport, insurances and custom payments (Mainfreight, 2017).

In the supply chain above first the raw materials are collected and transported by train to the factory. After processing the products get transported by truck to a port where they are loaded and get shipped overseas to another port where they are transhipped onto a smaller ship such as a feeder or barge. This ship brings the products to a center where additional activities of (re)packing and assembly are carried out, after which they get transported by truck to a warehouse. From the warehouse, the products can be transported by truck to for example a retailer or consumer.

The different means of transport can be bought by the relevant carriers but they can also be leased or rented, the same goes for the buildings. For deep-sea ships it is possible to charter a ship for a specific time or journey including crew but excluding for example fuel (Shipsbusiness, 2017). Ship building and insurance goes via multiple insurance companies as the risk is too big to bear for one enterprise (Curtis, 2012). For mortgages or loans the assets can serve as collateral. Payment for the products is either done in advance, in several terms of afterwards because of credit that parties give each other but is always done via a bank.

The different stages of the supply chain can be executed by the company itself, for example own trucks and drivers can be used. However, most of the time there is made use of external parties to transport the goods as that is more beneficial. The decision can even be made to outsource a part or the entire supply chain regarding the operational level to parties that offer for example warehousing and distribution activities by the use of their own resources or their network. This is called a third party logistics provider (3PL). The 3PL (partly) manages the supply chain logistics and the company can still be involved to a certain extent regarding the strategic decisions on the longer term, but it has more time to maybe focus on the more core business processes. The fourth party logistics provider (4PL) even goes a step further; a 4PL takes on the responsibility of the whole supply chain of a company. So this party is singularly accountable for the entire supply chain management (ADLI Logistics, 2017). Currently there even is an emerging trend of a fifth party logistics provider (5PL), where the demand of different supply chains is aggregated to negotiate more favorable rates (Bayt, 2016).

In short: there are a lot of actors involved in the supply chain and the same goes for the amount of paperwork. Sometimes the fax is still used for the exchange of documents (Brinknews, 2017). Regarding these ways of communication a more exceptional example of transport will be given after a review of some blockchain projects in the supply chain.

3.5.2 Blockchain experience lab PWC

The experience lab is created in Amsterdam by PWC. Every time there was the same experience within the transport sector with the problems of high risks, little transparency

and a substantial amount of effort that was required to perform transactions. In cooperation with LAB15, three different systems are developed in order to solve three different problems, which are:

- VAT-fraud with products together with the compliance burden
- Insurance and auditing
- The management of assets with regard to tracking and tracing in the supply chain

So far the results look promising. According to PWC it is not the question if, but when blockchain will disrupt entire industries (PWC, 2017).

3.5.3 Start-ups regarding origin of products

Provenance (2017) is a company that is mainly focused on the authenticity of products. With the help of this start-up it is possible to trace back products to where it all started just like in Figure 19. It can be found out where John West got his fish from and from which part of which animal the meat on a plate in a restaurant is obtained. The company Everledger (2017) has the same kind of approach, only here the products are of a higher value such as diamonds and wine. Apparently a lot of scams are committed when it comes to the sale of diamonds and insurance companies experience a lot of fraud with the very valuable material (Diamond Helpers, 2014).

Both companies can offer more transparency in the supply chain, verification and validation of the products and services by customers is better facilitated and this matter seems more pressing than ever. At the same time this can be done without giving up the entire journey of the product from the beginning to the end. For example manufacturers in the middle of the supply chain can pass certificates while keeping their identity private. Other than that it is possible to register repairs, see whether or not a product is tested on animals and keep track of insurances and valuation through which the information asymmetry can be reduced. With these applications it becomes unnecessary to stop serving spinach in an entire country; one can easily trace back which crops went to which companies and therefore where it can go wrong.

3.5.4 Walmart

In the retail sector, Walmart has started this year with a blockchain test as well to track and trace pork in China and produce in the United States. Next to the earlier mentioned project in Rotterdam, this is one of the other big projects that is not specifically aimed at financial services. According to Walmart, if this project is successful blockchain will be used for more products and hopefully this can lead to less delay and errors in the supply chain (Bitcoinmagazine, 2016).

3.5.5 Cargo shipment tracking

Mendix (2017) built a supply chain application to keep track of cargo shipments and the conditions under which they are transported. Where in the past RFID could be used, now a lot of conditions can be measured with sensors that can record humidity, temperature, movement and light. Even more remarkable is that this application was built in only ten days.

Nowadays track and trace-codes are used on a daily basis by consumers and companies. An example can be found at DHL. When a product is ordered online and sent with DHL, a track and trace-code is sent via e-mail with which can be checked if the product is still at the distribution center or already on the way to the customer. This whole idea can also be put on a blockchain, but the advantage is that any additional information can be stored there as well such as delays or whether or not the product is damaged on the way. If the customer can be immediately aware of this news, the damaged product can be returned sooner instead of the moment of unpacking at the destination. A new product can be requested directly and in the end this might lead to a decrease of the transportation costs.

3.5.6 Cargo shipment weight

When containers are packed, an indication of the weight of the content needs to be given. Especially this information is important for the ships in Figure 19, it is used to stow and balance vessels and for the stacking at the terminal. Often there is a substantial difference between the given weight and the actual weight of the container which can lead to incorrect stowage decisions. SolasVGM (2017) created a collaborative system between all landside parties, load point, shipper, driver, booking party, terminal and shipping line, reducing wrong stowage because of incorrect information to a minimum. Moreover, the loading of containers that are overweight can be stopped at the earliest moment as possible.

3.5.7 Blockchain platform IBM Watson

Next to the blockchain innovation center in Singapore (or maybe because of it), IBM Watson (2016) created a platform that can be used by different parties in the entire supply chain, see Figure 20.

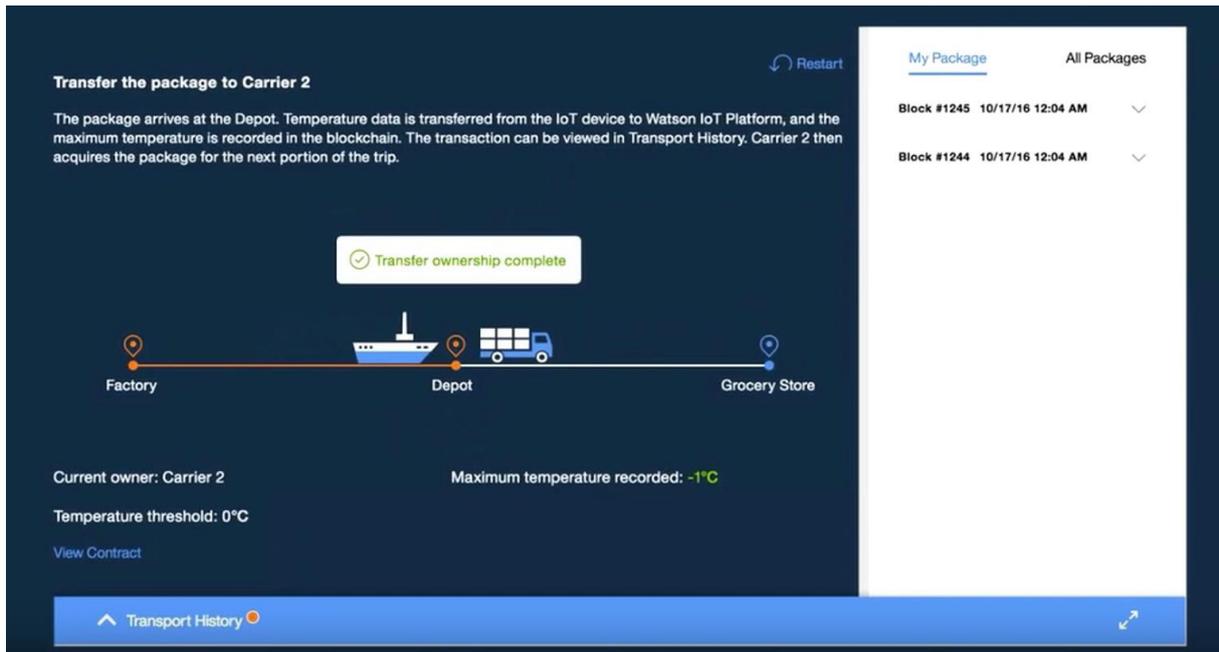


Figure 20 - The supply chain platform of IBM Watson (2016).

In this case a public blockchain is combined with a private blockchain. Frozen cherries are transported from the factory to the store with the help of two different carriers. Each party agreed that the temperature needs to stay below 0 degrees Celsius and has accepted liability for that. At the right of the figure one can have access - but only when granted - to the details about each block of the supply chain. For another more extensive video is referred to IBM Research (2016).

With regard to merely storage of documents blockchain can be compared with a safer but slower method of storage in the cloud. With the application of IBM we can see that there is a lot more going on than just some way of 'storage in the cloud'. The current owner, temperature and other vital information can be directly seen, just like where it may have gone wrong. The cloud is definitely not able to do this on its own.

3.5.8 Blockchain cooperation IBM and Maersk

As a shipping company, Maersk knows what the supply chain is about and is also partly aware of the amount of paperwork and effort that is involved with transport. Bills of lading, certificates of authenticity and documents for the customs have to be shown at every stage in the process. There are big costs attached to the release of information. Recently, Maersk (2015) researched this entire paper trail from beginning to end and concluded that this should and with modern technology can easily be simplified. What was done and what the outcome was, will be reviewed below.

3.5.8.1 The research

Maersk states that the invention of the container was a revolution for the global trade, as from then on there were only a couple standard size boxes instead of loads of different heights, lengths, widths, weights and materials. However, currently the global trade seems to be slowed down by the different ways of communication.

Maersk let researchers travel together with the products from A to Z while making copies of all necessary documents. Due to its complexity the transport of roses from a farm in Nairobi to a retailer in Europe in a refrigerated container was chosen. Several problems came to light. In Africa some parties do not even know if the flowers already arrived on the next address or suffered a delay. Furthermore it can happen that a container arrives before the documentation that can even become literally stuck in traffic. In this case the refrigerated container does not get plugged in and cannot cool before everything is arranged. In one of the last phases was discovered that the phytosanitary document¹⁴ was lost somewhere during the trip, but the problem was that this document was needed for the customs to release the container. In the end it appeared that the document was just stuck in a drawer of a desk of one of the people involved. The worst case scenario is that such things can cost the shipper the entire cargo because of some missing paper while in general a lot of time and effort has been put in to make sure that the flowers arrive in the best quality.

3.5.8.2 The problem

The main outcome of the research was that there actually seem to be two kinds of infrastructures. At the one hand there is the physical infrastructure in which every party sincerely tries to do its best to let the roses reach its potential. The physical trail is almost perfect in its current state and with the resources available according to Maersk.

At the other hand there exists an information structure. Or actually the structure in this paper trail is more or less missing. It took 34 days to transport one specific container with roses from Nairobi to the retailer in Europe. Of those 34 days, in total the container was waiting ten days for another document or approval from an organization. More than 24 organizations were involved for that one container. Furthermore a lot of the relevant parties in one stage of the supply chain were not aware of what happened in previous stages or of what will be happening in the next stages. In short, a big contrast with the physical infrastructure got revealed.

¹⁴ A phytosanitary document guarantees that the roses have been inspected and are free from pests conform the regulations of the importing country (CFIA, 2016), in this the case the country in Europe in which the retailer is established.

3.5.8.3 The solution

There is a complex communication and administration structure on both the import and the export side. It is not that the entire paper trail needs to be re-invented or something like that. An online, cloud-based solution would already give a lot more clearance so that documents cannot get lost or stuck anymore. Within that context the researchers are talking about 'an information pipeline in a supply chain visibility model' (Maersk, 2015).

3.5.8.4 The cooperation

Together with IBM, Maersk wants to launch an industry-wide supply chain solution with the basis of the blockchain technology. The idea is indeed to digitalize all the paperwork that is mentioned and incorporate it into one big system. The two companies have been working on pilots together with trading partners, governments and logistics companies. A scalable product will be developed later together with shippers, freight forwarders, ocean carriers, ports and customs authorities (Global Trade Review, 2017).

Apparently, if this administration and communication can be improved, this can result in a global increase of export of 1 trillion dollar (World Economic Forum, 2013). In general the implementation of blockchain in the shipping world can save around 5 million dollar per mega-ship because of easier processing and consequently less labor costs (Porttechnology, 2017).

3.5.8.5 The consequences

If the barriers within the supply chain can be reduced, the WTO says this can lead to an increase of worldwide GDP with 5% and an increase of the total trade volume of 15% (IBM Blockchain, 2017). Of course, blockchain can reduce or eliminate some of these barriers, but it is questionable if solely the system can be responsible for this entire growth. The communication and exchange of documents can be better facilitated, but there still is a lot of (digital) paperwork that needs to be created, checked and signed.

At the other hand the question is if indeed the physical infrastructure cannot become any better anymore. Research of Vernimmen, Dullaert and Engelen (2007) showed that 40% of the vessels arrive one or more days behind schedule. The causes like bad weather and port congestion are not always under their control, but maybe here is definitely some room for improvement. Although bad weather or strikes can never be prevented, better schedules were examined to improve the notorious untrustworthiness (Wang & Meng, 2012). With this perspective maybe the physical infrastructure is not so perfect after all and should both this one and the information structure be improved.

3.6 A simpler supply chain

With the help of blockchain, bitcoin can be used as a cryptocurrency and ethereum can be used for smart contracts. A combination of these two and other developments results in an almost endless amount of applications in the insurance industry, for public services and identification and for storage in general. Both new entrants and well-known incumbents are discovering this new trend, either alone or by working together. We are going from the internet of things, in which every physical object is connected to the internet and to other devices, to the internet of services, in which companies make use of this connection to offer services and value (Wired, 2017). For example Virgin Atlantic is buying planes of which every piece such as flaps, engines and landing gear has an internet connection. With these connections problems can be reported before becoming catastrophic (Internet of Business, 2016).

The aforementioned fields can also be used by transport and logistics companies but in the supply chain sector itself a lot of gains can be made as well with regard to transparency, communication and documents. The technology is ready for it. However, there are still a lot of complications. In the case that was researched by Maersk, do the farmers in Nairobi have devices to access any blockchain in general? Does every farmer need to be provided with high-tech systems and be taught about it? Moreover, can there be problems with regard to the compatibility worldwide or will any language barriers arise? Other than that there are some clauses in paper contracts that cannot be incorporated or automatically enforced in smart contracts. This is in the same line as the Paxos anomaly; transactions can only be made dependent upon another transaction to a certain extent. The clause 'B transfers money to C after he has received another amount of money from A' is not possible. Furthermore attention must be paid to clauses that are contradicting each other such as 'pay when the goods are shipped' for party A and 'ship when the goods are paid' for party B, in this way there will never be paid nor shipped.

In the end, all of these developments will probably result in a better facilitation of (financial) transactions and a supply chain that can work more effective, more efficient and more simple. What the future may look like and what this all can imply for CARU containers will be explained in the next chapter.

Chapter four - scenarios

In this chapter different future blockchain scenarios will be described. Also the role of and consequences for CARU containers will be discussed in each of these scenarios. First an introduction and some blueprints of the company are given.

4.1 Introduction to CARU containers

In 2000, the three companies CATU Rotterdam, Trade Craft and Lease Craft decided to join forces and started the company CARU containers. During the years it became one of the largest traders in the world of new and used shipping containers. Next to that the company is specialized in storage containers and DNV certified offshore containers. All these different types of containers can be bought, rented or leased. In 2016, the company took over CCA and ECB Group. There are offices in the Netherlands, Belgium, France, Czech Republic, Poland, Switzerland, Sweden, Germany, the United States and Asia.

CARU containers has 10,000 containers available worldwide that can be delivered from more than 200 depots. At the moment, more than 160,000 containers are leased and rented out (CARU containers, 2017).

4.2 Sales process

With the help of interviews and literature the sales process of CARU containers will be described. A summary of the interviews can be found in the appendix.

The sale of a container starts with a request of the customer. With the amount of containers readily available, sometimes the container can be directly delivered out of stock. If that is not possible, either CARU containers buys the container at the market and sells this one to the customer with a profit margin or transports the container from another location - where it is available - to the customer, see Figure 21 (Veenhof, 2016).

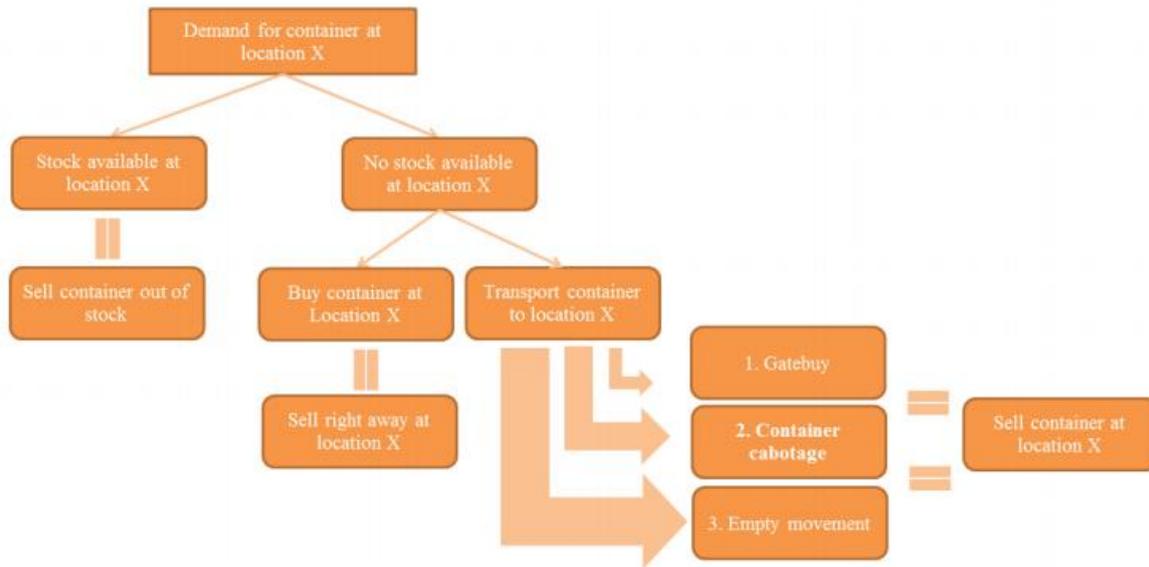


Figure 21 - The sales process of CARU containers (Veenhof, 2016).

When CARU containers decides to buy the container at the market, Mediterranean Shipping Company (MSC) is an important trading partner. MSC is a world leader in global container shipping and a company that offers global services with local knowledge (MSC, 2017). The gatebuy of MSC is often used by CARU containers to buy second hand containers and sell them again with a margin, but also containers are bought from other shipping companies. The net profit margin of the second hand container sales is around 12% (Simons, 2015).

For the business of renting and leasing, new containers are used. While still being owned by the company the containers are hard to track. The only options are the programs that are offered by the actors in the supply chain, for example the container status services of ECT Rotterdam (ECT, 2017) or the possibility to trace the location of the ship on which the container is travelling via Marine Traffic (2017), of which a screenshot of a part of Europe is given in Figure 22. As can be seen, there are a lot of ships travelling at sea. At the moment CARU containers is facing problems regarding retrieval of containers of which the rent has not been paid for a couple of months. Sometimes the company is not aware of the current location of the container so that it cannot be picked up.

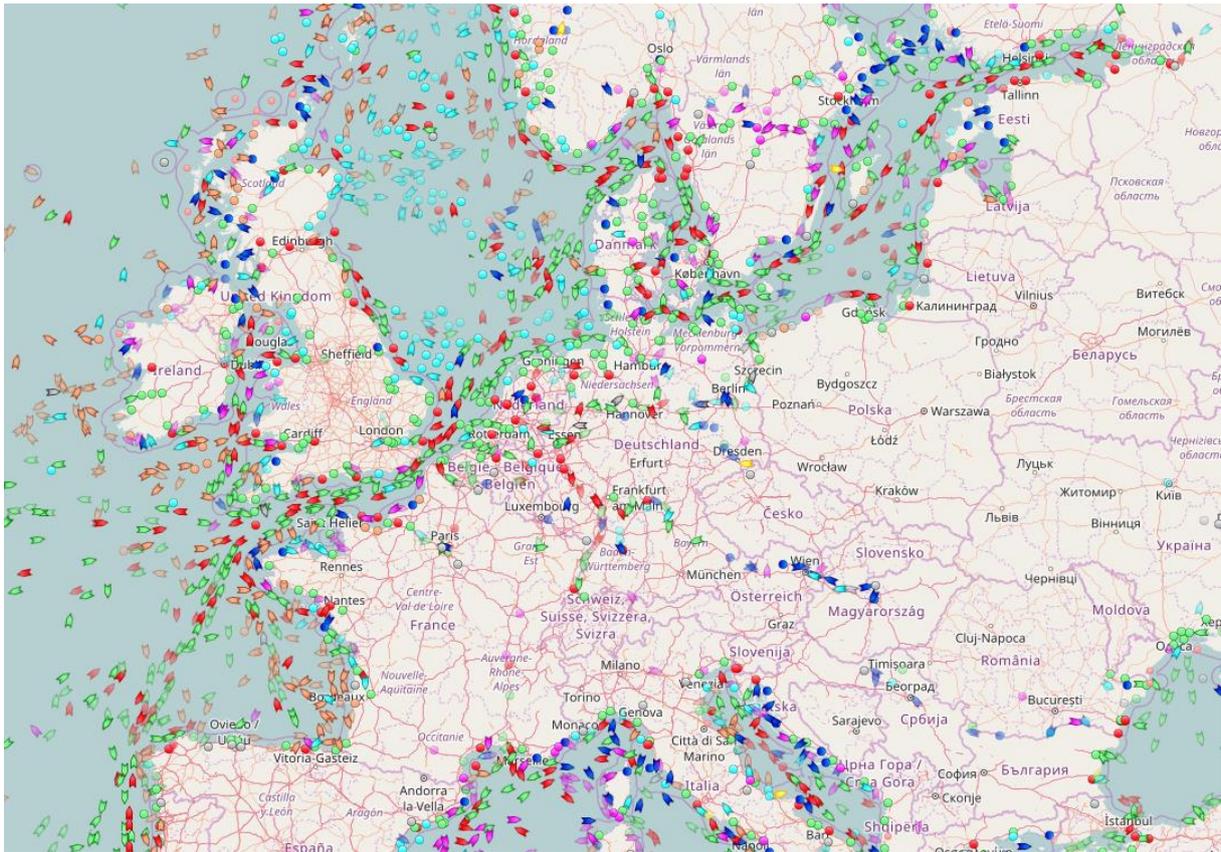


Figure 22 - Screenshot of Marine Traffic (2017), a company that displays vessel positions real-time on a map.

The systems of CARU containers are custom-made to the wishes of the relevant employees and highly automated. For the debtors there still is a matter of human touch and sense involved. For the payments of the bills there also exists a degree of human control and monitoring.

What became clear during the interviews is that CARU containers is very advanced when it comes to technology. Mainly CFO Rob Feenstra is responsible for this improvement; he thinks it is important to keep up with these developments. I cannot agree more, you have to keep achieving progress continuously in order to stay competitive; you cannot get behind because the risk will be getting overtaken by another player in the market.

As already became clear in Figure 21, both new and second-hand containers are bought by CARU containers. The company serves two different segments of customers as is showed in Figure 23.

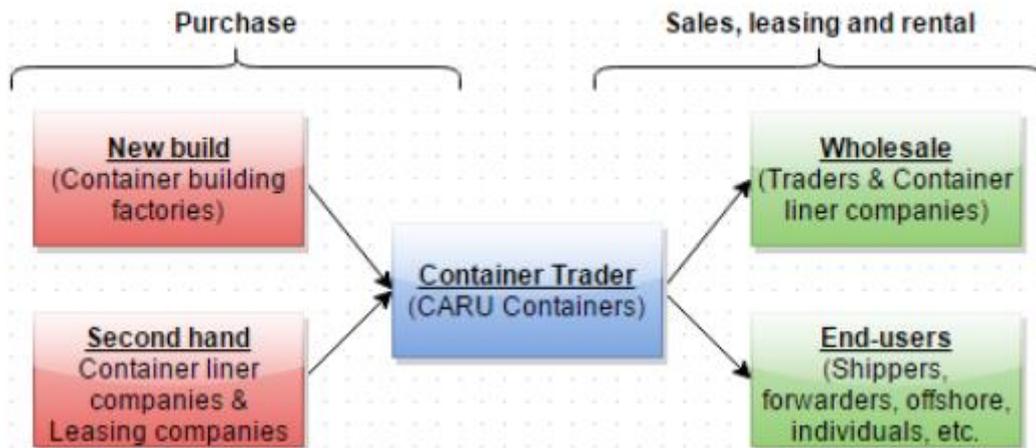


Figure 23 - The suppliers and customers of CARU containers (de Bruin, 2016)

The first segment of customers is wholesale. Sometimes these customers buy more than 30 containers per year. The end-user usually buys smaller amounts and the containers are only sold to this type of customer when there is a local office in that area (de Bruin, 2016).

4.3 Why blockchain and why CARU containers

The question might rise why blockchain is an important development specifically for CARU containers. As illustrated in the previous chapters, blockchain can be important for all kinds of companies in different fields. CARU containers can be faced with blockchain regarding insurances, government services or taxes, for the storage of all kinds of documents and for software applications and the proof of ownership.

As a selling and renting company CARU containers can be an actor in the supply chain of Figure 18 and Figure 19. Moreover, the containers that are rented and therefore still owned by CARU containers all have their own central role. With the container having revolutionized the entire transport industry (Leggate, McConville & Morvillo, 2004), there are probably not much supply chains without any containers involved.

Blockchain can actually be a big threat for the core business of the company as will also turn out when discussing the scenarios. Presently the firm serves as some kind of 'information broker'¹⁵, an intermediary that connects businesses that have containers with businesses that need containers. There are no value-added activities other than making use of the information asymmetry that is present. Sometimes the company

¹⁵ According to the Business Dictionary (2017) an information broker is a person or firm who locates and resells secondary (already published or otherwise available) information, such as articles, citations, competitor data and research data. Another type of information broker is meant in this article, that is why the term is between quotation marks.

literally only buys a container at location A and sells it with an additional margin to another client at location B again.

The most important reason however of why blockchain is specifically interesting for CARU containers is the development within Maersk and the cooperation with IBM in order to launch an industry-wide supply chain solution with a blockchain basis. Maersk and MSC often are cooperating. Recently it was announced that Maersk, MSC and HMM officially launched a new strategic cooperation on East-West trades (Maersk, 2017). With that in mind it will only be a matter of time before CARU containers will be confronted with the blockchain technology via Maersk and MSC.

4.4 Scenario planning

Below, three different outlines of the supply chain in the future will be given in relation to blockchain. Also the consequences for CARU containers will be described together with the best strategy to follow in that specific scenario.

4.4.1 Scenario 1 - blockchain fully implemented

In this case blockchain is fully implemented within a couple of months. The problems of scaling and security have been overcome at fast pace and the standards are set. Of course, once in a while there is a security breach discovered but this is comparable or in any case not worse than in the present situation without blockchain. All the applications that are mentioned in the previous chapter are used in the health and insurance industry, software and music world and the public sector. The documents of the supply chain of Figure 19 are put on the blockchain and accessible to every relevant party, by whom they can be signed or checked whenever necessary. Because of the application of smart contracts not a lot of calling, faxing or emailing has to take place anymore like in the flower-case of Maersk. Blockchain has been offering a lot of transparency in the supply chain but the consequence is that companies were also forced to give up a substantial amount of their secrets that basically were serving as a competitive advantage. With blockchain it can be found out where a company got its raw products from and how they are transported, processed and stored. Not every individual has direct access to every part of the blockchain but this information can be leaked or deduced and therefore the business plan can quite easily be copied. The emphasis is laid more on resources that are somehow exclusively available to an enterprise and on human skills and capabilities.

Most of the actors of Figure 19 do still exist as blockchain is not able to replace carriers or buildings. The big advantage is that carriers can communicate with each other via a blockchain platform or that most of the transportation and logistics activities can even be arranged automatically with the help of smart contracts. Possibly all the

containers have been converted into smart contracts and maybe they can book their entire journey on their own without any human intervention. In other words: the transaction costs of Coase and Williamson have been reduced to nearly zero. For companies that are not involved in any value-adding activities this is a huge problem. An example can be found in the earlier mentioned 3PL that does not own any warehouses or centers. If the 3PL was only involved in calling carriers and arranging storage, with this scenario that party most likely has disappeared out of the supply chain. No calls have to be made anymore to shipping lines and warehouses to verify whether or not there is any capacity available. The so called pure information brokers have become obsolete since all the information can be found on the blockchain against hardly any costs. Blockchain has replaced platforms like eBay and banks as payments take place via bitcoin or a similar cryptocurrency. Institutions for loans and insurances will still exist but every other intermediary that does not add any value directly to the product is absent. The supply chain has become as pellucid as it can be.

4.4.2 Implications of scenario 1 for CARU containers

This scenario is detrimental for CARU containers. The main activity of the company is basically being an information broker. Containers are either bought new or second-hand and sold or rented again with a profit margin. Every activity such as painting the container, transport or repair is done by third parties. With information publicly accessible on a blockchain containers can directly be bought from the container building factories or the shipping lines. So in case of a sale CARU containers becomes completely obsolete. The company may still rent or lease containers, but based on the current ratios the company will then shrink with roughly 60% (CARU containers, 2017). This is without taking into account that blockchain also can have consequences for the whole rental and leasing sector. It can be imagined that because of the transparency the margins on renting and leasing will converge and the profit will decrease even more or that containers can fully arrange their own rent, transport and repair via smart contracts.

Based on this scenario the future does not look favorable at all but the problem is that CARU containers cannot do anything about it. There should be a complete shift of the business activities in order to be profitable and durable in the future. Contrary to owning the plain information, the question is whether or not the company has knowledge that can be valued just like the knowledge and capabilities of a lawyer. Despite the fact that the law and jurisprudence can be found by almost anyone, the lawyers have not become obsolete due to their knowledge and specific skillset. Knowledge can only be stored in brains (Infogineering, 2017), although the deep learning of machines might be able to change this characteristic as will be explained later. If (the employees of) CARU containers can make itself valuable by providing knowledge due to the years of

experience in the container industry, for this application of knowledge can be paid by the clients in the form of consultancy services. It is doubtful however if the knowledge of CARU containers is that specific and valuable enough to make it sustainable. In any case the pure role of 'information broker' will not suffice; the entire core business needs to change or the company will cease to exist.

4.4.3 Scenario 2 - blockchain has disappeared

In this scenario blockchain has completely disappeared from the entire supply chain and the rest of the economy, for example because of the decisive problems of scaling and security. Another reason can be that the 'bubble' of bitcoin has been popped; the big rise of the price of bitcoin can all of a sudden also go in an opposite direction and cause a snowball effect for other systems that are based on blockchain. It can also be that the increasing cyber- and ransomware attacks have made people more scared of using the computer and communication via networks so that in the future even more paperwork will be introduced again.

Compared to the current situation, of course for this scenario there are not a lot of changes in the supply chain, it will more or less look the same as in Figure 19. Probably the trucks, logistics and terminal operations are more automated but there is still communication necessary between the different stages of the supply chain. The existence of information brokers is therefore more or less guaranteed. There is even a chance that a completely new paradigm has come and that we can speak of 6PL and 7PL that can for example sort the aggregate demand based on the nature of the goods and even take care of a better bargain. In this scenario there might be a possibility that the supply chain will be getting less pellucid and that all kinds of extra parties are involved.

4.4.4 Implications of scenario 2 for CARU containers

When blockchain is not implemented at all there is no risk regarding this technological advancement for CARU containers. It is important to keep up with the other developments but with Rob Feenstra as CFO, the current frequency of meetings and the open culture, this will not be an issue. The company can go on with its activities of the sale, rent and lease of containers. Perhaps CARU containers needs to get involved with more parties as the supply chain might be getting more complicated. Again, this will not cause any serious problems as the core business can continue.

The only downside may be that payments still need to be done via the bank and it still is hard to track and retrieve the containers that are rented or leased, but not paid for. Hence, the transaction costs will stay of the same proportions.

4.4.5 Scenario 3 - gradual introduction of blockchain

In this case blockchain will be introduced into the different sectors gradually. Several pilots are done and with trial and error is found out what does work and what does not work. This all will happen at a slow pace and during the years the standard are set. Some of the documents and activities are indeed put on a blockchain and different blockchains can be connected with the one- or two-way pegs. However, also a lot of information is purposely not put on a blockchain. At one side because companies do not want the information to be partially public but at the other hand also because this takes too much space, especially when you take into consideration that every party needs to have access to the same information including the information that other parties have access to. Next to that there is still the problem of the maximum amount of transactions that can be processed related to the computer power and energy consumption. For the blockchain often the master or supervisor option of Figure 14 is used to have some kind of control on the transactions and activities. Slowly but steadily smart contracts are getting accepted in the chain as well, but certainly not everything will be arranged by the contracts themselves.

The banks play a less prominent role but are still necessary for the system to work, for payments both bitcoin and similar cryptocurrencies can be used but also the option of transferring 'regular' money via a bank still exists. The supply chain as depicted in Figure 19 with its actors can stay intact for the biggest part. It is likely however that again the 3PL without any own assets or value-added activities does not have a very profitable business case in this scenario. The arrangement of transport and other supply chain activities can easily be arranged as the blockchain will reduce the transaction costs to almost zero over time. Most probably platforms like that of IBM Watson (2016) in Figure 20 will become the standard.

4.4.6 Implications of scenario 3 for CARU containers

In this case there are some less crucial consequences for CARU containers. The chances still are that containers will be directly bought via the blockchain at the container building factories and the shipping lines. In this scenario however this is less likely than in scenario 1; the problems of size, speed and security are still there and therefore only the most important information will be put on the blockchain. There still exists a certain amount of information asymmetry that can be used by information brokers. It is not profitable and therefore not possible to put the entire life cycle of the container from construction to demolition on a blockchain.

A big opportunity for CARU containers here is the fact that blockchain is not extant enough to completely make the company obsolete but that new possibilities are introduced thanks to blockchain. Maybe the project Zeecontainer.nl can be used and

extended. At the moment via this website containers of CARU containers can be directly bought and get delivered within two days. The biggest part of this process goes automatically and the containers are stored at depots of CARU containers.

With blockchain the website can be extended into the standard platform on which container building companies can put their new containers, shipping lines and other parties offer their second-hand containers and anyone interested can buy them while the containers stay where they are offered. Together with the current system and smart contracts the relevant transporting companies will automatically be notified and when the process is complete the container is removed from the website so that there are no availability problems. Given the level of technological advancements CARU containers would be a very appropriate company to take this role. The profit margin on the newly bought containers may decrease but at the other hand so does the amount of effort that is required. Still, a significant - but maybe lower - quantity of containers is bought via the regular current procedure as well just like the website is existing next to CARU containers now.

For leasing and renting maybe smart contracts can be created with which the container will be able check his own availability, sign the contract and rent itself whenever possible. Activities like checking damages and arranging repairs still need to be done by humans since that is too complicated for a smart contract, just like the arrangement of transport; compared to a normal sale there are a lot more combinations to make regarding transportation companies and locations of pick-up and drop-off. Other than that blockchain can be used to better link the current programs within CARU containers and to make real-time information updates. In this scenario blockchain will definitely be more a benefit than a burden and with some adjustments the core activities can continue. Here, the possibilities need to be explored over time in collaboration with the appropriate blockchain start-ups.

4.4.7 Scenario probability and overlap

In my opinion, the first two scenarios are equally unlikely. There are too much side effects of blockchain to completely make certain parties disappear but the potential is too big to not find its application in the economy at all. The actors in the supply chain recognize the options and are fairly positive about blockchain (Hackius & Petersen, 2017). The third scenario seems the most likely but within this scenario still a lot of variation in presence is possible. Regardless of the scenario the developments need to be followed meticulously by CARU containers in order to correctly predict to which scenario the company is heading and to take action accordingly.

What can be seen in all the scenarios is that the supply chains of Figure 18 and Figure 19 do not change a lot. This is because blockchain is not able to replace the physical infrastructure, it replaces trust and mostly it facilitates. The trend that now can be discovered is that documents of this physical infrastructure are increasingly becoming digital. Blockchain can also facilitate this paper trail but it does not offer a lot of advantages compared to normal storage in the cloud. In fact, blockchain might not even be the appropriate method for this type of storage as the processing goes relatively slow and when done no changes can be made at all; in that case another transaction needs to be conducted which also needs to be mined again.

The power of blockchain in the supply chain is in the smart contracts and the automatic execution of the conditions. It would be very convenient when for the transport from A to B only one system has to be checked instead of logging into different portals of several carriers while trying to fit a schedule. At the moment that the booking is finished, every relevant party gets notified including other potential customers. The comparison can be made with the reservation of a seat for a specific performance in the theater. After successful payment other potential visitors are also made aware of the fact that this seat is not available anymore by for example turning it from green to red. In this comparison the basics are the same but the supply chain is of course a lot more complicated regarding the type of goods, type of containers, origin, destination, time span and parties involved. That is also the reason why I think that it is a matter of years until blockchain has become a commonality here.

4.5 Blockchain and CARU containers

In any case it is possible that CARU containers will maybe within a couple of months be confronted with blockchain via other companies that they are doing business with of which MSC is already mentioned. Through all kinds of insurances the company might put the next claim on a blockchain. Also registering new property via the government can take place in this way, although the question can be posed if indeed governmental institutions are going to be an early adopter of this system. Other than that blockchain can provide in general information and storage opportunities for businesses next to the cloud.

In the more distant future blockchain can help or counter in the development of CARU containers, given the different scenarios. As time goes by, slowly but steadily more companies are busy developing blockchain-based systems and discovering the pros and cons. When concentrating on the supply chain, currently there is a pilot in the port of Antwerp together with the startup T-mining where blockchain needs to make sure that the interactions in the terminal are more automated and streamlined (Coindesk, 2017). In Finland the developments are going further, companies are working on a situation

where the containers know where they need to go and will become able to learn from past experiences and can improve their functionality (News BTC, 2016). This is called deep learning of machines. Just like human beings, systems can learn from what they have experienced in the past such as rough treatment or delay and the systems can anticipate on what might happen (SAS, 2017). In Greece the possibility of linking a hash to a container is investigated so that a container can automatically be tracked and typos are excluded (Foroglou & Tsilidou, 2015). As a freight forwarder, Marine Transport International is trying to use blockchain for the verification of containers (Data IQ, 2016).

The outcomes of the projects and pilots will become known after a while and it is predicted that through this process blockchain will gradually play a bigger role. Of course a lot of money is involved but can also be earned back when successfully investing. It might be better for CARU containers to not take part in these big investments regarding blockchain yet as it is still too unclear what the results will be. It is expected that there is nothing to become restless or worried about in the coming months. However, there is one exception mentioned in scenario 3 which can be very beneficial but should be started small just like the website Zeecontainer.nl.

For the reservation of space within a container blockchain can already offer solutions right now. It is possible to convert a container into a smart contract with which appointments can be made regarding storage. In case of a full container for the time requested the contract will not be signed. This kind of application can be built in one week by a company called Cegeka (2017) and is tailored to the preferences of the client. Although CARU containers does not offer mere storage in a container, similar applications for the rent of complete containers can possibly be built as well which is a very interesting opportunity for this company right now. If this pilot is going to be run, it is recommended to first start with only one or three containers or so to see how this theory works in practice and to keep the financial risk and the risk of putting the good name of the company at stake as low as possible.

Chapter five - conclusion

After all the information gathered, ordered and given in the previous chapters, in this chapter the conclusion will be drawn together with recommendations for further research and for CARU containers.

5.1 Blockchain through time

Blockchain started in 2008 during the credit crunch with a paper under the pseudonym Satoshi Nakamoto. It introduced a complete new digital method of doing payments on the basis of a system that both makes trust and intermediaries such as banks unnecessary. With Nakamoto being the first to solve the problem of double spending this way, he was able to create a public ledger that is distributed amongst all its users while being synchronized and cryptographically secured. In principle with bitcoin or the alternative coins that were created afterwards you can pay any business and any individual.

Blockchain, the underlying system, is even more promising. In combination with smart contracts and easy storage this basis can offer a wide array of applications within every industry and sector and different companies are exploring this at the moment. Because it is still in its infancy, there are a number of problems concerning privacy, scalability and speed.

Money as we know it today emerged during time because it was very hard to trade on the basis of a barter economy. One universal medium of exchange was needed; at first this material was valuable of itself, later it was valuable on the basis of a general agreement like the dollar or euro. As the distances between trading partners became bigger during time, the demand for a third party arose that could be trusted due to the lacking dense informal network. With blockchain and cryptocurrencies both the need for trust and third parties in transactions can be taken away again, which can result in a new paradigm in the economy.

5.2 A new revolution

With the blocks even being similar to little containers, will blockchain be the new revolution in the supply chain after the container? Without going too deep into detail about this definition linguistically, I am moderately optimistic. At the one hand there are still a lot of problems that need to be overcome regarding mainly security and scalability. A credit crunch like in 2008 for example with bitcoin indeed seems unlikely, but because

the cryptocurrency only exists for ten years maybe another type of crunch is possible, when the 'faith' in bitcoin suddenly disappears, for instance. When comparing stability and volatility the choice for bitcoin is discouraged but also this can change over time. Regarding global warming blockchain cannot take away this problem as it does not replace carriers. What it can do, is replacing some of the communication but at the downside the whole process of linking transactions and mining does cost a lot of computer power and energy. All in all there are still a lot of uncertainties.

At the other hand, blockchain can provide transparency in different sectors and give a better overview. It can serve as one platform for all the parties involved on which information can be put. With the exception of a few clauses, contracts can be drafted and automatically checked and executed which can become a great advantage in the information structure in the supply chain. However, I think the prediction of the WTO that the total trade volume can increase with 15% solely because of blockchain (IBM Blockchain, 2017) is too optimistic. Blockchain can offer support, clearance and take over a part of the work in transactions, it makes the process more efficient and reduces some of the transaction costs significantly. Next to that it can take away trust, irritation and unnecessary effort on an individual level but still a lot of work needs to be done to physically move products. Because the world trade is better facilitated it might increase to some extent, but I do not think with this magnitude. Two more extreme scenarios were given of what blockchain can or cannot do in the future, the third scenario was the middle ground and the most probable. The conclusion can be that instead of a disruptive revolution blockchain can better be seen as a gradual evolution in the coming years.

5.3 Recommendation for further research

With blockchain being relatively new, the recommendations for further research would be in the area of the bottlenecks of blockchain that are mentioned in this thesis, especially in the field of scalability and security. So far blockchain has been infallible but it would also be recommended to test this statement extensively in all kinds of ways before it becomes a worldwide regularity. Maybe with the traditional definition and methods of hacking, the system is indeed completely perfect. However it can be imagined that the data is changed somehow beyond the blockchain without breaking the chain with a mechanism that is unknown so far. Or would it be for example possible to change the content of the last block in such a way that the first four digits of the hash will still be zero and the block will stay green? Can a computer achieve this situation with trial and error with the same technique as the normal mining takes place now? If that is the case, the 'truth' can be changed in an irreversible way and the consequences will be radical. With loads of computer power available in the future, the chance of a 51%-attack might not be that unimaginable either.

In any case, the applications that were built on blockchain are definitely not watertight as appeared for example with bitcoin. When taking the supply chain into account: can we really introduce this system in developing countries when documents are sometimes still getting stuck in traffic or is this the exact reason that it needs to be implemented preferably sooner than later? There are numerous questions unanswered and the logistics and supply chain management research on blockchain is still in its infancy (Hackius & Petersen, 2017).

Yet, quite an amount of solutions need to be found and a lot of applications can still be invented. Next to that, also regarding the user friendliness of the systems some gains can be made. In order for businesses and individuals to make use of the possibilities, it is important to make clear in which situation blockchain can be used and what the consequences are. Currently there still is some mystical atmosphere hanging around it.

5.4 Implications for CARU containers

The implications and value for CARU containers hopefully has become more clear. Maersk is busy with pilots regarding blockchain in cooperation with IBM. If it is going to be successful, partner MSC will also be involved or at least be confronted with the blockchain-system that Maersk is going to introduce on a big scale. With Maersk being one of the largest shipping companies (Marine Insight, 2017) and often pioneering company and trendsetter (JOC, 2009 & Shipping Watch, 2013), it is highly likely that more shipping companies and other actors in the supply chain are going to follow this tendency and will work with blockchain in the future as well. Moreover, blockchain is perhaps going to have a more central role in the entire financial sector on the longer term.

Direct action of CARU containers at this moment is not necessarily required, but the company needs to be on its guard and follow the developments of blockchain very closely as it is able to replace a significant portion of the business activities of CARU containers. Furthermore it is recommended to have a meeting with the company Cegeka about the creation of smart contracts in combination with the rent of containers. The possibilities for both now and in the future need to be explored.

It is better to be prepared than to be surprised, hence this thesis. The value of it is in the offer of a good overview of the current situation of blockchain while illustrating several aspects without trying to be all-embracing. In fact, on a management level of any company this paper can be supportive, but for CARU containers this contribution is specifically important because of the description of the supply chain and container sector, the activities of CARU containers and the given scenarios and recommendations.

5.5 The future

Without a doubt, both now and in the future blockchain can definitely be helpful but it is important that we do not expect too much of the new technology. When having a hammer it is tempting to treat everything like a nail, however it is not the all-time solution to most of the problems in the world. During time both new applications of blockchain and integration of the technology into the current systems will provide a better physical, financial and information flow.

When more and more millennials will graduate and be getting jobs at companies, the implementation will perhaps also go faster and smoother as this generation grew up with a lot of technological advancements. Millennials understand the power of technology more than any other working generation (Downing, 2006) and most of them are comfortable with and enjoy using technology (McGlynn, 2005). It is not illusory that the Generation Z, the generation after the Millennials, will even have more feeling with (the possibilities of) technology. Only time will tell how technology will progress, whether or not blockchain is included and to what extent. In the end, the past cannot be changed and the future belongs to those who create it.

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Blockstream	- www.blockstream.com
Bitcoin cash	- www.bitcoincash.org
Blockverify	- www.blockverify.io
Cegeka	- www.cegeka.com
DASH	- www.dash.org
Everledger	- www.everledger.io
Factom	- www.factom.com
LAB15	- www.lab15.io
Litecoin	- www.litecoin.org
Mendix	- www.mendix.com
Namecoin	- www.namecoin.org
Peercoin	- www.peercoin.net
Pixelbar	- www.pixelbar.nl
Primecoin	- www.primecoin.io
Provenance	- www.provenance.org
Safecoin	- www.maidsafe.net
Solas VGM	- www.solasvgm.com
T-mining	- www.t-mining.be

Appendix

Interviews employees CARU containers

To get a better insight into the course of events and the accompanying documentation, interviews were held with employees in the office of CARU containers Rotterdam. A summary of these interviews will be given below.

Account management, Allard Langenhuijsen

Mr. Langenhuijsen is an account manager on an international level, for example he is responsible for the contact with customers in South-America. This interview was mainly exploratory. He wanted to know more about blockchain and what it could mean for CARU containers while I was interested in the activities of the company.

Although the company mainly buys second hand containers from MSC, also containers are bought from other shipping companies. The containers that are sold or rented can only be followed via the programs that are offered by the actors in the supply chain, for example the container status of the services of ECT Rotterdam (ECT, 2017) or the possibility to trace the location of the ship on which the container is travelling via Marine Traffic (2017), of which a screenshot of a part of Europe is given in Figure 22.

Those programs give a possibility to see where the rented containers of CARU containers are, but it also happens that after a sale the containers are bought back from the customer to sell again to another customer. For the initial customer there is a guarantee to get a decent price for the container while at the same time CARU containers can prevent that the containers are dumped on the market for a price that is way too low and thereby lowering the container rates in general. This course of events also contributes to a long and durable relationship with the customer.

Credit management, Simone Ewijk

Ms. Ewijk is solely responsible for around a thousand debtors of the company. Where normally the maximum amount of debtors for one person is somewhere around 300, ms. Ewijk is able to handle a higher amount on her own because of the tailor made IT-system that the company is working with.

Usually a customer is always linked to one of the account managers. In case of selling containers and a total amount of below 5000 euros, in principle the customer always has a credit of 30 days, however also the common sense of the relevant account manager is appreciated. For amounts above 5000 euros a credit check is done. For this credit check there is always made use of the services of the company Dun & Bradstreet

(2017). The software of the credit management is custom made to the wishes of ms. Ewijk and partially automatic. Usually the customer has 30 days to pay the bill. When payment is not received two days after the expiration of the period, the customer will receive a reminder. If the payment still has not happened after nine days, an admonition will be sent that is more pressing. 20 days after expiration the customer can expect a phone call to see whether or not the invoice may have mistakenly be overlooked or if maybe the e-mail address has changed in the meantime. After around 100 days that the debtor is in default, after multiple calls and when the account manager has also tried everything possible, the claim will be referred to a third party for collection. Next to that customers can be blocked for granting new credit for a payment, based on the amount or the time outstanding. In that case they first need to pay the previous invoices. With regard to the rent of containers, things more or less work the same. A big advantage is that there is more leverage as the rented container can ultimately be recovered.

The customers that need to be reminded, need to receive an admonition or a call automatically appear in the 'to-do list'. It is even possible to automatically send emails with information, but the decision is made to no do that. Credit management also is a matter of a human touch and sense. The information that is obtained during this process can all be put into the same program to which the entry is also linked. This makes sure that in case ms. Ewijk is not present, other people can quite easily pick up her work.

Zeecontainer.nl, Lennart de Bruin

Mr. de Bruin is project manager of Zeecontainer.nl, a platform on which both new and second-hand containers can be put in a shopping cart, bought, paid and will be delivered after two days. During his traineeship at CARU containers, this idea rose when working together with the management. The URL was actually obtained from one of the companies that was taken over and during brainstorming there was an ambitious plan to become the Amazon.com of shipping containers. Because that required a lot of investments, the start is slightly smaller.

The big advantage of this platform is that almost everything is automatized. After registration on the website the customer will automatically be put into the system. After successful payment (which needs to be done in advance), the closest and cheapest partnering transporting company will automatically receive a message which container needs to be picked up at which depot and where it needs to be delivered. In the past half year around 600 containers are sold this way.

Because the system is almost fully automatic, mr. de Bruin is the only one who is involved in this project except for of course the transporting companies. He spends around 10 hours a week for Zeecontainer.nl, which is mainly answering questions from potential customers. The rest of the week he is doing work for CARU containers. Although

Zeecontainer.nl is a part of CARU containers, this is not made clear on the website. The platform is created as an experiment. If it turns out to be successful, it can be scaled. In any case the good reputation of CARU containers is not endangered. Since Zeecontainer.nl is the first platform on which shipping containers can be bought this way, the company can still grow a lot and become a market leader. After having established the teething problems, it can still compete with Amazon in the future by making one big automatic system with for example relatively cheap RFID chips and algorithms with which containers can be scanned and tracked during the process. The difference is the amount of capital available between a company as CARU containers and Amazon. Another disadvantage that mr. de Bruin experienced is that the prices can be directly seen on the website, not only by the customers but also by the competitors that take action accordingly.

Financial administration, Dennis Paantjens

Together with the accountants, mr. Paantjens is responsible for the official financial statements at the end of the year. He is involved in the monthly and quarterly individual financial statements of CARU containers Rotterdam and the yearly consolidated numbers of the entire company. In total the company consists of around 15 businesses with limited liability. Because of this amount of separate entities it is sometimes hard to find out why some of the numbers do not match while they should, although the problems are quite small. Roughly estimated, of the profit made in 2017 in the first quarter 60% comes from the sales of the containers and 40% from the leasing and renting.

Similar to the debtor system that ms. Ewijk is working with, also the creditor system is highly automated. Invoices of suppliers and other partners can be sent to a specific e-mail address. From there on, they are put into a sub-map in which software is able to scan the invoice. The creditor can be recognized and linked. All the data that can be read from the invoice is put into a template. This is checked after which it can directly be paid. The whole idea of automatization of these processes started in 2013. Where in the past the office was filled with cabinets with folders, currently all the 'paperwork' is stored on hard drives. The company is completely paperless, which makes it slightly vulnerable for a cyber-attack.

What became clear during this interview is that CARU containers is very advanced when it comes to technology. Mainly CFO Rob Feenstra is responsible for this improvement; he thinks it is important to keep up with these developments in order to stay competitive. I cannot agree more, you have to stay progressive continuously in order to stay competitive; you cannot get behind because the risk will be getting overtaken by another player in the market.