Blockchain in Logistics

Is blockchain in logistics hyped, or has it true potential to be a game changer?

Sander ter Stege
University of Twente
PO Box 217, 7500 AE Enschede
the Netherlands

s.terstege@student.utwente.nl

ABSTRACT

The paper investigates the application of blockchain in logistics on true potential. Also, for each application, a time estimation is given for the adoption of blockchain in logistics. In order to have a grounded view on the potential of blockchain technology as a whole, a literature review is done on the strengths, weaknesses, opportunities and threats of blockchain technology, which are summarized a SWOT diagram. Besides, a literature review and expert interview are done for applications of blockchain in logistics. This resulted in "Track and Trace" and "Digitalization of paperwork" as main applications of blockchain in logistics, of which "Track and Trace" has high potential to disturb logistics on the short-term, and "Digitalization of paperwork" can be useful in logistics on short-term.

Keywords

Blockchain Technology, Logistics, Supply Chain Management, Potential

1. INTRODUCTION

Blockchain is an upcoming technology already being active in the logistics and finance sectors. Several multinationals with processes in logistics are investigating how blockchain can support their processes and empower their organizations [2, 22, 47].

Blockchain is a digital ledger handling additions or adaptations of data in a chain structure [6, 19]. The digital ledger is saved at (all) users' computers which makes everyone owner of the data. For privacy reasons, the data is made senseless by the use of hash codes to prevent every user to be able to see all data concerning other users [49].

Blockchain functionality can be extended by the use of smart contracts [8, 31]. Smart contracts are small pieces of code which will execute an action if a certain condition is met. Smart contracts are an interesting combination with IoT. It gives blockchain the ability to reach consensus between parties to execute an action if a given condition is met. According to Yuan, Xia and Chen et al. (2017), the use of smart contracts even has potential to automate trusted third parties' activities, processes which were unable to be automatized before blockchain technology [11].

Several logistics processes can be supported by blockchain technology [27]. Due to the possible high potential of blockchain in (global) logistics, blockchain might be got in the position of being hyped over its true potential. Blockchain is even seen as a technology with the potential to be as great of an influence as TCP-IP was which laid the basis for the internet as we know it today [4]. A hype can cause organizations and researchers to overestimate the true potential blockchain can have in logistics and thereby be inaccurate in describing the true potential. Are the statements about blockchain in logistics part of a hype, or is blockchain in logistics a true game changer?

To measure whether the current state of art is not overrating blockchain in logistics in terms of its potential, the research paper will identify whether current statements are reflecting the true potential of blockchain in logistics, or whether the current statements are influenced by a hype and are thereby not representing the true potential of blockchain. Following the above, the research question below will be central in the research paper:

What is the true potential of blockchain technology for the logistics field?

To get a complete picture of blockchain in general, blockchain in logistics, and to conduct a grounded answer to the research question, the following sub-questions are answered:

1. *What is blockchain and how does it work?*
2. *Where and how can blockchain be applied in logistics?*
3. *What is the potential of blockchain applications in logistics in the short term?*
4. *What is the potential of blockchain applications in logistics in the long term?*

2. BACKGROUND

2.1 Blockchain

Blockchain is a database but differs from traditional databases. Traditional databases are active on one Database Management System which is saved at one or more places [35]. By design, a traditional database's data can be altered by all users without the adaptations being traced [29]. Databases which are not secured properly can lead to users falsely changing or copying

29th Twente Student Conference on IT, July 6th, 2018, Enschede, The Netherlands.

data without being noticed. In traditional databases, this is usually prevented by building in restrictions to prevent false adaptation of data [35].

Blockchain is a digital ledger handling blocks of transactions in a chain structure and is distributed over (all) users [6, 19]. A transaction is an addition of data. Transactions are collected in blocks which are added to the chain of blockchain. Those blocks are chained by referring to the hash of the previous block [6]. The hash value is a sort of ID of a block based on the content in the block [49]. A change within a block will lead to a change in the hash of the block which makes blockchain tamper-free [19]. This makes blockchain technology immutable by design. Blocks of transactions are verified before adding to the blockchain to ensure all data in the Blockchain is in line with the rules implemented in the blockchain [19]. Figure 1 is an example of how the structure of blocks in the blockchain could be implemented, including the type of data saved in the blocks [49]. TA is short for transaction and timestamping is a way to notate the time the block is added.

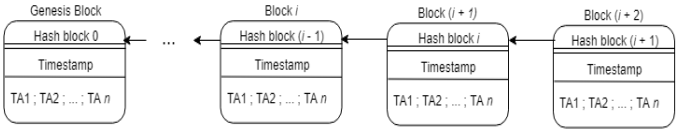

Fig. 1 Blockchain example (Zheng et al. 2016) [49]

2.2 Smart Contract

Smart contracts are advanced transactions through the use of scripts in addition to the data of the transaction [8, 31]. The term "smart contract" is often referred to as a replacement for traditional contracts [38], instead of relating to its more general use. Smart contracts extend the use of blockchain by supporting conditions before or after executing a certain task. Ethereum is a blockchain example which supports scripts. This support can be used to implement financial derivatives in the form of smart contracts but can have other uses as well [8]. The further implementation possibilities of smart contracts will be discussed in the Literature Review.

3. LITERATURE REVIEW

The literature research is done to construct a SWOT analysis of blockchain, containing the strengths and weaknesses of blockchain and its environment. Also, the literature research gives an overview of currently investigated applications of blockchain in logistics, including examples in development.

The literature research is done using the (digital) university library facilitated by the University of Twente, which includes databases of Scopus, Web of Science and Google Scholar. Due to the novelty of the field, more popular literature needs to be studied, including whitepapers and blogs. The literature research will be done in a structured manner, following the five-stage grounded-theory method to systemize the reviewing process [48].

3.1 Blockchain SWOT Analysis

To outline the true potential of blockchain technology in logistics, it is important to analyse the opportunities and issues of blockchain technology in general. To do so, the SWOT analysis technique is used to make sure the blockchain is analysed in a structured way. The SWOT is summarized in figure 2 given below. Each component of the SWOT analysis is discussed in the following sections.

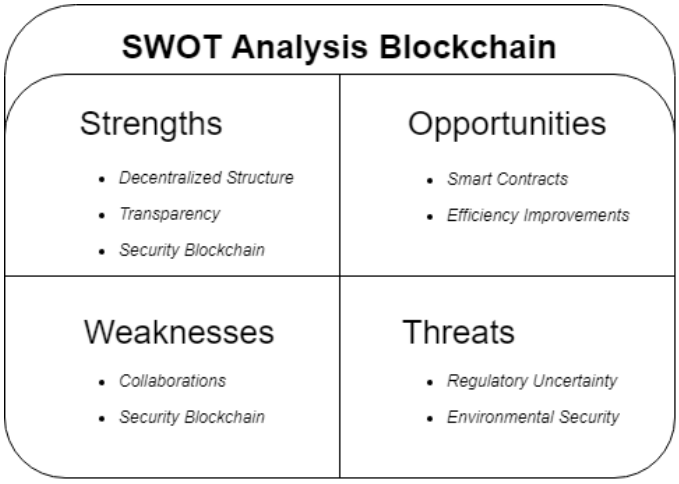

Fig. 2 SWOT Analysis Blockchain

3.1.1 Strengths

Decentralized Structure

Decentralized refers to the lack of a central authority that maintains, validates and controls the system [4]. Blockchains are run by its members [19]. This structure implicates that the users of the system do not have to rely on a central authority that established trust [19]. Every action a blockchain does is executed by its members, which is intended to save costs and increase efficiency [49]. Besides, the decentralized structure opens doors to new decentralized business models and decentralized politics, though these applications are yet to be designed [12, 37].

On the contrary, Abramova and Böhme (2016) are a bit more sceptical. A survey they conducted revealed Bitcoin users see decentralization as the smallest benefit of blockchain [1]. The scepticism might be influenced by the application blockchain is used, since the Bitcoin does not fully exploit the possible advantages decentralized systems can have. Besides, Bitcoin users might not be interested in the techniques behind blockchain, but see blockchain as an investment platform to make money. Thereby the outcomes of the survey might not reflect the true value of the techniques behind blockchain technology.

Transparency

Traditional systems cannot cope with the demands of the complex supply chains. According to Kshetri (2018), there is a "*severe lack of transparency and accountability across complex supply chains*" [27]. A blockchain is a transparent system which solves that problem: every stakeholder has access to and maintains the same shared dataset creating a single point of truth [19, 22, 40]. Each user on a blockchain can choose to remain anonymous or provide proof of their identity to others [24]. It depends on the system how this evidence is given. In case of Bitcoin, this is given by a digital "signature" in the form of a hash code [33]. Transparency can increase trust by revealing all data in the blockchain, though it depends on the application of the blockchain whether that is desirable.

Security Blockchain

Single servers represent a single point of failure and raise data security concerns [19]. Though several methods exist to minimize the risk of being hacked and to minimize the effect of data breaches [32], there still is a risk for the database owner of a traditional database to give access to all data, once

breached by a hacker [22]. Besides, the intermediary of a traditional database can see all data, which leads to a trust requirement by the users in the intermediary [34]. To solve that problem, blockchains use cryptographic methods. Through the use of cryptographic methods, data which makes sense is encrypted into a series of number and letters. Because of that, users can see a hash code in the blockchain, but cannot see the data behind the hash code [19, 22]. Typically, only the users legitimized to the data can read the decrypted data [34]. Besides, the consensus mechanism also causes an addition, change or deletion of false data to be rejected by the blockchain system. However, it is still to be researched whether this strength is a critical strength for users and if so, for what type of users. For example, elderly might find security more important than teenagers [26].

3.1.2 Weaknesses

Collaborations

Valuable blockchain solutions require not only strong internal changes at intermediaries, but also new organizational collaborations [3, 14]. The organizations' possible differences in culture and functionality goals for the blockchain system might differ. Thereby, blockchain systems which require collaborations could be harder to develop than traditional information systems.

Security Blockchain

Besides its unique security strengths given in the strengths section, blockchain technology also has security weaknesses which need to be dealt with. In 2010, organizations started to invest in computing power to mine in cryptocurrencies [49]. Nowadays, the Top 3 mining pools together own larger than 51% of the hash power in the Blockchain network and BTC.com already has 29,6% of the total mining hash power [9]. The platforms might come to the point that they have enough power to reverse the blockchain and completed transactions. Though it is unlikely to happen, it can happen and users should be aware of the risk. Developers should solve the flaw in the system to prevent possible reputational and financial losses of blockchain technology as a whole.

3.1.3 Opportunities

Smart Contracts

As there are more and more smart contract development platforms, more and more different smart contracts are under development [49]. Smart contracts have the potential to replace lawyers and banks that have been involved in contracts for asset deals depending on predefined factors [16]. Also, smart contracts might be used to control the ownership of properties in the future, both tangible (houses, automobiles) and intangible assets (shares, access rights) [34]. Use of smart contracts in these applications has the potential to significantly improve efficiency and transparency [6].

Efficiency Improvements

Blockchain has room for improvement when it comes to efficiency. In most cases, blockchain currently does the same actions more inefficiently than traditional databases [27]. The most well-known application of blockchain technology, Blockchain, is inefficient and has a massive cost base issue [34]. Nonetheless, according to Heutger et al. (2017) blockchain does have the potential to be an efficiently run system and is seen as a potential improvement compared to traditional databases [22]. This potential depends on the application for which blockchain technology is developed. Applications in logistics are examples of blockchain technology applied to improve efficiency by greatly reducing paperwork and bureaucracy [22]. The possible new applications to improve efficiency are an opportunity for blockchain to be more attractive for wide adoption.

3.1.4 Threats

Regulatory uncertainty

Legal questions have to be solved to implement contracts and ownership on the blockchain [6]. Yet, it is not clear whether a legal contract registered on blockchain would be valid or illegal. The requirements for a contract or ownership of a blockchain should be globally set to prevent legal mistakes. Besides, if the blockchain system somehow fails, who will be responsible? Finding a solution to this problem should be done in close collaboration with scholars of law and will take a long time to evolve [24, 36]. The Dutch Blockchain Coalition made a to-do list for the development of blockchain in 2017. They include the investigation of possible threats of the current Dutch law system for blockchain and will investigate this further [15].

Environmental security

Besides the pros and cons of blockchain security described in the strengths and weaknesses sections, the environment of blockchain needs attention as well. The environment of blockchain exists of all applications communicating with the blockchain. Several central sites for cryptocurrency exchanges have been hacked in the past, resulting in a high number of lost crypto coins [24]. From January until June 2018, already three cryptocurrency exchanges have been hacked resulting in the disappearance of approximately 600 million euros worth of tokens [21, 45, 46]. Those hacks of exchanges should not be confused with breaches within blockchain technology, but still reveal a weakness and financial risk in the environment of blockchain technology. In the case intermediaries are involved, as is the case at trading cryptocurrencies, the organization has risks to be hacked and this should be taken into account. These hacks might not be applicable on every cryptocurrency exchange. These hacks could be incidents which are harsh lessons for improving security. However, it should be something to take into account, since breaches might have the risk of a global decrease of trust in blockchain technology.

3.2 Applications Blockchain in Logistics

In order to get a view on how blockchain can be applied in logistics, a literature review is done on applications of blockchain in logistics. The literature review gives an overview of current applications which are investigated and possible new applications which could be investigated in the future. The section is structured from most to least promising applications. The applications are first broadly described and are followed by a description of at least two examples of applications in practice.

3.2.1 Track and trace

Track and trace can broadly be seen as the registration of information of specific products within a supply chain. Using

blockchain, the track and trace of complex supply chains can be transparent and fully automated [4]. Track and trace by using blockchain technology has several benefits. First, due to the transparency, security and immutability of blockchain, consumers can trust the origin of (components of) the bought product [4]. This could be useful for organizations to show transparency of their process and increase trust of consumers in their organization, processes or products. It can also be useful to trace back failed products more efficiently, as is shown in the IBM and Walmart example. Besides, origin tracking by use of blockchain could be useful to give customers the ability to precisely track where their product comes from and whether a fair price is paid for the product [4]. An example of such an application is Bext360, which is developing a blockchain to track products such as coffee, cacao and palm oil with the goal to see whether the farmers were paid fairly [5].

Internet of Things (IoT) can be used to advance track and trace. Using IoT the current and past locations of products, packages and containers can be real-time tracked. Besides, IoT has the potential to enable real-time measurements of other variables such as temperature which might be useful for food or medicines [25]. To advance tracking, the IoT system can support GPS tags and chips, sensors and barcodes [27]. Modum and Gemalto are two examples of organizations who are developing a blockchain system using IoT for medicine use-cases, though this paper will not elaborate on those use-cases [27].

3.2.1.1 Examples

IBM and Walmart

IBM and Walmart are cooperating to develop an origin tracking solution. In case of foodborne illness, Walmart wants the ability to track a specific load of products back [43]. According to IBM and Walmart origin tracking is useful for recalling a load of ill products to prevent people from falling ill due to foodborne deceases [43]. The effective recall of a specific load of ill products would be an improvement compared to recalling the entire product line [27]. Besides, having less broad recalls could lead to maintaining current consumers' confidence in products [13]. Currently, recalls at Walmart take approximately a week to complete [44]. Use of blockchain technology should lead to time reduced and more specific origin tracking to recall ill food loads faster and more precise. At February 2017, two pilots have been run and Walmart reported the first finished version could be ready "within a few years" [30]. May 31. 2017, Walmart reported they managed to reduce the origin tracking time to minutes [23]. Walmart expects the origin tracking time to reduce to seconds in the future [44]. Ultimately, Walmart believes Blockchain could also reduce food waste if newly available data on shelf life is used as the parameter for supply chain optimization [39].

Everledger

The proof of origin of high-value items is often identified using paperwork which can get lost or be tampered with [19]. In contrast, blockchain records are permanent and are immutable [22]. Everledger is a startup which tends to solve that problem by providing a blockchain-based solution for secured proofs of origins [22]. Everledger starts with diamonds and records a digital 'thumbprint' to uniquely identify a diamond [22]. A trader in diamonds should be able to identify the 'thumbprint' to determine whether the diamond is registered in the blockchain and thus fairly cut or is 'blood diamond' mined for the gains of war zones [42]. Due to both the tracking of the diamonds and the reduction in paperwork, Everledger would be an example which could be used in both the "Track and trace" section as the "Digitalize paperwork processes" section. However, the tracking is different from the track and trace most organizations investigate due to the tracking of diamonds focused on ownership. That is why the example is used here and not in the next section.

3.2.2 Digitalize paperwork processes

Following from the two examples explained below, organizations still use paperwork in some processes to register and process information. The processes include validation processes in which two or more parties are involved and registration processes including actions in which two or more parties are involved. To organize those processes efficiently, communication is key: At a shipping process of refrigerated goods of East Africa to Europe, the shipping requires validation of approximately 30 people and organisations must interact with each other on over 200 occasions [19]. Having the data on a blockchain would cause the right data to be accessible by the right stakeholder. According to Chu et al. (2016) and Morabito (2017), the problems associated with extensive paperwork are not limited to these specific use cases and can be extended to all kinds of trade flows [19]. Two examples will further explain the potential blockchain has in digitalizing paperwork to improve safety and efficiency.

3.2.2.1 Examples

Registration and validation processes: Customs paperwork

There is room for improvement in the validation of files and information in port logistics. Costs of in trade-related paperwork processing are estimated to be between 15 and 50 per cent of the total costs of physical transport [18, 30]. According to IBM and Maersk validation of paperwork at ports can save up to one-fifth of the total costs of shipping [28]. Earlier attempts to implement better tracking of products all stranded on the key problem of "mountains of paperwork" [27]. No wonder these parties are investigating ways to make the process more efficient and they started investigating blockchain based solutions in 2015 [28]. Until 2017, Maersk hopes to register one in seven of their container shipments on the blockchain – around 10 million boxes per year [18]. In January 2018, Maersk and IBM announced the intention to start a joint venture to further develop the blockchain technology for global trading [28]. Though not specifically stated, the decision to start a joint venture shows that IBM and Maersk see true potential in blockchain technology.

Registration processes: Letters of Credit

Letter of Credit (L/C) is under development by the BofAML, HSBC and IDA to be digitalized using blockchain technology in order to accelerate the paper-based process – a process which currently tends to take from a few days to weeks [22]. The platforms will be a platform to share information through the three parties involved – exporters, importers and their respective bank – and gives the possibility to automatically execute trade deals through a series of smart contracts [22]. The initiative should lead to a more efficient processing of documents, increase security by reducing errors, and increase convenience by providing all involved parties with a platform to communicate through [22].

Using blockchain solution Corda by technology consortium R3, HSBC and ING bank managed it to complete its first pilot of L/C in May 2018 [7]. The blockchain platform made it possible to transfer money from HSBC to ING bank, though it is unclear how the platform technically operates and what actions were performed automatically and what actions were performed manually [10]. Use of smart contracts is not mentioned and thereby can be assumed that advancement is not used. Concluding, the pilot is a start of the use of blockchain but does not yet use its full potential through smart contracts.

Registration process: Bill of Lading

The bill of lading is a document used for the shipper to know what cargo to transport and also functions as a contract [22]. Currently, the process is stuck in the paper phase, but still used due to its necessary details such as shipment description, quantity and destination, as well as how goods should be handled and billed in transport [22]. ZIM has conducted a pilot to digitalize the bill of lading [22]. During the pilot, the actions of issuing, transferring, and retrieval of original documents were successfully executed [22]. ZIM refers to it as the 'Holy Grail' of the logistics industry [41]. According to ZIM CEO Eyal Ben-Amram, the system should improve efficiency in the process [20]. Based on the contents above, one could say that the improvement is mainly to improve communication efficiency, giving different organizations access to the same documents and giving them a single point of truth. Thereby, actions based on the information are executed by the stakeholders using the system, making this system digitalize the process and is not an automation of the process.

4. EXPERT INTERVIEW

The literature review gives an overview of the most important applications of blockchain in logistics according to the literature. However, the literature review may not give a complete overview of all applications currently investigated by the industries. In order to investigate the industries' opinions, experts in the blockchain and/or logistics fields were contacted and interviewed. The participants in the research were interviewed in a semi-structured order, which indicates interview questions were both set-up beforehand and generated on the spot depending on the answer a participant gives [17].

The participants were interviewed for their opinions on the applications given in the literature review, as well as their general comments on the field they are expert in. For each of the applications discussed, their expected potential and time for adoption were asked. Also, all participants were asked for applications of blockchain in logistics not included in the literature research. The interviews should be an addition to the applications listed above, due to the addition of views from practitioners.

Three experts were interviewed. Two of the participants are practitioners in applying blockchain in the logistics sector. These two experts are informed about developments of blockchain in logistics and take part in the development of a blockchain system. Thereby, the blockchain experts could share their knowledge of applying blockchain in practice, as well as their theoretical knowledge. One participant is an expert in logistics. As a practitioner in logistics, he might be informed about differences between logistics processes and might have the ability to identify inefficiencies within those processes which could be an addition to the applications described earlier.

4.1 Outcomes Interview

4.1.1 Blockchain in Logistics

Blockchain is a fitting solution for situations with a need for consensus between multiple stakeholders which have a lack of trust in each other. The way blockchain can solve this, is through the concept of consensus, which is a solid due to its precise implementation possibilities of conditions. This is necessary since the parties do not fully trust each other and parties involved can implement their agreement in the blockchain system in detail. Deciding the conditions and deciding what data will be shared among the stakeholders can be a tricky negotiation, due to the lack of trust. This can result in the development of applications to be slowed down. Though, according to one of the experts in blockchain, there is no doubt blockchain will be a success in certain situations, due to the strong concept of reaching consensus.

Blockchain is a fitting solution for the supply chain, since supply chains are, same as blockchain, decentralized by design. Though for blockchain to be necessary, there still should be a lack of trust in the stakeholders within the logistics processes. Otherwise, traditional methods could be a fitting solution as well, since there is trust the central stakeholder maintaining the system will not misuse its position.

4.1.2 Applications blockchain in logistics

The first application discussed with the experts is track and trace. Track and trace through blockchain technology could have the potential to improve a process which has not been improved for years. Traditional systems did not fit due to the lack of trust. The stakeholders within a supply chain have the same point of truth, which results in fewer communication problems if something goes wrong since all parties involved would ground their opinions based on the same data. The same point of truth is ideally created together, which implicates agreements have been made on the registration of the to be tracked item. Challenges within the track and trace process are the negotiations between stakeholders and is developing a system which guarantees the data on the blockchain application is true. What makes applying blockchain interesting is the ability to register real-time variables and automatization through smart contracts and IoT. Efficiency improvements following from the automatization is an important driver of developing blockchain technology.

The second application discussed with experts is digitalization of paperwork. The discussion of this application resulted in different opinions among the participants. The logistics expert likes the solution due to the possibility of more efficient communication and the insurance of the right stakeholder having and sharing the right data, which makes the process more efficient. One of the blockchain experts thinks the solution is a decent one, though not a very exciting one due to the limited possibilities of automatization. It will make the process more efficient, but it will not have a disruptive effect. The other blockchain expert is sceptical and finds the solution not an innovative one. The expert thinks the digitalization of paperwork does not optimally serve the goals of the process, which is, in the case of Letter of Credit, the guarantee of being paid. There might be other ways to serve the goal without digitalizing the current paperwork by redesigning the process.

4.1.3 Future Blockchain in Logistics

All in all, the application of blockchain in logistics will depend on the negotiation speed between stakeholders, as well as the complexity of the to be developed blockchain solution. In some cases, blockchain technology already is ready to run and negotiating is the highest hurdle to take. Nevertheless, the

blockchain experts agreed on estimations for future applications of blockchain in logistics. They both indicated the end of 2018, beginning of 2019 as the period for the first simple applications of blockchain in logistics to start running. These are likely to be blockchain applications only registering certain information and thereby digitalize a process, but these processes are not yet an automatization of the process. One of the experts thinks the first more advanced applications will start running Q2 of 2019, while the other estimated more advanced applications Q3 of 2019 to start running.

5. DISCUSSION

5.1 Conclusions

The paper identifies the strengths, weaknesses, threats and opportunities of blockchain technology by a literature review and identifies how blockchain technology can be applied to logistics by both a literature review and expert interviews. Following from this research, it can be concluded that blockchain technology has the potential to disturb logistics on the long-term, and has the potential to be applied on the short-term. As both the literature review and expert interviews indicate, there is no doubt blockchain will be applied in logistics. Especially the potential of track and trace could be disturbing for the field of logistics, due to its automatization potential by the combination of IoT and smart contracts. Also, digitalization of paperwork has the potential to be useful, though is unlikely to disturb the processes given in the examples. As one of the experts indicates, for a disturbance the process should be redesigned and automated for optimal improvements in the process. However, according to both the other experts and literature review applying blockchain to digitalize paperwork does make the processes more efficient and thus can be useful for adoption. Besides, ways to automate the processes could be found in the future and could be built on the already developed blockchain technology.

According to the experts, the term for adoption of simple blockchain applications to be applied in practice will be approximate Q4 2018, Q1 2019. Experts indicate the first blockchain systems in logistics seem to be finished. After testing of these blockchain systems, these systems can be used on the short term. However, negotiation between the stakeholders plays a role in the development of the system and might slow the development of blockchain applications. Nevertheless, more complex applications are expected to start running approximately Q3 2019. Concluding, both the short-term and long-term potential of blockchain in logistics is high and blockchain is expected to run its first applications around the end of 2018, beginning of 2019.

5.2 Practical and Scientific Relevance

The practical relevance of this research is to give practitioners insights into the current developments of blockchain in logistics. The reader is informed by the various applications blockchain can have in logistics, including examples. Besides, practitioners are provided with an estimation of development time until simple and more advanced applications of blockchain in logistics will be applied. Also, the potential of blockchain applications is given broadly, for both simple and more advanced application.

Scientists get an overview of the state of the current literature related to blockchain's SWOT and related to blockchain's applications in logistics. Besides, scientists can learn about the current thoughts about blockchain and its applications in logistics through the expert interviews.

5.3 Limitations

The research has a limitation in each core component. First, due to the quick developments in blockchain technology, the current literature review could be extended by recent literature. This is likely to result in an increase of useful information and thus will result in a more detailed discussion of the Blockchain SWOT and the applications in logistics. Second, the expert interviews sample is rather small. A larger sample of experts would have resulted in a more detailed answer to the questions. Also, the general opinion of practitioners could have been statistically supported if the sampling size is large enough. Third, the worked-out case studies (examples) could be explored in more depth by a broader research for sources and by an attempt to interview employees involved in the development of the case.

5.4 Future Work

While doing this research, several new research questions came to mind which might be interesting to investigate. The goal of this research was giving the reader an idea of when and how blockchain could have a role in logistics. As given in this research, blockchain could have a rather dominating role in supporting complex supply chains by track and trace and by registration and validation of files which need to be accessed by multiple parties. As a result of this research, two main future research subjects come to mind.

First, research could focus more on new applications of blockchain in logistics in the future. As this research focuses on describing current applications of blockchain in logistics a blockchain's strengths and weaknesses, possible future applications would be interesting to use for a more advanced overview of blockchain applications in logistics.

Second, the applications of blockchain in logistics could be ordered from simple to advanced implementations and linked to an example in practice. The link between techniques within blockchain technology and logistics can make the examples in practice clearer. To do so, the model of Iansiti et al. could be applied in the field of logistics [24]. Besides, logistics processes might be easier to test on implementability by blockchain, since the research methods should cause the building blocks to be sorted systematically and all possible advantages of the techniques to be stated specifically.

Third, this research goal could be worked out in more detail by the generation of indicators which might influence the development duration of blockchain in general and blockchain in logistics. These indicators could be applied to the several applications of blockchain in logistics to get a more structured and detailed description of each application and its development curve. Besides, these indicators may also be applicable to applications of blockchain in other fields than logistics, which could be investigated as well.

6. ACKNOWLEDGEMENTS

I would like to thank the people who contributed to the research paper. First, I would like to thank the experts who contributed to the research by sharing their knowledge. Both theoretical and practical knowledge of blockchain and logistics were a welcome addition to the paper.

Expert Participants:

Aljosja Beije (Blockchain Expert): *Logistics and Technology Lead at Blocklab Rotterdam*.

Tom van Dijk (Blockchain Expert): *Business Consultant at CGI. Subjects of interest: Blockchain; Smart Shipping; Smart Logistics*.

Frans Savenije (Logistics Expert): *Operations Analyst at Bolk Transport BV*.

I also would like to thank my supervisor who contributed to each aspect of the paper by giving me advice.

Supervisor:

Hans Moonen: *Expert Transport & Logistics at CGI and Assistant Professor at the University of Twente*

7. REFERENCES

[1] Abramova, S., Böhme, R. 2016. *Perceived Benefit and Risk as Multidimensional Determinants of Bitcoin Use*. Thirty Seventh International Conference on Information Systems. Retrieved June 22, 2018 from: https://informationsecurity.uibk.ac.at/pdfs/Abramova2016_Bitcoin_ICIS.pdf

[2] Aitken, R. 2017. *IBM & Walmart Launching Blockchain Food Safety Alliance In China With Fortune 500's JD.com*. Forbes (December 14, 2017). Retrieved June 22, 2018 from: https://www.forbes.com/sites/rogeraitken/2017/12/14/ibm-walmart-launching-blockchain-food-safety-alliance-in-china-with-fortune-500s-jd-com/#1838cc1e7d9c

[3] Beck, R., and Müller-Bloch, C. 2017. *Blockchain as Radical Innovation: A Framework for Engaging with Distributed Ledgers as Incumbent Organization.* Hawaii International Conference on System Sciences. Proceedings of the 50th Hawaii International Conference on System Sciences (January 4, 2017). DOI = https://doi.org/10.24251/HICSS.2017.653

[4] Beije, A., and Jullens, J. 2016. *A lead via Blockchain technology*. City of Rotterdam (October 9, 2016). Retrieved May 1, 2018 from: http://www.blocklab.nl/media/uploads/2017/09/A-lead-via-Blockchain-Technology.pdf?x54716

[5] Bext360 Platform Homepage. Retrieved on June 21, 2018 from: https://www.bext360.com

[6] Brown, R.G., Treleaven, P., and Yang, D. 2017. *Blockchain Technology in Finance*. Computer (September 22, 2017), Vol. 50, Is. 9, 14-17. DOI = https://doi.org/10.1109/MC.2017.3571047

[7] Browne, R. 2018. *HSBC says it's made the world's first trade finance transaction using blockchain*. CNBC (May 14, 2018; Last update June 1, 2018). Retrieved on June 15, 2018 from: https://www.cnbc.com/2018/05/14/hsbc-makes-worlds-first-trade-finance-transaction-using-blockchain.html

[8] Buterin V. 2018. *A next generation Smart Contract & Decentralized Application Platform*. Ethereum White Paper (Last edit: June 20, 2018) Retrieved June 20, 2018 from: https://github.com/ethereum/wiki/wiki/White-Paper#decentralized-autonomous-organizations

[9] Buy Bitcoin Worldwide. 2018. *Bitcoin Mining Pools: The Biggest Mining Pools*. Retrieved on June 21, 2018 from: https://www.buybitcoinworldwide.com/mining/pools/

[10] Cargill, HSBC, ING, and R3. 2018. *HSBC and ING execute groundbreaking live trade finance transaction on R3's Corda Blockchain platform.* Press Release HSBC (May 14, 2018). Retrieved on June 15, 2018 from: https://www.hsbc.com/news-and-insight/media-resources/media-releases/2018/hsbc-trade-blockchain-transaction-press-release

[11] Chen, H.B., Xie, J., Xia, Y.B., Yuan, R., and Zang, B.Y. 2017. *ShadowEth: Private Smart Contracts on Public Blockchain.* Journal of Computer Science and Technology. J Comput Sci Technol (May 2018), Vol. 33, Is. 3, 542-556. DOI = https://doi.org/10.1007/s11390-018-1839-y

[12] Crudu, R., Grant, L.G., and Pilkington, M. 2017. *Blockchain and bitcoin as a way to lift a country out of poverty – tourism 2.0 and e-governance in the Republic of Moldova*. International Journal of Internet Technology and Secured Transactions (2017), Vol 7, No. 2, 115-143. DOI = https://doi.org/10.1504/IJITST.2017.10008012

[13] De Jesus, C. 2016. *Walmart is using blockchain to find contaminated food sources.* Futurism (November 21, 2016) Retrieved June 5, 2018 from: https://futurism.com/walmart-is-using-blockchain-to-find-contaminated-food-sources/

[14] Dorri, A., Jurdak, R., Kanhere, S.S., and Steger, M. 2017. *BlockChain: A Distributed Solution to Automotive Security and Privacy*. IEEE Communications Magazine. IEEE Commun Mag (December 13, 2017), Vol 55, Is. 12, 119-125. DOI = https://doi.org/10.1109/MCOM.2017.1700879

[15] Dutch Blockchain Coalition. 2017. *Actieagenda Nationale Blockchain Coalitie*. White Paper (March 2017). Retrieved on June 12, 2018 from: https://www.dutchdigitaldelta.nl/uploads/pdf/Blockchain-actieagenda-v2.pdf

[16] Fairfield, J.A.T. 2014. *Smart Contracts, Bitcoin Bots, and Consumer Protection*. Washington And Lee Law Review Online (2014), Vol. 71, Is. 2, 34-50. Retrieved June 22, 2018 from: https://scholarlycommons.law.wlu.edu/wlulr-online/vol71/iss2/3

[17] Galletta, A. 2013. *Mastering the Semi-Structured Interview and Beyond*. NYU Press. (June 2013) Retrieved on June 19, 2018 from: https://nyupress.org/books/9780814732946/

[18] Groenfeldt, T. 2017. *IBM and Maersk apply blockchain to container shipping.* Forbes (March 5, 2017). Retrieved June 2, 2018 from: https://www.forbes.com/sites/tomgroenfeldt/2017/03/05/ibm-and-maersk-apply-blockchain-to-container-shipping/3/#1cfd0f2e7d33

[19] Hackius, N., and Petersen, M. 2017. *Blockchain in Logistics and Supply Chain: Trick or Treat?*. Technische Universität Hamburg (Oktober 2017). DOI = https://doi.org/10.15480/882.1444

[20] Hampstead, J.P. *ZIM ships containers with blockchain bills-of-lading*. Freight Waves (December 1, 2017). Retrieved June 14, 2018 from: https://www.freightwaves.com/news/2017/12/1/kp8t60pg6jjqfwrzjwxlgnft8cwa57

[21] Hendrikman, M. 2018. *Italiaanse cryptocurrency-exchange verliest 139 miljoen euro aan Nano door hack*. Tweakers (February 11, 2018). Retrieved on June 16, 2018 from: https://tweakers.net/nieuws/135105/italiaanse-cryptocurrency-exchange-verliest-139-miljoen-euro-aan-nano-door-hack.html

[22] Heutger, M. 2018. *Blockchain in Logistics*. DHL Trend Research. Retrieved May 1, 2018 from https://www.logistics.dhl/content/dam/dhl/global/core/documents/pdf/glo-core-blockchain-trend-report.pdf

[23] Higgins, S. 2017. *Walmart: Blockchain Food Tracking Test Results Are 'Very encoiuraging'*. Coindesk (June 5, 2017). Retrieved on June 14, 2018 from: https://www.coindesk.com/walmart-blockchain-food-tracking-test-results-encouraging/

[24] Iansiti, M., and Lakhani, K. 2017. *The truth about blockchain*. Harvard Business Review. Harvard Bus. Rev. (January 1, 2017), Vol. 95, No. 1, 118-127. Retrieved May 2, 2018 from: https://hbr.org/2017/01/the-truth-about-blockchain

[25] Kharif, O. 2016. *Blockchain goes beyond cryptocurrency*. Bloomberg (May 19, 2016). Retrieved May 25, 2018 from: http://www.bloomberg.com/news/articles/2016-05-19/built-for-bitcoin-blockchain-goes-beyond-crypto-currency

[26] King, N.J., and Raja, V.T. 2012. *Protecting the privacy and security of sensitive customer data in the cloud*. Computer Law

& Security Review. Comput Law Secur Rev (2012), Vol. 28, Is. 03, 308-319. DOI = https://doi.org/10.1016/j.clsr.2012.03.003.

[27] Kshetri, N. 2018. *Blockchain's roles in meeting key supply chain management objectives*. International Journal of Information Management. Int. J. Inform. Manage. (April 2018), Vol. 39, 80-89. DOI = https://doi.org/10.1016/j.ijinfomgt.2017.12.005.

[28] Linnet, M.E., and Mosquera, K. 2018. *Maersk and IBM to Form Joint Venture Applying Blockchain to Improve Global Trade and Digitalize Supply Chains*. Maersk Press Release (January 16, 2018). Retrieved June 22, 2018 from: https://www.maersk.com/press/press-release-archive/maersk-and-ibm-to-form-joint-venture

[29] Lightstone, S., Nadeau, T., and Teory, T. 2006. *Database Modeling and Design – Transforming the Conceputal Data Model to SQL*. Morgan Kaufmann (2006), 83-106. DOI = https://doi.org/10.1016/B978-012685352-0/50005-7

[30] Lohr, S., and Popper, N. 2017. *Blockchain: A better way to track pork chops, bonds, bad peanut butter?* The New York Times (March 4, 2017). Retrieved June 13, 2018 from: https://www.nytimes.com/2017/03/04/business/dealbook/blockchain-ibm-bitcoin.html

[31] Magazzeni, D., McBurney, P., Nash, W. 2017. *Validation and Verification of Smart Contracts: A research agenda*. Computer (September 22, 2017), Vol 50, Is. 9, 50-57. DOI = https://doi.org/10.1109/MC.2017.3571045

[32] Martin, J., and Talabis, M. 2013. *Information security risk assessment toolkit*. Syngress (2013), 27-62. DOI = https://doi.org/10.1016/B978-1-59-749735-0.00002-6

[33] Nakamoto, S. 2008. *Bitcoin: A Peer-to-Peer Electronic Cash System*. White Paper. Retrieved June 5, 2018 from: https://bitcoin.org/bitcoin.pdf

[34] Nofer, M., Gomber, P., Hinz, O., and Schiereck, D. 2017. *Blockchain*. Business & Information Systems Engineering. Bus Inf Syst Eng (2017), Vol. 59, Is. 3, 183-187. DOI = https://doi.org/10.1007/s12559-017-0467-3

[35] Ponniah, P. 2003. *Database design and development: an essential guide for IT professionals*. Wiley-IEEE Press (2003). Retrieved May 18, 2018 from: http://ieeexplore.ieee.org.ezproxy2.utwente.nl/servlet/opac?bknumber=5238105

[36] Risius, M., and Spohrer, K. 2017. *A Blockchain Research Framework*. Business & Information Systems Engineering. Bus Inf Syst Eng (December 2017), Vol. 59, Is. 06, 385-409. DOI = https://doi.org/10.1007/s12599-017-0506-0

[37] Price, R. 2016. *Digital currency Ethereum is cratering because of a $50 million hack*. Business Insider (June 17, 2016). Retrieved June 22, 2018 from: https://www.businessinsider.de/dao-hacked-ethereum-crashing-in-value-tens-of-millions-allegedly-stolen-2016-6?r=UK&IR=T

[38] Savelyev, A. 2017. *Contract Law 2.0: 'Smart' contracts as the beginning of the end of classic contract law*. Information & Communications Technology Law (April 07, 2017), Vol 26, No. 2, 116-134. DOI = https://doi.org/10.1080/13600834.2017.1301036

[39] Shaffer, E. 2017. *Walmart, IBM provide blockchain update*. Meat & Poultry (June 2, 2017). Retrieved June 22, 2018 from: http://www.meatpoultry.com/articles/news_home/Business/2017/06/Walmart_IBM_provide_blockchain.aspx?ID=%7B24B47705-09C1-4A89-A98C-28403AF874C1%7D&cck=1

[40] Tapscott, A., and Tapscott, D. 2016. *The impact of the blockchain goes beyond financial services.* Harvard Business Review. Harvard Bus. Rev. (March 10, 2016). Retrieved June 22, 2018 from: https://hbr.org/2016/05/the-impact-of-the-blockchain-goes-beyond-financial-services#comment-section

[41] The Maritime Executive. 2017. *ZIM Trials Blockchain Bill of Lading*. Maritime Executive (November 20, 2017). Retrieved on June 14, 2018 from: https://www.maritime-executive.com/article/zim-trials-blockchain-bill-of-lading#gs.FNZh7u0

[42] Underwood, S. 2016. *Blockchain Beyond Bitcoin*. Communications of the ACM. Commun. ACM (November 2016), Vol 59, 11, 15-17. DOI = https://doi.org/10.1145/2994581

[43] Unuvar, M. 2017. *Blockchain and food safety at the CGF Global Summit*. Blockchain Unleashed: IBM Blockchain Blog (May 16, 2017). Retrieved June 22, 2018 from: https://www.ibm.com/blogs/blockchain/2017/05/blockchain-and-food-safety-at-the-cgf-global-summit/

[44] Unuvar, M. 2017. *The food industry gets an upgrade with blockchain*. Blockchain Unleashed: IBM Blockchain Blog (June 15, 2017). Retrieved June 22, 2018 from: https://www.ibm.com/blogs/blockchain/2017/06/the-food-industry-gets-an-upgrade-with-blockchain/

[45] Van Voorst, S. 2018. *'Japanse cryptocurrency-exchange verliest 430 miljoen euro aan tokens door hack'*. Tweakers (January 26, 2018). Retrieved on June 16, 2018 from: https://tweakers.net/nieuws/134531/japanse-cryptocurrency-exchange-verliest-430-miljoen-euro-aan-tokens-door-hack.html

[46] Van Voorst, S. 2018. *Zuid-Koreaanse exchange Coinrail meldt diefstal van cryptovaluta na hack*. Tweakers (June 11, 2018) Retrieved on June 16, 2018 from: https://tweakers.net/nieuws/139641/zuid-koreaanse-exchange-coinrail-meldt-diefstal-van-cryptovaluta-na-hack.html

[47] White, M. 2018. *Digitalizing Global Trade with Maersk and IBM*. Press Release (January 16, 2018). Retrieved May 1, 2018 from: https://www.ibm.com/blogs/blockchain/2018/01/digitizing-global-trade-maersk-ibm/

[48] Wolfswinkel, J.F., Furtmueller, E., and Wilderom, C.P.M. 2013. *Using grounded theory as a method for rigorously reviewing literature*. European Journal of Information Systems. Eur. J. Inform. Syst. (January 2013) Vol 22, 1, 45-55. DOI = https://doi.org/10.1057/ejis.2011.51

[49] Zheng, Z., Wang, H., Xie, S., Dai, H., and Chen, X. 2017. *Blockchain Challenges and Opportunities: A Survey*. International Journal of Web and Grid Services. Int. J. Web and Grid Serv. (December 2017)