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Master in Management Program

Smart Contract Development in Supply Chain Management:
Requirements and Potentials for Utilizing Blockchain Technology

Master's Thesis by the 2nd year student
Concentration – General track
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ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

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АННОТАЦИЯ

Автор	Вивиен Сермягин
Название магистерской диссертации	Развитие смарт-контрактов в управлении цепями поставок: Требования и использования технологии блокчейн
Факультет	Высшая Школа Менеджмента
Направление подготовки	Профиль Менеджмент (общий профиль)
Год	2018
Научный руководитель	Шульте Аксель Тео, PhD, доцент
Описание цели, задач и основных результатов	Технология Blockchain может быть большим конкурентным преимуществом для цепочки поставок, чтобы улучшить время выполнения заказа, а также время обработки заказов, интегрировать процессы цепочки поставок по всей логистической сети. Смарт контракты снижают административные затраты, обеспечивают прозрачность транзакций в режиме реального времени, повышают взаимодоверие участников цепочки поставок, повышают гибкость цепочки поставок. Целью диссертационного исследования было изучение того, как смарт-контракты могут решать проблемы цепочки поставок, такие как взаимодоверие и прозрачность в реальном времени, разработать методологию разработки смарт-контрактов и сравнить существующие технологии блокчейн относительно их соответствия менеджменту цепочки поставок. Для достижения цели и ответа на вопросы исследования было проведено несколько тематических обзоров. Эмпирические данные включают примеры трех компаний с опытом использования блокчейна для процессов цепочки поставок. С помощью внутри и кросс-кейсового анализа были выявлены возможные процессы цепочки поставок, проведено сравнение технологий и, наконец, создана методология для разработки смарт-контрактов и внедрения блокчейна..
Ключевые слова	Блокчейн, смарт-контракт, управление цепями поставок, дигитализация логистики

ABSTRACT

Master Student's Name	Vivien Szermjagin
Master Thesis Title	Smart Contract development in Supply Chain Management: Requirements and potentials for utilizing Blockchain Technology
Faculty	Graduate School of Management
Main field of study	Master in Management - General Track
Year	2018
Academic Advisor's Name	Axel Theo Schulte, Dr./PhD, Associate Professor
Description of the goal, tasks and main results	Blockchain technology can be a great competitive advantage for supply chain to improve lead time, and order processing time and integrate the supply chain processes across the network. Smart contracts reduce administration costs, offers real-time transparency of transactions, improves confidence and trust among supply chain members and it enhances the agility of the supply chain. The research goal of the thesis was to investigate how smart contracts can solve recent supply chain issues, such as real time transparency and trust, develop a methodology of smart contract development and compare existing blockchain technologies due to their fit to supply chain environment. For achieving the research goal and answering the research questions multiple case study was carried out. Empirical evidence includes cases of three companies with experience in blockchain utilization for supply chain processes. By within-case and cross-case analysis possible supply chain processes were revealed, technologies were compared and finally a methodology was created for smart contract design and blockchain implementation.
Keywords	Blockchain, Smart Contract, Supply Chain Management, Digitalization of supply chain management

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List of Abbreviations

AI – artificial intelligence
3PL – third party logistics
BCT – blockchain technology
BFT – Byzantine Fault Tolerance (consensus protocol)
BLE – Bluetooth Low Energy
DAO - decentralized autonomous organization
DApp – decentralized application
DLT – distributed ledger technology
EDI – electronic data interchange
ERP – enterprise resource planning
EVM – Ethereum Virtual Machine
FTA – (Russian) Fintech Association
IoT – internet of things
IT – Information Technology
KPIs – key performance indicators
M2M – machine to machine
P2P – peer-to-peer
PBFT - Practical Byzantine fault tolerance
PoET – Proof of Elapsed Time (consensus protocol)
PoS – Proof of Stake (consensus protocol)
PoW – Proof of Work (consensus protocol)
RFID – radio frequency identification
RFTA – Russian Fintech Association
SC – Smart Contract
SCM – supply chain management

Introduction

10 years ago, shortly after the 2008 global financial crash a white paper emerged from an unknown person or a group of people under the name: Satoshi Nakamato. In this white paper a new peer to peer financial system was discussed. It was about a digital currency called Bitcoin, an interesting idea in order to revolutionize our financial and economic systems, which are too highly influenced by centralized power. The technology invented to power this new system is called blockchain. However, the author should place emphasis on the fact that blockchain is not only a technology behind cryptocurrencies, the use of the technology goes far beyond that, and businesses start to realize its usability. Several interorganizational research projects are developed currently to capitalize the technology in different industries. In order to give the reader a basic understanding of the technology, it can be broken down to one simple sentence: *Blockchain is a continuously updated record of who holds what.* This records are split into linked blocks, and then secured using cryptography. The cryptography part means that you can be sure about the records, it is secured through math and code, thus trust is inherently built into the system. The list of records (known as a distributed ledger) is decentralized, available to everyone to see and verify. In addition, blockchain is tamper-evident and practically unhackable due to its distributed nature. The relevance of the topic is shown by the fact that there are several conferences in the topic and several researchers working on new blockchain solutions for businesses. The technology is called by many "the next generation of internet". In current stage the internet is based on the concept of copying and distributing information. Blockchain can take this further to the next stage, distributing assets that provide real values, such as contracts regarding a bond, money, votes, or ownership of assets (e.g.: in everyday life a car, a house or in business any product moving through supply chain). The main issue of sending values via internet is that you do not want to have these assets as copies. For example if you send $5000 but you still have your $5000 dollar under your name, one of the record is a copy. This problem is called double spending by cryptographers, otherwise speaking, to have two digital copies of something that should have one identical identity. The cryptography element of Blockchain is the first to solve this double spending problem. Ultimately value can be transferred via Internet with the help of cryptography, digital signatures and hash algorithms, which are the underlying technology of blockchain. The importance of the topic is showed by the fact that the year of 2017 was filled of starting Blockchain projects supported by some of the world's biggest companies. Bitcoin, Ethereum and Hyperledger opened a door for real blockchain use cases, and the technology is getting a growing interest of government, institutions and investors.

Research Gap: As the topic gained interest just a few years ago, and continuously new blockchain platforms are developed, there is not enough up-to-date research done regarding the business implementation of the technology, especially in the application of supply chain management. Although there are several technological research done in the field Information Technology, and some business research in the field of Finance, there are a lack of research done regarding blockchain technologies in Supply Chain management, although according to specialists it is a promising field to utilize the technology. Furthermore, there are most certainly no research written on smart contracts particularly.

Aim of the research:

The aim of the research is to analyse how smart contracts could solve recent supply chain issues, such as lack of trust and real-time transparency and generate a methodology for smart contract development in Supply Chain Management, analysing existing Blockchain technologies as a platform for Smart Contract.

Research questions:

Q1: Which Supply Chain Processes are suitable for Smart Contracts (which are not)?

Q2: What are the requirements (success criteria) out of the supply chain for Smart Contract design?

Q3: Which Block Chain technology(ies) fit(s) and is (are) appropriate for Smart Contract modelling in the Supply Chain Environment?

Chapter 1. Review of the State of the Art

1.1. Contemporary concepts of supply chain and supply chain management

Before discussing the supply chain concept, it is worth noting that a wide range of terms are used in relation with the term supply chain in different literature. Such terms include demand flow management, demand chain management, value chain management, value networks etc. Supply chain management is viewed by some authors to be narrowly focused on suppliers and materials, not demand for finished products. The above mentioned terms originate from the idea that the chain should be driven by the market, not by suppliers. Some authors use the term "network" instead of "chain", since there are normally multiple suppliers and customers in the

total system. Despite of the appearance of these terms, Supply Chain Management is the most accepted term for the management of present demand driven networks. The author of this paper considers the term supply chain management to be a broad and comprehensive term where demand and value are relevant factors, therefore takes it as a synonym of the above mentioned terms.

The term Supply chain appeared first in literature in 1982, from 1990 academics started to describe the concept. Some of the statements regarding SCM was that it is logistics taken across inter-organization boundaries, other views of SCM include more functions than logistics being integrated across firm boundaries. With reference to a definition developed in 1994 by the members of International center for Competitive Excellence: "Supply chain management is the integration of business processes from end user to original suppliers that provide products, services and information that add value for customers." (Cooper, Lambert, and Pagh 1997) La Londe and Masters (1997) refer to the "strategy of applying integrated logistics management to all the elements of the supply chain" as supply chain management. According to their research some firms were referring to the practice as "partnering", other firms as "strategic alliances", therefore as we see it was seen as a strategic option for achieving competitive advantage. Another SCM definition is from Aitken (1998), which states that supply chain is a network of connected and interdependent organizations mutually and co-operatively working together to control, manage and improve the flow of material and information from suppliers to end users. Cristopher (2013) builds upon this idea, he suggests that SCM is the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole. Otherwise speaking the focus of SCM is on co-operation and trust, and the recognition that "whole can be greater than the sum of parts", managing the relationships a more profitable outcome can be realized by the parties of the chain. In another article he (2000) calls the supply chain and "extended enterprise". He argues, that shared information between supply chain partners can be fully leveraged only through process integration, relying on trust and transparency of information. In other words buyers and suppliers should collaborate through shared information, joint product development and common systems. In his opinion cooperation became increasingly important as companies are focusing on their core competencies and outsource all other activities, therefore usually working with 3PL companies. According to other academics (Coyle et al. 2013) supply chain is a series of integrated enterprises that must share information and coordinate physical execution to ensure a smooth, integrated flow of goods, services, information and cash through the pipeline. Therefore, SCM is the art and science of integrating the flows of products, information, and financials through the entire supply pipeline from the supplier's supplier to the customer's customer.

1.1.2. Trust in the supply chains

Trust is a key factor in inter-organizational relationships (Talay and Akdeniz 2014). It is an old technique that influenced relationships long before technology appeared. Trust can defined as the confidence or predictability in one's expectations about another's behavior (Zaheer, McEvily, and Perrone 1998) and the belief that the other individual behaves according to commitments, is honest, does not take advantage of another even when the opportunity is available (Cummings and Bromiley 1996). According to Mayer trust is "Willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or confront that other party." (Mayer, Davis, and Schoorman 1995) In Supply Chain environment, a collective optimization with sharing and cooperation is a key to success, therefore trust between chain members is essential. Besides reducing transaction costs, an important consequence of trusting relationship between organizations are the reduction of uncertainty and information asymmetry. (Dyer and Chu 2011) All in all, trust is a key factor for developing partnership between supply chain members, however, organizations are cautious of sharing information across organizational boundaries. Also issues such as clash of personalities, quests of personalities, inadequate communication and betrayal may underlie unsuccessful collaborations. (Mentzer, Foggin, and Golicic 2000) A solution to the above mentioned problems is to solve trust issues between partners, as in a range of studies lack of trust between partners was found to be a barrier to good supply chain relationship. (Singh and Teng 2016) Trust is incredibly important between the participants of the supply chain, thus when a party of a transaction has been paid for the requested goods or services, the party who paid wants the provider to act in a particular way in order to receive the goods or service desired. (Kannan and Tan 2006) For long time trust issues in Supply Chain is a popular research topic, researchers over the years try to come up with new solutions. However even the current developed communications systems and the support of legal contracts are not comprehensive solutions for all trust issues. Smart Contract development based on block chain technology, in combination with IoT technology can be a tool for solving these type of trust problems and reducing opportunistic behavior between supply chain parties. With sensors sending constant information on the status of an ordered items, allows the client track his order and with a computer code based smart contract transaction will be completed, when the order is fulfilled.

1.1.3. Value and value transfer in supply chains

In current supply chains, when transfer of any value is happening (cash or asset) the companies of the supply chain keep count of the transactions on their separate ledger in their accounting system. When keeping separate ledgers of the same value, they are not harmonized, the members of the supply chain cannot see information in real time about the transaction, when data is tampered it is more difficult to observe. Value transfer is executed with help of a 3rd party e.g.: bank, notary. The transfer of value and ownership is often confirmed by a paper based system of the 3rd party. An excellent business use of blockchain is the introduction of a shared ledger system, where the peers manage the ledger together, every transaction is seen in real time in a tamperproof system, preventing fraud, thus value can be transferred peer to peer without the help of a trusted intermediary. With the help of cryptography and digital signature we can transfer value via internet without facing the double spending problem (discussed earlier in introduction). The time of sharing data and transferring value is reduced by using the same shared ledger with the others. Considering a traditional example, in a supply chain participant 'A' and participant 'B' has separate records of the value transfer, also the bank, the insurer, the regulator and the auditor has their own records. Problems can arise when in one ledger records differ from the other, then a waste of time and energy go for finding the mistake, moreover even in ideal situations the process of data appearing in other participant's ledger takes time and work of several people to record the same transaction. The several separate ledger makes the documentation of the value transfer inefficient, expensive and vulnerable. For this problem a blockchain based distributed ledger system could be an efficient, cost saving and secure solution, where everyone would see the same records appeared in some minutes or even seconds.

Real world examples of Blockchain implementation already exist in logistics to facilitate value transfer across supply chain. A Belgian company T-Mining is piloting a project with the port of Antwerp, liner carrier Mediterranean Shipping Co., and a freight forwarder and road transport company. Currently, when they transfer valuable object, they use a trusted intermediary to carry out the transfer, but this intermediary does not work for free and the additional step causes extra delay. With an every-day example: when you want to sell your house, the notary carries out all the paperwork, ensures that your money lands in your bank account and the buyer receives full title to the property. Their blockchain solution is designed to result in a faster and safer transfer of valuable objects, fully digitally without a middleman, so that the right truck driver is given clearance to collect a particular container, without any possibility of the process being interrupted. Moreover their blockchain platform uses a distributed network, so that transactions can go ahead only if there is a consensus among all parties, in such way excluding

all attempts to fraud or any manipulations. (Johnson, 2017) There is a number of another ongoing or finished blockchain pilots existing related to shipping or trade. The most famous one is Maersk Line and IBM pilot, which demonstrate how a blockchain-backed bill of lading could eliminate stacks of paperwork related to a single shipment. Kontainers, the digital freight forwarder, signed a memorandum of understanding in April with Blockfreight, a startup focusing on building blockchain solutions for the global freight industry. Kontainers' target is to focus on providing online editable and sharable bill of ladings, which helps their clients to get paid faster. Also SAP launched in May its blockchain-as-a-service offering, part of its cognitive learning platform Leonardo. (Johnson, 2017) The quite long list of early projects show the expected potential of using blockchain technologies to facilitate value transfer in supply chain and logistics.

1.1.3. Technology in supply chain management

On one hand technology can viewed as a change driver in all aspects of a business, on the other hand it can be seen as a facilitator of the change which leads to higher efficiency and effectiveness. The challenge is in business, therefore also in SCM to evaluate and successfully implement technology to reach the aimed improvements. In a lot of cases technology is used without thinking through, analyzing processes and preparing for the change, which can lead to frustration and failure. For successful implementation of new technologies it is necessary to analyze, adjust, or maybe even change processes, educate the people involved, and then select and implement the technology to facilitate the changes in the process. (Coyle et al. 2013) The current paper addresses this issue by developing a methodology, which assist supply chain departments to design Smart Contracts in the framework of blockchain technology.

After the launch of public blockchains like Ethereum and Hyperledger, developers can freely built their own applications on them. However, the adoption to blockchain technology requires a certain level of technical expertise and the access to blockchain developers can be a challenge for businesses, especially for non-tech ventures. The current trend in the business world is, that in order to face this challenge businesses get into partnership with tech companies and work on development projects together. (e.g. IBM – Maersk) According to specialists businesses can benefit much from adopting blockchain. Moreover, it is highly certain that modern business environment will require supply chains to make the technology integral to their strategy. However, as with any technology adoption that would significantly change the way an organization is working. In the case off supply chains such blockchain technology implementation is even more challenging, since the whole chain has to implement it in order to

work properly, thus implementation needs cooperation between the supply chain members. Implementing blockchain technology and smart contracts would require prudent planning and strategy, most certainly partnering with IT companies or relying on their services as a client. Nothing shows more this tendency, than the fact that recently major technology providers such as IBM, Microsoft and SAP are offering their blockchain solutions to enterprise clients focusing on field like international trade and supply chain management. According to researchers, blockchain technology will go hand in hand with new technologies such as IoT, 3D printing, artificial intelligence, big data, machine learning etc. Therefore, these new technologies will most definitely transform supply chains into more demand driven chains. However in order to exploit potentials of the new technologies there is a need for decentralized mediation, which is promised by Blockchain technology.

Currently there are several challenges to the widespread use of permissionless and permissioned distributed ledger technologies. Key among them are regulatory challenges, challenges around the lack of standards, and the lack of knowledge about distributed ledger technologies. These challenges are general to any new technological infrastructure that replaces an older infrastructure. This master thesis aims to decrease the third challenge, i.e. to provide knowledge for supply chain professionals about the technology.

1.2. Distributed ledger technology and Blockchain

There is a confusion regarding the difference of the terms blockchain and distributed ledger technology. In literature, some authors refer to them as synonyms, some of them see distributed ledger technology as a broader term including blockchain and smart contract (Hyperledger), some of them state that blockchain is the underlying technology of distributed ledger technology, others claim that blockchain is a type of distributed ledger technology, others state that the idea of DLT is created by the invention of Blockchain, although in the future there could be other realizations of distributed ledgers beside blockchain. According to specialists at Hyperledger, distributed ledgers existed before the appearance of blockchain, however Bitcoin revolutionized the technology with timestamping the transactions, peer-to-peer (P2P) networks, cryptography, and shared computational power, along with a new consensus algorithm As the aim of this thesis not to dig deep into technological definitions of the technology, but the managerial use of the solutions based on the it, thus the author considers the term Blockchain technology and Distributed Ledger technology as equivalent terms. In the authors opinion the term ‘blockchain’ describes more of the technology bases of the phenomena (chain of blocks) and the term “distributed ledger technology’ refers to the characteristics of it (distributed ledgers

among computer in different geographical areas without central authority). The term DLT might be invented also in order to enhance the wider possibility of using blockchain technology, other than a cryptocurrency, as blockchain seems to be associated tightly with Bitcoin, which is undeniably a revolutionary invention, however using the technology in a narrow financial sense.

Before diving into the definition of blockchain or distributed technology (DLT), it is reasonable to define, what a distributed ledger is. A distributed ledger is a type of data structure, which is located across multiple computer devices. The data is shared across all the nodes of the network, thus every participant of the network can access it and has an identical copy of it. Any change or additions to the ledger is seen in seconds or minutes by all participants.

The name 'blockchain' stand for its technical structure – a chain of blocks. Each block is linked to the previous block with a cryptographic hence. A block is a data structure, which stores a list of transactions. Transactions are created and exchanged by the peers of the blockchain network. These transactions can exchange monetary amounts, however they are not restricted to financial transactions, they also allow to execute arbitrary codes, which are the basis of so called smart contracts. (Wüst and Gervais 2017)

According to hyperledger.org, "A blockchain is a peer-to-peer distributed ledger forged by consensus, combined with a system for "smart contracts" and other assistive technologies." Consensus refers to a system of ensuring that parties agree to a certain state of the system as the true state. Timestamping is another key feature of blockchain technology. Each block is timestamped, with each new block referring to the previous block. Combined with cryptographic hashes, this timestamped chain of blocks provides an immutable record of all transactions in the network, from the very first (or genesis) block

It can be also described by a distributed data structure that is replicated and shared among the members of the network. Blockchain was introduced with Bitcoin.

1.2.1. How does blockchain work?

Each block of the blockchain carries a list of transactions and a hash to the previous block. The exception to this is the first block, which is called genesis block, common to all clients in the network and has no parent. Each block in the network is identified by its cryptographic hash, which establishes a link between the blocks and creating a chain of blocks, thus the blockchain. Users interact with the blockchain through their node of the network, thus every user has a pair of private/public keys. They use their private keys to sign their own transactions, and they are addressable on the network via their public key. The neighboring peers make sure this incoming transaction is valid before relaying it any further, as a result invalid transactions are discarded.

The peers verify that the suggested block contains valid transactions, and references via hash the correct previous block on the chain. Finally the transaction is spread across the whole network and receives a timestamp. (Christidis and Devetsikiotis 2016)

Every blockchain system is working upon set rules, on which everyone has agreed on, that each database transaction should meet. When each node of the network follows the steps listed above, the shared blockchain becomes an authenticated and timestamped record of the network's activity. The peers do not have to trust each other, the system can work in a "trustless" environment, as trust is achieved from the interactions of different participants of the chain. (Christidis and Devetsikiotis 2016) In literature blockchains are often called as "trustless" technology, however it does not actually eliminate trust, but minimize the amount of trust needed from any actor from the system. The members of the blockchain network distribute trust among each other according to rules defined by the protocol. In other words you still need to trust the underlying blockchain system (so that it ensures sender authenticity and currency validity) when you digitally transfer value from one account to another. Thus when experts say blockchain are trustless, what they mean is that there are special mechanisms by which all parties can reach a consensus on what the canonical truth is. Power and trust is distributed among the network's stakeholders (developers, miners and consumers), rather than concentrated in a single individual or entity (e.g.: governments, banks, financial institutions etc.) (Kasireddy, 2017)

In Figure 1 below, it is visualized how a blockchain works. The first step is when transaction is initiated, appears online, and after that the nodes of the blockchain network validate the transaction. When verified, the transaction will be combined with other transactions from which a new block is created, which will be connected to the chain by hashes and ensures that it stays permanently there. (DHL, 2017)

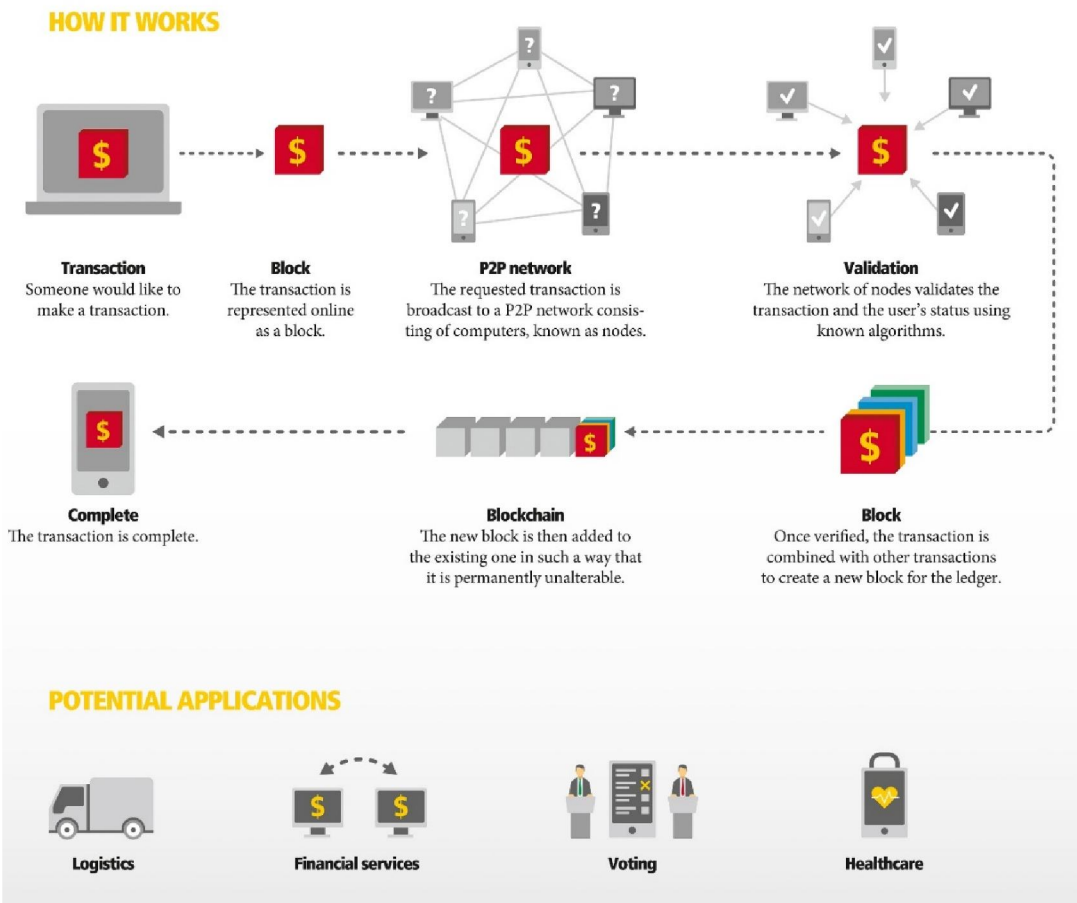


Figure 1 How Blockchain works (source: DHL 2017)

There are two type of blockchains described in the literature – permissionless and permissioned.

Current examples of permissionless blockchains are Bitcoin and Ethereum, which are open and decentralized. Any peer can join and leave the network, and there is no central entity which manages the membership. This openness implies that the content is readable by any peers. However with the use of cryptographic primitives it is technically possible to design a permissionless blockchain which hides privacy relevant information. (Wüst and Gervais 2017)

In permissioned blockchains a central entity decides and attributes the right to individual peers to participate in the write or read operations of the blockchain. The most well-known permissioned blockchains are Hyperledger Fabric and R3 Corda. In the framework of permissioned blockchain we can distinguish between public or private permissioned blockchains. The difference between the two is, that the public blockchain allows anyone in the network to read the contents of the chain and thus verify the validity of the data, while private blockchains have restriction of accessing some encrypted data for those who do not have the key. (Wüst and Gervais 2017)

To summarize, the following three type of blockchain configurations discussed in literature, and has current market application:

- *Permissionless Public Ledger:* It is accessible by any user (unknown/untrusted), who can access the ledger, conduct transaction and write on the ledger. These platforms are characterized by many untrusted/unknown miners or validators

- *Permissioned Public Ledger:* These systems are created on behalf of a community of interest, where a limited number of authenticated participants have access to the ledger. These platforms are characterized by multiple trusted/known miners or validators. New nodes need permission to enter the network.

- *Permissioned Private Ledger:* The access is given exclusively to a defined community of known and trusted users, who are the only ones that have access and can contribute to the ledger. These platforms are characterized by single (sometimes the community can designate an authority) or multiple trusted/known miners or validators. (Francisconi, 2017)

Blockchains has a significant property, they can run code, which makes it possible to run smart contracts on it (discussed in depth later). The first blockchains were designed for a small set of simple operations – mostly the transaction of a currency-like token. Later on technology developed, which made it possible for blockchains to perform more complex operations, defined in a qualified programming language. (Josh Stark 2016)

1.3. Defining Smart contracts

The term "smart contract" has no clear and settled definition. It recently became a "hype" in business discussions, conferences and a wide range of journals as a central component of blockchain platforms and as a key capability for a range of practical enterprise application. Smart contract is however not a brand new term. It was introduced by Nick Sabo in 1997, he described smart contract as a "computerized transaction protocol that executes the term of a contract". To make it understandable, he used a simple illustration: the example of a vending machine. A vending machine is a contract with the owner of the machine. Anybody who puts coins in the vending machine participates in the transaction with the owner of the particular machine. After putting the coin, the purchaser chooses the product, and the machine with a simple code gives him the good he paid for, gives back change, and in the same time the lockbox

and the security machine protect the stored coins and products from attackers. (Szabo 1997) The term revoked just a few years ago, as blockchain technology ensures a secure platform for smart contracts. Before there were no such technology which made possible to have smart contract which were impossible to tamper with.

Smart contracts are defined variously in literature, e.g. as “autonomous machines”, “contract between partners stored on a blockchain”, “any computation that takes place in blockchain” etc. The definitions usually fall into two categories, - to specify a specific technology, thus a code that is stored, verified and executed on blockchain – or refer to a specific application of that technology, as a complement or substitute of legal contracts. (Josh Stark 2016)

According to Stark, if we look at the term smart contract as a code, it can be described as a program recorded on the blockchain (this is a characteristic, what distinguish smart contract from other softwares). This characteristic ensures permanence and censorship resistance. The program controls blockchain assets, stores and transfers amounts of cryptocurrency, no one can interfere in the execution process. To sum up, the term refer to any complex program that is stored and executed on the blockchain. Calling the programs as contracts shows that the code is governing something important or valuable. We are creating a contract, when it is important the enforce it, similarly we use smart contract code when the code controls something important, such as money or identity. In many cases smart contract codes are used not isolated, but as a part of an application. For instance DApp, DAO, or other blockchain applications is built using smart contract code to perform operations on the chosen blockchain. (Josh Stark 2016)

Among those, who work in finance or law the term “smart contract” differs in meaning from the above mentioned definition. They consider the term smart contract, a way to use blockchain technology and the smart contract code to complement or replace existing legal contracts. John Stark defines smart contracts in his article as: “the use of code to articulate, verify, and enforce an agreement between parties. A smart legal contract”. (Josh Stark 2016) In his view these smart contracts would be some kind of a combination between the smart contract code and more traditional legal language. He gives for the idea the following example, when we assume that a supplier enters into a smart legal contract with a retailer. The payments can be defined by the code and executed automatically when requirements are met and goods are delivered. However retailer might insist on an indemnity clause, where supplier agrees to indemnify the retailer in case of defective product, which gives a challenge to currently existing smart contract options. (Josh Stark 2016) It is a rational problem to address, although the author of this master thesis thinks that in the future using IoT implications in combination with blockchain and smart contracts could not only complement but until a certain point even

substitute the latter mentioned clause, as with sensors for instance we can track the temperature of the tracks (set as requirements in contract), also we can make payment based on quality control when receiving (measured by machines), thus in case of damaged product the smart contract could send back the money automatically to the retailer rather than sending it to supplier. Undoubted that in some cases smart contracts will require a blend of code and natural language. Thus the questions arise could smart contract become legally enforceable and can they comprise all components of a real contract? Because practical smart contracts are relatively new technology, it is not clear what extend they are legally binding. (Wüst and Gervais 2017) Most probably in near future smart contract won't be accepted as legal documents, however, at court they could mean clear evidence, which can assist the decision making of the judges, and also it will be inevitable in the future to start the process of embedment of smart contracts into legal systems.

Many specialists see larger possibilities in smart contracts, rather than just imitate or complement legal contracts. Perhaps smart contract code could be used to facilitate new types of commercial arrangements. Extensively discussed opportunity is for instance machine –to-machine commerce. The expanding network of smart devices will probably engage in basic commercial interactions with each other. (Josh Stark 2016) An example in supply chain could be autonomous ordering in warehouse. Smart alternative contracts might enable an entirely new type of commerce carried out between our computers, cars, phones, and appliances.

According to Karl Wüst and Arthur Gervais smart contracts are digital contracts, which are self-enforcing or make it prohibitively expensive to break contracts. As the blockchain can be used as a "distributed state machine" without a trusted third party, distributed ledger technology is suitable to support smart contracts. Bitcoin supports a limited set of smart contracts, Ethereum was the first blockchain platform which supports arbitrary code execution on the blockchain, allowing any kind of smart contract. (Wüst and Gervais 2017)

Since there are usually some extend of trust issues between partners, smart contracts can be used to come over these issues, without relying on a trusted third party (e.g. government). Put it in another way, smart contracts can simplify trustless protocols between multiple parties. Depending on the settings and the requirements, permissionless or permissioned blockchain can be used. (Wüst and Gervais 2017)

1.3.1. How smart contracts work on blockchain?

Within the blockchain context, smart contracts are scripts stored on the blockchain. Since they are located on the chain, they possess a unique address. We trigger a smart contract by

addressing a transaction to it, then the contract executes automatically in the prescribed manner on every node in the network, according to the data that was received by the triggering transaction. The smart contract has its own account on the blockchain. It contains electronic clauses that trigger processes according to the terms of the contract. Properly written smart contract should describe all possible outcomes of the contract. Smart contracts are deterministic; the same input will lead always to the same output. In a properly built blockchain platform, writing non-deterministic contracts is either impossible, or if it is possible, the system will reject the attempt to deploy. Since all the interactions with the contract are the result of signed messages on the blockchain, all participants of the network get a cryptographically verifiable trace of the operations of the contract. A blockchain supported smart contract supports interactions between mutually distrustful counterparties, as the possibility of despise is eliminated, since the parties cannot disagree on the final outcome of the verifiable process they engaged in. Smart contracts act autonomously, their behavior is absolutely predictable, and thus they can be trusted to fulfill any on-chain logic that can be expressed as a function. (Christidis and Devetsikiotis 2016)

A smart contract works through automated conditional performance. When a contractual obligation is met, the corresponding obligation is triggered. For example, an obligation could be triggered by:

- a specific event ("if X happens, then action Y")
- a specific date or at the expiration of a period of time ("at X date, action Y")

1.4. Business use of Blockchain technology and smart contracts in supply chains

In retail, manufacturing and other industries supply chains are critical in the movement of goods and services across organizational boundaries. Supply chain contracts are complex, dynamic, multiplayer agreements, which often cross jurisdictional boundaries, and which have regulatory and logistical constraints. The information exchange among supply chain members has the same level of significance as the physical exchange of the goods. For instance, customs inspections would not start until both the physical goods and the information about them arrived. Therefore trust is extremely important when values are transferred through the supply chain. Confidence in supply chain documentation can accelerate customs processes, reduce risk and insurance costs, and can be used as advantage in trade finance. In the supply chain payments are made between parties at many points. Thereby, supply chains are promising area for the application of blockchain technologies. The neutral ground provided by a blockchain could assist in integration of different participants in a supply chain, as well as the integrity and audit trail of

a blockchain ledger is foreseen to improve transparency, confidence and trust across the supply chain. With the help of Smart contracts and digital currencies on a blockchain payments can be executed automatically when linked to key supply chain events/processes. (Staples et al. 2017)

For manufacturers, their suppliers and logistic partners a transaction in a block might hold bills of lading for raw materials or finished goods, proof of origin, information on place and time of delivery etc. Blockchain enables also the creation of smart contracts, with terms and conditions specified by both parties. Smart contracts ensure trust in the enforceability of the contract and the identity of the contracting partner. As already discussed blockchain is a system of distributed trust, which allows for lower transaction costs in supply chain management in short-term, and also in the long term utilization of smart contracts could result in more agile supply chains, closer cooperation with business partners and faster integration with other developing technologies such as Internet of Things (IoT) and artificial intelligence (AI). (Satyavolu and Sangamnerkar 2016) We also have to consider the development spread of M2M communication in Supply Chains for which blockchain based smart contract opportunities could open a window for machines getting into contracts with each other making transactions among them without human interference. Smart machines could issue replenishment orders when restocking is needed, they could find the needed products at the best price and order and pay without manual interference with the help of smart contracts. (Satyavolu and Sangamnerkar 2016)

According to Heinen (2017) there are three major fields in supply chain management, where blockchain can be beneficial for businesses: traceability, Smart Contracts and safe transactions.

Traceability is significant mostly (but not exclusively) in food industry. The traceability of the ingredients' origins is important in order to run a trustworthy business. With the help of Blockchain technology and electronic tracking technology (such as WiFi, BLE or RFID) traceability can be accelerated, simplified and automated. In the future the origin of every raw material could be traced back and stored on the blockchain.

Smart contracts are also promising application in supply chain management. The 'electronic' contracts based on automated actions that are triggered through predefined events, can be used for instance for automated execution of payments when delivery is on-time and the right quality.

Safe Transactions is the third potential for the technology. Blockchain has the capabilities for validation of data, including a valid timestamp, which allows track the journey of data. It is useful when businesses exchange confidential business documents, transfer shipping documents and order confirmations. In combination with smart contracts it has an even bigger potential, as it could enable for example the automation of order books. (Heinen 2017)

In today's global supply chain environment paper contracts can take weeks to travel around the globe, while digital documents are uncomfortably easy to forge. This could be a problem solved with blockchain based smart contracts. As mentioned earlier, smart contract is an agreement in the form of a computer program that is executed automatically, when conditions set before are satisfied. On the blockchain, the goal of smart contracts is to simplify business and trade between both anonymous and identified parties, thus applicable both in case of public and private blockchains depending on the business model and structure. The utilization of smart contracts facilitate the reduction of formality and costs associated with traditional methods, without compromising on credibility and authenticity. Smart contracts have the potential to introduce radical change in the way international business and trade are executed by speeding up transactions, reducing paperwork, and improving cost-efficiency. (Kukkuru, 2017) Smart contracts could not only have the same details as a traditional contracts, but they could do something a physical contract cannot: perform such tasks as price negotiation, inventory level monitoring etc. This replaces expensive manual effort with automated processes in order to maximize profit. (Satyavolu and Sangamnerkar 2016)

Some benefits of smart contracts for supply chain management:

- *Security* – As the distributed ledger is practically impossible to alter and tamper with and there is no risk of insolvency
- *"One version of truth"* - Identical, dynamic copies of the contract are kept across the blockchain. Amendments to the contract has to be verified by all parties in accordance to the consensus algorithm, which solves the problem of version control. (No need of running comparison software over documents to avoid slight amendments made by the other party)
- *Accuracy*: Automated transactions are not only faster but less prone to error
- *Disintermediation* – As blockchain technology enables peer-to-peer agreements without large dependence on any intermediary. Smart contracts can enable less reliance onto third-party intermediaries that provide "trust" services.
- *Higher cost efficiency* – Smart contracts require less human intervention and fewer intermediaries, therefore they reduce administration costs.
- *Near real-time execution* – As transaction takes place almost simultaneously across participating computers, once the necessary criteria is satisfied
- *Transparency* – Creates an environment of trust as the logic and information in the contract is visible to all participants in the blockchain network (although in private

blockchains confidential information can be secured by appropriate visibility) Contracting parties can view and track the contract (possibly even in real time), which makes it possible to know which conditions are already met.

1.4.1. Challenges to deal with

- *Confidentiality:* Although companies desire transparency, they may hesitate on sharing contractual information on blockchain, which may contain confidential information, such as competitive strategies. On one hand Hyperledger (a blockchain platform) is permission driven and enables parties to engage in a private smart contract (visible only to parties involved in the contract), Ethereum on the other hand (another blockchain platform), has no such option as private smart contract. To sum up, companies and supply chains should select their blockchain platform based on their needs and business model.
- *Accuracy and comprehensiveness*: Since a smart contract is a computer program, each term and condition of the contract needs to be coded. As coders are not lawyers, there is possibility of misinterpretation and omission by the coder, which may lead to loopholes in the contract. The more we use smart contracts the more we will encounter with these loopholes, so there will be a need of new professionals with perfect judicial and programming skills
- *Unreliable inputs:* It has to be sure, that all input data on the blockchain is reliable, as the contract executes according to this data, which could lead to false contracts or non-execution of contracts. In case of traditional contracts there is a possibility for redressal by proceeding to judicial court. As mentioned before, in case of smart contracts there is no such option yet, as their legal validity is still debated upon.
- *Bugs and errors in the code:* These are major issues why smart contracts may fail, and can cause unforeseen unintended consequences. Such as the case when a hacker exploited a vulnerable code of the Decentralized Autonomous Organization (DAO) on Ethereum (which is a piece of smart contract) and stole 50 million Ether in June 2016
- *Rogue Contracts:* Taking advantage of self-execution and anonymity of smart contracts, illegal activities could also be conducted by smugglers, terrorists, hackers and others (Kukkuru 2017)

1.5. A review of existing Blockchain technologies for Smart Contract modelling

1.5.1. Ethereum

Ethereum has a public blockchain. It also groups transactions into blocks, however it enables developers to build and deploy smart contracts and decentralized applications (Dapps). Ethereum project claims that their aim is to take the internet to its logical conclusion: to total decentralization. It is important to mention that besides the Ethereum public and permissionless blockchain, there are several versions of Ethereum, which are designed be private and are permissioned. On Ethereum, a transaction involves a payload that can invoke a smart contract, the results of which affect the state of the blockchain. The Ethereum blockchain platform facilitates smart contracts, which are run through the network. Consequently, unlike Bitcoin, it does not just track transactions but programs them. The platform was proposed by Vitalik Buterin in 2013 in a white paper. Interesting fact about the network, that as it is a global distributed network (meaning that it does not run on central servers), the computational power of that runs the network is contributed by nodes across the world. As a result, they cannot be switched of, even if the system lose one node, it is continuing to work.

In Ethereum network the state (some sort of "balance sheet") is made up of so called "**accounts**" , each account has a 20-byte address and the state transitions are direct transfers of information and value between accounts. In other words, if all the accounts are considered together, they make the state on the Ethereum network. An Ethereum account consists of four fields:

- The nonce: which is a counter, that makes sure that each transaction is processed only once
- The account's current ether balance
- The account's contract code (if there is)
- The accounts storage (it is empty by default) (Buterin 2014)

"**Ether**" is the main internal crypto-fuel of Ethereum, and it is used to pay transaction fees. There are two types of accounts: externally owned accounts (controlled by private keys) and contract accounts (controlled by their contract code). **Externally owned accounts** are the ones owned by a person or a business. An externally owned account has no code, thus for sending a message from an externally owned account, the owner has to create and sign the transaction. An externally owned account has an address, an Ether balance, can send transactions: transfer Ether to other accounts or trigger a contract code. **The contract account** on the other hand works with

a code, every time it gets a message (function calls) from another contract or an EOA the code activates, allowing to read and write to internal storage and send other message or create contracts. Contracts have a persistence storage, contracts account also have an address and an Ether balance, however no one has direct control over them, they are autonomous accounts people or businesses can interact with (make transactions on it or call functions on it). As we discussed before, contracts on Ethereum are not something to be "fulfilled or comply with", they are more like "autonomous agents" executing a specific code when triggered by a message or transaction. They have control over their own ether balance, and keep track of their own variables. (Buterin 2014)

The term **transaction** in Ethereum refers to a "signed data package" that stores a message to be sent from an externally owned account. The transaction consists of: the recipient of the message, a signature identifying the sender, the amount of ether to transfer to the recipient, an optional data field, a "STARTGAS" value (representing the maximal number of computational steps the transaction is allowed to take) and a "GASPRICE" value (representing the fee the sender pays per computational step) (Buterin 2014).

The data field has no function by default, but the virtual machine has an opcode, using which a contract can access the data. The "STARTGAS" and "STARTPRICE" fields are important for preventing accidental or hostile infinite loops or other computational wastage in a code. For each transaction a limit has to be set about how many computational steps of code execution it can use. A fundamental unit of computation is "gas". Generally one computation step costs one gas, however some operations cost higher amount of gas, because they are or more computionally expensive or increase the data that has to be stored as a part of state. Additionally, every byte of the transaction data costs 5 gas. The intent of this fee system is to require an attacker to pay proportionately for every resource they consume (computation, storage, bandwidth). (Buterin 2014) In order to understand it more, STARTGAS value is a maximum amount a sender would pay for the code execution, and the GASPRICE is a fee in Ether the sender is willing to pay per unit gas, when the code is executed, the remaining gas is refunded to the sender, however if the contract execution runs out of gas before it finishes, the execution fails and returns to the original state, and STARTGAS and GASPRICE are not refunded. Malicious actors still can write infinite loops, but they will be not infinite, as at some point they run out of gas (no one has infinite resources), and it would be extremely costly for them to fund these loops.

Contracts have the ability to send **messages** to other contracts. The message contains: the sender of the message, the recipient of the message, the amount of ether to transfer alongside the message, an optional data field, a "STARTGAS" value. Actually a message is like a transaction,

with the difference that it is sent by a contract. A message is produced when a contract executing a code executes the "CALL" opcode, which produces and executes a message. Like a transaction, a message leads to the recipient to run its code. Therefore, contracts can have relationships with other contracts exactly like external actors can. (Buterin 2014)

Ethereum blockchain: Ethereum blocks contain a copy of both the transaction list and the most recent state. Aside from that, two other values, the block number and the difficulty, are also stored in the block.

As it was discussed earlier, the state of all accounts is the state of the Ethereum network. As a system, the entire Ethereum network should agree on the state of every single account: the current balance, storage state, contract code etc. This is all part of the consensus process of Ethereum. Ethereum network state is updated by every new block created on the blockchain. A new block is some sort of state transition function, a block takes the previous state and produces a new network state, upon which every node has to agree.

Code execution on Ethereum blockchain

In general, contract execution on Ethereum is expensive, as they are redundantly replicated across nodes, which creates an incentive not to use blockchain for computations that can be done off the chain more effectively. As everyone is putting their smart contracts onto the global network and sharing the same resources, there is always a bottleneck of the computational resources of one computer.

EVM (Ethereum Virtual Machine) on Ethereum

Ethereum Virtual Machine runs contract codes. "Ethereum Virtual Machine is designed to serve as a runtime environment for smart contracts based on Ethereum." (Buntinx 2017) The code in Ethereum contracts is written in a low-level, stack-based bytecode **language**, referred to as "Ethereum virtual machine code" or "EVM code". The code consists of a series of bytes, where each byte represents an operation. (Buterin 2014) Thus in EVM you do not writecode in high level language like Turing Complete. It is important to mention that the Ethereum Virtual Machine is isolated from the rest of the main network, so it is a perfect testing environment for smart contracts. Any company can create a smart contract using EVM without effecting the main blockchain operations. It can work as a learning environment for smart contract design in order to be able to build bigger and more complex smart contracts. The design goals of EVM are

simplicity, in order to easily keep it secure, space efficiency, the execution code should be deterministic, the same input state will yield the same output state.

Solidity on Ethereum

Solidity is a language created for the development of smart contracts, it is a Turing complete programming language. Its development began relatively recently, in 2014.

A contract in the sense of Solidity is a collection of code (its functions) and data (its state) that resides at a specific address on the Ethereum blockchain. When you have a contract written in Turing Complete language (solidity), you run it through the solidity compiler and that generates the EVM code. All of the complexity of the solidity is managed through this compiler to be EVM ready, transfers it to a simple stack-based language.

Smart contracts on Ethereum

The smart contracts in Ethereum are executed by the network without a trusted third party, without anyone being able to violate the contract. Hypothetically, if someone wants to violate the contract he has to subvert the entire Ethereum network. Ethereum allows peer-to-peer agreements that live on the blockchain forever. Ethereum allows developers to program their own smart contracts, called 'autonomous agents', in the Ethereum white paper. As explained above Ethereum runs smart contracts when a user or another contract triggers it by sending a message with enough transaction fees. After that the Virtual Machine executes smart contracts in 'bytecode', which is a series of ones and zeroes that can be read and interpreted by the network. (Buterin 2014) Smart contracts react to external world when stimulated by transactions (which can a function or send Ether), they have control over internal balance, internal contract state and permanent storage.

Ethereum smart contracts generally serve **four purposes** (obviously a combination of them is also possible):

- **Store and maintain data:** e.g.: implementing a token currency or organization membership on a smart contract, so representing something useful for users or other contract
- **Manage contract or relationship between untrusted users:** terms of the contract are publicly available, anyone can read it, by checking the terms anyone can agree and transact with other people in a trustless way, e.g.: escrow, financial contracts, insurance

- **Provide functions to other contracts:** serving as a software library, e.g.: having a smart contract working as an "alarm clock", the smart contract can be set to trigger all your other smart contracts occasionally.
- **Complex authentication:** to set a list of accounts that are able to interact with the smart contract, e.g.: M-of-N multisignature access

Consensus on Ethereum

Since Ethereum database is distributed across a peer-to-peer network and has no central authority, network participants have to agree on the validity of transactions so that they can be recorded. This agreement is called "consensus," and is achieved through a process called "mining." Miners perform complex, resource-intense computational equations to justify the validity of the transaction. Ethereum has a "proof of work" consensus protocol. "The proof of work is a piece of data that is costly and time-consuming to produce but can easily be verified by others." (IBM, 2017) In order to validate a transaction on the blockchain, an individual record must carry a proof of work to prove that consensus was achieved. This design enables that transaction records on Ethereum cannot be changed or tampered with after added to the blockchain. Ethereum has a very efficient way of achieving consensus without needed trusted third parties.

1.5.2. Quorum – a fork of the Ethereum public blockchain

Quorum is a permissioned implementation of Ethereum which supports data privacy. It achieves this data privacy by allowing data visibility on need to know basis by voting-based consensus algorithm to provide an enterprise focused distributed ledger and smart contract platform. Data privacy is achieved within the network by allowing data visibility on a need-to-know basis. The platform is designed to support "both transaction-level privacy and network-wide transparency" (jpmorgan.com). It was created and open-sourced by JPMorgen.

1.5.3. Hyperledger

Hyperledger is created to make progress in cross-industry blockchain technologies. The Hyperledger projects are hosted by The Linux Foundation, which is a global collaboration of members from various industries and organizations. Hyperledger develops enterprise-ready

blockchain solutions. It can be seen as an umbrella of open-source projects, and also as an open system for marketplaces, including decentralized data sharing networks and digital communities. Hyperledger projects contains communities of software developers building blockchain frameworks and platforms for businesses. The author will describe in the following paragraphs some current hyper ledger projects, such as Fabric, Sawtooth and Iroha. In 2017 more than 100 organizations is part of the Hyperledger community, collaborators include industry leaders in technology, finance, banking, supply chain management, manufacturing, and IoT. Hyperledger blockchains are generally permissioned blockchains, which means, as we discussed earlier, that the parties that join the network are authenticated and authorized to participate on the network. Hyperledger's main goal is to create enterprise grade, open source, distributed ledger frameworks and code bases to support business use cases. Otherwise speaking Hyperledger blockchains are designed on purpose to be enterprise solutions. As demonstrated on Figure 1 below, Hyperledger consists of eight projects, five of which are distributed ledger frameworks, the other three projects are modules that support these frameworks. (Hyperledger whitepaper)

Hyperledger frameworks are used to build enterprise blockchains for a consortium of organizations. They differ from public ledgers like the Bitcoin blockchain and Ethereum. The Hyperledger frameworks include:

- An append-only **distributed ledger**
- A **consensus algorithm** for agreeing to changes in the ledger
- **Privacy** of transactions through permissioned access
- **Smart contracts** to process transaction requests.

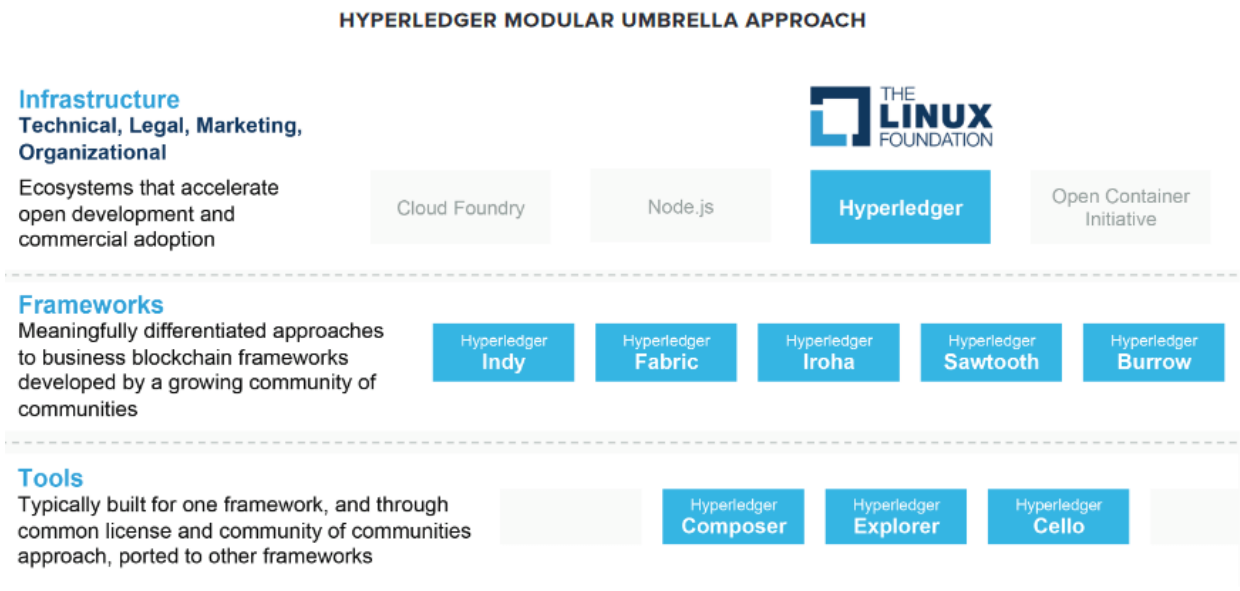


Figure 2 Hyperledger modular umbrella approach, source: Hyperledger white paper

Hyperledger Fabric

Hyperledger Fabric is a platform for distributed ledger solutions, supported by a modular architecture, which is able to deliver high degrees of confidentiality, resiliency, flexibility and scalability. It was the first proposal for a codebase. The modular architecture allows components such as consensus and membership services to be plug-and-play. Fabric is designed for pluggable implementations of different components, and for adaption to the complexity that exist in the economic ecosystem. Hyperledger Fabric is **private** and **permissioned**. Instead of an open permissionless system which allows unknown identities to participate in the network (requiring protocols like Proof of Work to validate transactions and secure the network), the members of a Hyperledger Fabric network join through a Membership Service Provider (MSP). Hyperledger Fabric provides several pluggable options. Ledger data can be stored in multiple formats, consensus mechanisms can be switched in and out, and different MSPs are supported. Hyperledger Fabric is revolutionary in allowing entities to conduct confidential transactions without passing information through a central authority. This is accomplished through different channels that run within the network, as well as the division of labor that characterizes the different nodes within the network. Hyperledger Fabric offers the ability to create **channels**, allowing a group of participants to create a separate ledger of transactions. This option is important in particular for networks where some participants might be competitors and not want every transaction they make known to every participant. (e.g.: special price offered to some participants, but not others) If two participants are a member of a channel, only they and no other network members have copies of the ledger for that channel. This option solves confidentiality issues. (Hyperledger.org)

Hyperledger Fabric has a **ledger subsystem** with two components: **the world state** and the **transaction log**. Each participant has a copy of the ledger to every Hyperledger Fabric network they belong to. The world state demonstrates the state of the ledger at a given point in time, it is the database of the ledger. The transaction log records all transactions which have led to the current value of the world state. It is the update history of the world state. To conclude: the ledger is a combination of the world state database and the transaction log history. (Hyperledger.org)

Smart contracts on Hyperledger Fabric

Hyperledger Fabric smart contracts are written in **chaincode** and are put into effect by an application external to the blockchain when that application needs to interact with the ledger. Usually chaincode interacts just with the database component of the ledger, and not the transaction log. Chaincode can be written in several programming languages. The supported chaincode language at present is "Go" with support for Java and other languages which will be in future releases. (Hyperledger.org)

Hyperledger Sawtooth

Hyperledger Sawtooth is a blockchain framework that employs a modular platform for building, deploying, and running distributed ledgers. Based on the size of the network, distributed ledger solutions built with Hyperledger Sawtooth can use various consensus algorithms. By default, it uses the Proof of Elapsed Time (PoET), which offers the same level of scalability as the Bitcoin blockchain without the high energy consumption. PoET allows for a highly scalable network of validator nodes. Hyperledger Sawtooth is designed for flexibility, supporting both permissioned and permissionless application.

There are some unique characteristics of Sawtooth. It is the only Hyperledger project that provides distributed state agreement, which means that you can trust that every node in the network has the same understanding of the information. It has a unique transaction processing interface, special adaptors are created in order to compile and run any kind of Ethereum Virtual Machine code, like Solidity. Hyperledger claims that Sawtooth can be well utilized in supply chain environment for provenance use cases. Since supply chain network will probably grow over time, Sawtooth is designed so, that the network is able to expand. You can also change the consensus mechanism in the meantime, which is also a unique characteristic of Sawtooth. Enterprises can have a policy within the network to accept new consensus which is submitted as a transaction. Than the network can move from e.g.: PBFT to PoET or to some leader election consensus. As a result it allows you to have ten, hundreds or thousands of nodes on your network, and the platform gives you the flexibility of your network which is supposed to work for long years. (Hyperledger.org)

Hyperledger Iroha

Hyperledger Iroha is designed to be simple and easy to blend into infrastructure projects requiring distributed ledger technology. Hyperledger Iroha **emphasizes mobile application** development with client libraries for Android and iOS, this makes it different from other Hyperledger frameworks. Hyperledger Iroha seeks to complement Hyperledger Fabric and Hyperledger Sawtooth, while providing a development environment for C++ developers to contribute to Hyperledger. Hyperledger Iroha features a simple construction, modern, domain-driven C++ design, along with the consensus algorithm YAC (= vote based algorithm for private blockchain). (Hyperledger.org)

Hyperledger Indi

Hyperledger Indy is a distributed ledger built for decentralized identity. (Hyperledger.org)

Hyperledger Burrow

Hyperledger Burrow is a permissionable smart contract machine. The first of its kind when released in December, 2014, Burrow provides a modular blockchain client with a permissioned smart contract interpreter built in part to the specification of the Ethereum Virtual Machine (EVM). (Hyperledger.org)

Hyperledger Explorer

In this short paragraph the Hyperledger Explorer is presented, which is a tool for visualizing blockchain operations for the users. With the help of the user-friendly web application anyone can explore the distributed ledger projects being created by Hyperledger's members from the inside, without compromising their privacy. Hyperledger Explorer can view, invoke, deploy, or query:

- Blocks
- Transactions and associated data
- Network information (name, status, list of nodes)
- Smart contracts (chain codes and transaction families)
- Other relevant information stored in the ledger. (Hyperledger.org)

1.5.4. Masterchain

Masterchain is a blockchain platform created by the Russian Fintech Assocoation for financial market, which is currently being certified and is preparing for mass commercial use - the launch is scheduled for 2019. Bank of Russia calls it “the first legally clean Blockchain in Russia”. On the base of Masterchain four pilots are implemented, all in the banking sector. The platform is working within the framework of Russian regulations and with the use of Russian cryptography. The technology is accepted by the Bank of Russia, and by the leading players of the market - so far only banking. The Association for the Development of Financial Technologies (FinTech Association) was established in 2016, which members are the most important players of Russia in banking sector, including Bank of Russia, “Sberbank”, “VTB”, “Alfa-Bank”, “Gazprombank”, “Bank Otkritie”, “KIVI Bank” and “NSPK (National System of Payment Cards)”. The Fintech Association’s aim is to develop standards and implement blockchain pilots for improving reliability, reduce costs and mitigate the risks associated with financial transactions in the financial markets. Their objectives are: reducing the number of intermediaries, making information available to all stakeholders at the time of making changes, and ensuring controlled transfer or exchange of ownership rights for financial instruments and assets, and associated record-keeping. In 2017 “Qiwi”, one of Russia's largest payment firms, which has launched a new subsidiary in March 2017 focused on Blockchain development and consulting, also joined the association. Moreover, the CEO of “Qiwi”, Sergey Solonin, became the leader of the FinTech Association. (FTA, 2017)

Masterchain is built using a fork of the Ethereum blockchain, however there is one key difference: Masterchain is built according to domestic cryptography standards. Masterchain is a private blockchain.

1.5.5. Corda

Corda is a distributed ledger platform (it is technologically not a blockchain) developed by R2 especially for financial services industry to the benefits of its clients. As Supply Chains has a financial aspect, according to the author of the thesis it is worth to list in line with existing blockchain platforms. Corda is a distributed ledger created for recording and processing financial agreements. The platform supports smart contracts. A smart contract on corda contains computer code and legal prose as well, thus it is an agreement whose execution is automatable by computer code (working with human input and control), and whose rights and obligations, as

expressed in legal prose, are legally enforceable. Corda's smart contract combines business logic with associated legal prose in order to ensure that the financial agreements on the platform are rooted firmly in law and can be enforced. Corda is specialized for highly regulated financial institutions. It is inspired by blockchain systems, however without the design choices that make traditional blockchains inappropriate for many financial scenarios. (Brown et al., 2016)

Corda presents a framework for running **smart contracts** with the following key activities and features:

- Recording and managing the evolution of financial agreements and other shared data between two or more identifiable parties in a way that is grounded in existing legal constructs and compatible with existing and emerging regulation
- Work flow between firms without a central controller.
- Supporting consensus between firms at the level of individual deals, not a global system.
- Supporting the inclusion of regulatory and supervisory observer nodes.
- Validating transactions solely between parties of the particular transaction.
- Supporting a variety of consensus mechanisms.
- Explicit links between human-language legal prose documents and smart contract code.
- Using industry-standard tools.
- Restricting access to the data within an agreement to only those explicitly entitled or logically privileged to it. (Brown et al., 2016)

Corda has the idea of a global ledger, however, transactions and ledger entries are not globally visible. In cases where transactions only involve a small subgroup of parties the blockchain keeps the relevant data purely within that subgroup. The foundational object in our concept is a state object, which is a digital document which records the existence, content and current state of an agreement between two or more parties. It is intended to be shared only with those who have a legitimate reason to see it. To ensure consistency in a global, shared system where not all data is visible to all participants, we rely heavily on secure cryptographic hashes to identify parties and data. The ledger is defined as a set of immutable state objects. (Brown et al., 2016)

Consensus in Corda:

In Corda, updates are applied using transactions, which consume existing state objects and produce new state objects. There are two aspects of consensus:

1. *Transaction validity*: parties can get certain about the validity of a proposed update transaction defining output states by checking that the associated contract code runs

successfully and has all the required signatures; and so any transactions to which this transaction refers are valid as well.

2. *Transaction uniqueness*: parties can reach consensus that the transaction in question is the unique consumer of all its input states. In other words, there exists no other transaction, over which participants have previously reached consensus (validity and uniqueness), that consumes any of the same states.

Parties can agree on transaction validity by running independently the same contract code and validation logic. However, consensus over uniqueness requires a predetermined observer, which in lot of the cases will be necessary to be independent. (Brown et al., 2016)

1.6. Research Gap

After conducted a comprehensive literature review around the topic of Blockchain Technologies and Smart Contracts in Supply chain management, it can be identified that the technology seems to be the next technology which will lead to changes in supply chain management and in international trade. More and more companies join the Ethereum or Hyperledger projects in order to develop Blockchain based systems with automatic Smart contracts on it in order to stay competitive in the future and increase profit by the higher efficiency it promises. Moreover, it was observed that according to a range of specialist supply chain management could be the most influenced field in Smart Contract implications as besides finance it has the most potential utilizing the technology. Blockchain solutions can be a certain supply chain's competitive advantage in the future, thus companies should understand how to implement the technology in a proper way.

From the literature review it was determined that there are several technical studies about how Blockchain and Smart Contracts work, however there is a lack of business studies and studies touch upon the aspects of Supply Chain Management or Logistics.

Accordingly, the following research questions were stated:

- Which Supply Chain Processes are suitable for Smart Contracts (which are not)?
- What are the requirements (success criteria) out of the supply chain for Smart Contract design?
- Which Block Chain technology(ies) fit(s) and is (are) appropriate for Smart Contract modelling in the Supply Chain Environment?

Research gap exists in both theoretical and practical perspectives. From the theoretical perspective the research contributes to the sphere of Blockchain and Smart Contract theory, which is quite uninvestigated. Thus, methods for Smart Contract development and different

blockchain solutions in Supply chain management is expected to be revealed. Additionally, the study is expected to be valuable to the theoretical spheres.

From the practical perspective during the research a collective of "first smart contract developers" is expected to collect information from, in order to develop a methodology of requirements and processes of supply chain management Smart contracts can address, especially for businesses interested in keeping up with technology and willing to implement Blockchain technology in their supply chain environment. The study is expected to hold value for supply chain managers, financial managers and accountants, IT managers and other employees, who participate in implementation of digital solutions in Supply chain management.

1.7. Summary of Chapter 1

The literature review of Smart contract in Supply Chain environment, which is presented in the first chapter, is conducted thematically. It consists of the following parts parts: The concept of supply chain and supply chain management, followed by several issues in supply chain management which is connected to this new technology, such as trust, value transfer and technology implementation in supply chain management. In the first part of the chapter different concepts of supply chain management was investigated, and also the different definitions of supply chain and supply chain management, in order to have a holistic view of the field we plan to locate our research. Both the terms and concepts and its development over time was reviewed, and supply chain trends were identified. Additionally, implications of blockchain technology for supply chain management and logistics were mentioned, as well as different Blockchain technologies that exists and are suitable for Smart Contract design. The most developed Blockchain technologies on the market which are able to run smart contract codes are Ethereum and Hyperledger, thus the emphasis is put on this two technologies, however a description of Masterchain and Corda is also a part of the technology review. By choosing the main blockchain platform, the author took into account the boundaries of time for a master thesis, and the fact that all the other Blockchain startups appeared in 2017 are brand new for deciding which ones will survive on the market in the future, thus they are not relevant or widespread yet. They might be a future outlook for further research. During research work the functionality of the mentioned technologies, as well as their benefits, drawbacks and recommendations for implementation are expected to be found.

Having analyzed articles on Blockchain technology and Smart contracts, it was found out that there are very few studies, which identify Smart contract solutions in supply chain

management. This indicates that there is a research gap, thus this topic can be investigated in this master thesis.

The author discovers a lack of clear terminology and some contrasting determination of the technology. Lawyers often see smart contracts as marginally improved legal agreements, without appreciating the fuller potential of blockchain-code to extend beyond law's reach. On the other hand, developers consider smart contracts without appreciating the nuance and commercial realities reflected in traditional legal agreements. (Josh Stark 2016)

Blockchain coupled with smart contract technologies removes the reliance on central systems between transacting parties. Untrusting parties can transact directly with each other using smart contracts, which are stored on the blockchain with all parties having a copy of. The smart contract can execute agreed stored process when triggered by an authorized/agreed event just like traditional and all contract transactions are stored in a chronological order on the blockchain for future access along with the complete audit trail of events. If any party tries to change a contract/transaction on the blockchain, all other parties can detect and prevent it. It does not rely on a central authority, as any party fails the system continues to function with no loss of data or integrity. With smart contracts businesses can trust their customers/suppliers as business agreements are executed automatically.

Chapter 2. Methodology of research

2.1. Research strategy

This study is based on a qualitative research approach, which is chosen according to research goal of the current master thesis. The qualitative approach allows to investigate deeply the research questions stated in the introduction. Qualitative research has several advantages, including observation and measurements in natural settings, interpretation and rational approach, subjective 'insider' view, holistic perspective and others. (Ghauri and Grønhaug 2010) Moreover, as the topic of Smart contract implementation is currently under development, especially in Russia, it is early to carry out quantitative research and measure any data. The business implication of blockchain and its smart contracts is in fact new and complex, thus extant theories are not fully available to explain the phenomenon, this is why a qualitative approach is the preferred one. Furthermore the topic of Smart contracts, their utilization in. A

qualitative exploration in is generally flexible, with low level of formalization, compared to other research strategies, furthermore it is not focused on representativeness of the sample.

In order to apply qualitative approach, a wide range of research methods in logistics and supply chain management can be used, for instance surveys, case study, interviews, focus groups, modelling, experiments etc. (Larson and Halldorsson 2004) All the above mentioned methods can be useful tools for research in supply chain management (Larson and Halldorsson 2004), however it is crucial to choose a research method, which corresponds the best with the research problem and research goal of the study.

After studying several articles and textbooks regarding research strategies, multiple case study was chosen as method for achieving the research goal. One benefit of the case study method that it enables to address 'What?', 'Why?' and 'How?' questions in the research process (Ellram 1996) (Meredith 1993) (Yin 2009). Since in the research all research question point to the direction to 'how' to utilize this new technology in order that businesses could keep up with future trends of further digitalization, investigating the suitable processes, requirements of Supply Chains and appropriate Blockchain Technology, multiple case study will be a suitable research design in order to discover this information.

Case studies are applied in academia to achieve different goals: to provide description (Kidder, 1982), test theory (Pinfield, 1986; Anderson, 1983), or generate theory (Gersick, 1988; Harris and Sutton, 1986). As stated by Yin (2009), there are three types of case studies: exploratory, explanatory and descriptive. In the research a combination of descriptive and exploratory case studies will be used, as these types of research allow us to deeply describe a phenomenon within its context and to define open questions (Kotzab et al. 2005). Supply Chain Management, and the comparison of different blockchain technologies is not well structured in existing secondary sources, thus the lack of theory in the field of supply chain management and logistics also support the decision of using case study as a research strategy. Furthermore, Stuart (2002) proposes that case study is an appropriate research method for supply chain studies, as it enables to map the field of supply chain management, and allows the identification and description of critical variables

According to Yin (2009) there are two classifications of case studies: single case study and multiple case study, and holistic and embedded case study. A single case study is usually used when it represents a critical case or a unique case. Furthermore, a single case can be chosen if it is typical or provides an opportunity to observe and analyze a phenomenon which was studied only by few researchers. Multiple case strategy implies using more than one case study for the research. In multiple case strategy it is expected that findings of the first case occur in other cases as well and as a result these findings can be generalized. In this thesis multiple case

study will be used, in order to provide a more comprehensive research result. There are certain criteria, which should be taken into account while selecting case studies. For multiple case study method a replication logic often can be used, but it is also can be used within a certain domain (Eisenhardt 1989). Regarding second classification, it is referred to the unit of analysis. When holistic case study is used, it means that the research is concerned with the organization as a whole. As for embedded case study it is applied when there is a need of examining a number of logical sub-units within the organization, perhaps departments or work groups, which means that several units of analysis will be involved for the analysis (Eisenhardt 1989). In the research embedded case studies will be used, since we are looking at only supply chain aspects of the problem (not the whole organization is in focus), however the case studies will have also a holistic point of you in a way that we are assessing whole supply chains and not just certain units of the organization.

A five stage research process model is developed by Stuart et al. (2002) for qualitative case based research. The five stage model is represented below.

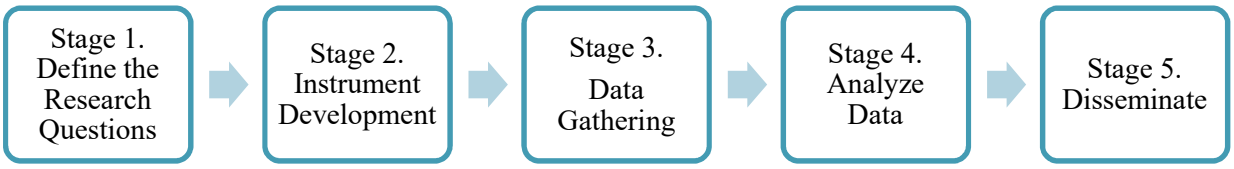


Figure 3 The five-stage research process model

The research of the master thesis is conducted according to this model. The first stage represents the theoretical chapter about defining the state of the art, where the researcher lays down the basis of the research, describing the existing concepts about the topic, finds a research gap, defines the aim of the research, and places the research questions. In the second stage research methodology is developed. In stage three the researcher finds companies to work with and begins with data gathering. After data is gathered the analysis of data begins, and finally research result are stated at the end of the master thesis.

2.2. Research tactics

2.2.1. Data collection

The case study research, according to Yin (2009), may include such data collection methods as interviews, documentation, archival records, direct observations, participant

observations and physical artifacts. Case study allows us to use multiple sources of evidence in order to get a more comprehensive result, this called by Yin (2009) as data triangulation. In order to carry out comprehensive research both primary and secondary data will be used during the research process. Secondary data are frequently used in descriptive and explanatory research, which corresponds to chosen research design (Saunders, Lewis, and Thornhill 2015). Secondary data is especially important in order to laying down a basis for the empirical research in form of a literature review. For the empirical study in particular primary data was used. Primary data sources for the master thesis were internal company documents, official companies' websites and semi structured expert interviews. Additional secondary data sources were newspaper and journal articles, which were very important source in the beginning of the empirical study when companies were selected for the case study analysis. For exploring business cases semi-structured interviews were conducted with representatives of companies who were ready to share their experience and opinions. Such type of interview allows you to cover a preliminary set of issues. On one hand semi-structured interviews are open, allowing new ways of interpretations to come up, based on what the interviewee answered, on the other hand they are more structured than in-depth interviews, which allow us to stay focused on the main issues of the research. Qu and Dumay (Qu and Dumay 2011) claimed that the interview is one of the most important qualitative data collection methods and this method has been widely applied in various studies, this argument supports the data collection method of the master thesis. The researcher succeeded to contact a Russian Transportation company "Traft", a Russian bank "VTB", and a Russian retailer M.Video. The specifics of the subject investigated within the research requires direct communication with companies applying blockchain technology. In order to receive diverse result, so that they could applicable in different situations, in the selection procedure companies from different fields of operation were chosen. It is important to find people who are both experienced enough in the subject and enthusiastic in order share his/her insights with the researcher. The observations and opinion of professionals, who are at the leading edge of the implementation of Blockchain technology, are of high value. In order to have comprehensive analysis set of documentation was also examined, such as industrial reports, press-releases, and articles appearing in mass media or in community newspapers. These types of documents are increasingly available through Internet searches. In the table below (Table 1) strengths and weaknesses of data sources are listed.

	Strengths	Weaknesses
Documentation	• Stable – can reviewed repeatedly • Unobtrusive – not created	• Retrievability – can be difficult to find • Biased selectivity, if

	as a result of a case study • Specific – can contain the exact names, references, and details of an event • Broad – can cover a long span of time, many events and settings	collection is incomplete • Reporting bias – reflects (unknown) bias of any given document's author • Access – may be deliberately withheld
Interviews	• Targeted – focuses on case study topics • Insightful – provides explanations as well as personal views (e.g. perceptions, attitudes, and meanings)	• Bias due to poorly articulated questions • Response bias • Inaccuracies due to poor recall • Reflexivity – interviewee gives what interviewer wants to hear

Table 1 Sources of Evidence: Strengths and Weaknesses, source: Yin (2009)

Conducting interviews with experienced professionals is highly precious for a research, and also a useful research tool. The purpose of conducting expert interviews was to reveal the potentials, that blockchain technology and smart contracts can bring to companies' supply chain practices. Professionals asked purposely represent different industries in order to gain a more extensive view of Smart Contract application. Professionals from corporate world were approached in different ways: directly by e-mail, phone, LinkedIn message or with the help of University career center. Since utilization of blockchain technology is in the initial stage not just in Russian Federation, but worldwide, which implies that there is a lack of required data available to analyze the technology's potentials. In such conditions, gathering the opinion of people, who has already some experience with the topic, and actively engaged in technology implementation is an important way to receive first-hand knowledge.

According to Fisher (2010) in order to conduct a semi-structured interview, the following steps of preparation should be taken.

1. Sort and list the areas of questioning
2. Edit and prioritize questions
3. Consider methods for analysis of the questions
4. Place the questions into sequence
5. Check the questions for relevance of the research topic

These steps seems to be obvious, however they should be taken, since interview is a tool for the empirical research, which needs to be clearly organized.

During the interviewing process all characteristics of a semi-structured interview was met. The interviewer and the respondents engaged in a formal interview. The interviewer developed an interview guide with the help of mind-mapping in order to be able to cover all the topics needed during the conversation. The interviewer followed the guide however at the same time allowing to move away from the guide when necessary in order to receive valuable new information, which may bring the opportunity for identifying new ways of seeing and understanding the topic at hand. The interview guide provided a clear set of instructions for the interviewer and as a result reliable, comparable qualitative data to analysis. For easier analysis the conversations were tape-recorded with the permission of the interviewees and later tapes were transcripted.

In the following table the companies and their representatives are listed, who participated in the current study.

Case Company	**Respondents' position**
Traft	• Executive director • Chief Communications Officer
VTB Bank	• Director for Project Management, Digital Transformation Department
M.Video	• Head of treasury (Project manager of the implementation)

Table 2 Interview respondents

In the following figure (Figure 4) three planned stages of data collection is described.

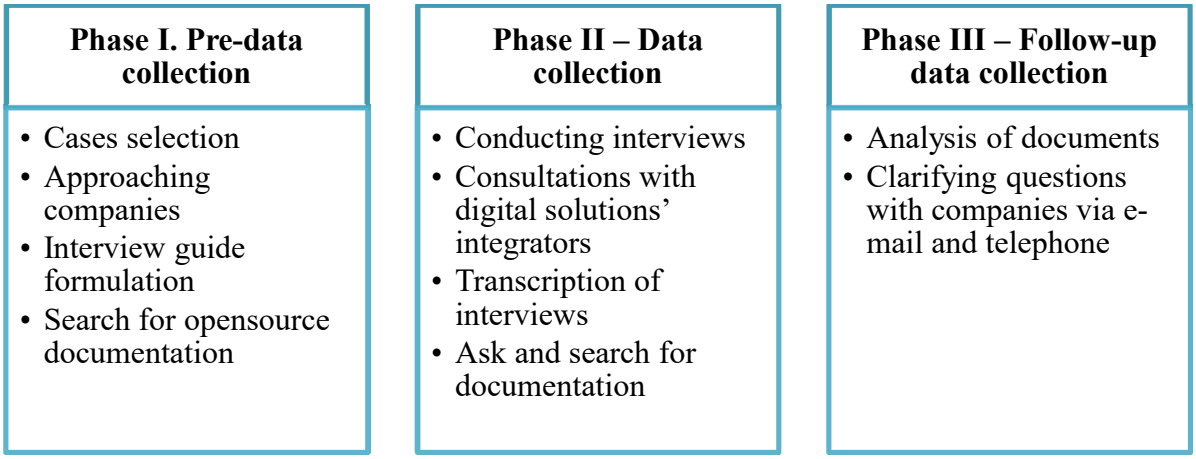


Figure 4 Data collection process

2.2.2. Data analysis

Since the research strategy of the thesis is case study, data analysis procedure can divided into two categories: within-case study analysis and cross-case study analysis.

Generally, within-case analysis includes detailed description of cases based on obtained data from interviews, consultations, company documentation, official websites, and observation. Within-case analysis can be helpful at the beginning of the data analysis since it allows to structure great volume of received data. Also, within-case analysis allows to obtain unique patterns for each case before making generalizations across cases (Eisenhardt, 1989). Moreover, within-case analysis can facilitate cross-case comparison.

Cross-case analysis can be typically performed using two tactics (Eisenhardt, 1989). The first tactic is to select dimensions and then search for within-group similarities and intergroup differences. Dimensions can be identified based on the existing literature or research problem or the researcher can choose them. The second tactic consists of selecting pairs of cases and then listing similarities and differences between each pair of cases. There is also an extension to this tactic, which consists of grouping cases into larger groups (more than two cases in a group) for comparison. As Eisenhardt (1989) pointed out comparison of cases can lead to novel findings such as new concepts and categories in terms of the research problem. For the research the first tactic was chosen and dimensions were chosen by the researcher.

In the research both within- and cross-case analysis is employed. In the within case studies particular companies were explored according to some dimension chosen. In cross-case analysis a cross-case synthesis technique was used in a form of a word table with several aspects to compare upon. The created word table displays the data from the individual cases according to a various categories, which enables to draw a cross-case conclusion from the individual cases.

2.3. Summary of chapter 2

In the current chapter the methodology and research design were presented, including research strategy and research tactics and limitations. The research has an exploratory and qualitative nature, the research strategy is a multiple case-study in a form of within case and cross-case analysis.

The first step in collecting empirical data is conducting semi-structured interview with industry experts and simultaneously analyzing documentation related to the issue studied. Professional currently working with blockchain technology were addressed, and chosen as

interviewees. Semi-structured interview design was applied in order to gain more valuable insides connected to the preliminary set of topics.

Regarding data, primary and secondary sources were used. In this master thesis secondary data includes articles from mass media and professional journals. As for the primary sources, in this research qualitative semi-structured interviews with companies' managers were conducted, internal company documents, companies' websites were analyzed.

As for the criteria for cases selection, Russian companies or Russian branches of international companies were chosen. An obligatory criterion was experience of companies in implementing blockchain technology in supply chain management. In the master thesis interviews were the main parts of case study strategy. In some cases interviews were followed by additional consultations with the respondents to clarify some aspects and verify data.

To summarize, triangulation principle is fulfilled in the master thesis, since data is collected from different sources, and different research methods are used. This in result allows to decrease the level of subjectivism and bias in the current study.

Chapter 3. Application and best practices of implementation of blockchain technology in SCM and logistics in the Russian market

Supply Chain Management is an important topic when it comes to industrial applications of the Blockchain Technology – beyond Cryptocurrencies. This is the major focus of the current research. However, in Supply Chains there are several financial transactions (payments, financing etc.) that are part of the so-called Financial Supply Chain. These transactions and the interaction between all partners in the Supply Chains (Suppliers, Buyers, Logistics Service Providers etc.) can be facilitated with Blockchain applications and Smart Contracts – this is the Hypothesis that researchers are investigating all around the world. Knowing that some part of the traditional Business of Banks is threatened by new Technologies, banks have an increasing interest in understanding Supply Chains in order to see potential for future Business. This is the reason of interviewing not only companies but also some banks in order to gather the necessary information for the cases. For the research, several implementations of blockchain technology regarding supply chain management were selected in the Russian market.

The following criteria were chosen for case selection of companies:

- Logistics providers (3PL), distribution companies, manufacturing companies or retail companies
- Experience in implementing blockchain technology in supply chain management

- Russian companies or Russian branches of international companies

The following criteria were chosen for cases selection of banks:

- Russian banks or Russian branches of international banks
- Experience in implementing blockchain technology regarding processes connected to Supply chain management and logistics (e.g. trade finance, payment etc.)

In the following cases will be analyzed with the help of within case studies and cross case studies.

3.1. Within case studies

Case 1 – Traft

Company overview

Transport Company "Traft" was established in 2000 as a representative office of the German company TRAFT-GROUP for the implementation of intercity transportation in Moscow and Moscow region. In 2005, the transport company Traft became a separate legal entity. The company primarily deals with last mile deliveries. Besides remaining one of the leaders of transport companies in Moscow, the company expanded its scope of activity and entered the intercity transportation market. They have also branches in the large cities, St. Petersburg, Krasnoyarsk, Krasnodar. The main directions of their activity are: cargo transportation in Moscow, Moscow region and Russia, provision of warehouses for temporary storage and cross-docking. The company's services are used by many well-known international and Russian companies. Among their clients there are both small enterprises and large companies such as DHL Deutsche Post, General Motors, Mercedes-Benz, Gillette, Colin's, Konica Minolta, SONY, TARGET, Solo, Calzedonia, Boeing Boeing Company, MTS and so on. The main priority for the company is the quality of their logistics services, as they positioned themselves with a higher than average price for their services. They guarantee responsibility by partner insurance companies: "Soglasie" and "Alliance". The company has their own fleet with wide range of vehicles. Refrigerated vans and isothermal cars are able to transport perishable products according to safety standards, for oversized cargo transportation low-slung vans with special ramps are provided. The company is ready to carry out dangerous goods transportation and develop a logistics solution for any special situation. They transport both goods with a small lot and goods weighing from 1 to 20 tons. In 2014 the company decided to delve into what is now called "digital logistics", "digital economy". The organization decided to develop its own

software product that allows its partners to more flexibly, manually control everything related to transportation. At that time 4-5 years ago the level of logistics in Russia was simply "prehistoric". All communication between the client and the carriers took place exclusively by phone, Fax, e-mail, and the client could never control every stage of transportation. The company understood that their clients would like to get all information regarding their logistic processes. They looked at modern business models such as Uber, Yandex, Gett, AirBNB and tried to move these principles to logistics market. For this Blockchain seemed a good opportunity. The company joined the international Association of developers and operators of blockchain in logistics - Blockchain in Trucking Alliance (BiTA) in 2017.

Business use of Blockchain and Smart Contracts

TRAFT is the first company in Russian freight market, which carried out reconciliation and verification of transport documents using blockchain technology. The prototype of the solution with the encryption algorithm and confirmation of cargo transportation data, followed by guaranteed storage of information, was developed in the company's own IT department. They are using blockchain as a decentralized data storage, in other words information is synchronized and stored at each participant of the transaction. Thanks to blockchain, the human factor is completely excluded from this process – the reconciliation of commercial information takes place automatically. The platform compares the hashed data of documents for each cargo transportation (contracts, invoices, waybills): if they are corresponding with each other at both participants, the delivery is confirmed and the invoice for payment is automatically generated from the customer who ordered the shipment. Due to the blockchain technology, Traft can enhance the security of financial transactions between the client and the transport company and reduce the time spent on confirming cargo transportation. Especially when a new, previously unverified driver is carrying out the transportation, or if the client cooperates with Traft within the framework of its own software, through which it also delivers the order of other transport companies in parallel. Such a closed process completely eliminates the risk of information leakage and fraud related to hijacking of a vehicle or theft of its cargo. The new system makes it even more convenient to manage cargo transportation, carried out by retail and online retail companies, which already switched to fully electronic checks.

The company operates a cloud platform based on blockchain technology, which provides customers with full automation of cargo operations and implements the function of "physical Internet" in logistics. The technology of "physical Internet" implies unification of containers (universal containers for goods of all sizes), standardization of transportation, creation of unified

hubs and routes and transparency of processes through full control of the movement of each truck.

The company has an online interface for their clients where they can enter into deal with the freight company. This interface is called TRAFT-Online. TRAFT-Online is an intelligent freight management system that works on the SaaS model and allows users through a universal interface designed in flat design format to create and control all parts of the supply chain, including packaging, transportation and unloading of any cargo, as well as placing orders for cross-docking and warehousing services. Each client, connected to the Traft-OnLine platform, is transferred to the blockchain, where they can enter into individual smart contracts (automatically executed contracts) with a carrier or a series of carriers, describing the terms of the contract, such as: the transfer of goods to the next member in the supply chain, tracking the terms and conditions of carriage (for example, temperature in a container). A smart contract is created based on the Ethereum platform. (standard ERC20). Data on the transportations necessary for the execution of contracts are obtained from existing GLONASS / GPS-systems and other sensors installed in the vehicle. The data of all transportations in the system are protected by end-to-end encryption, only the immediate participants in the transaction can access the data. It is also possible to include the role of an auditor having access to all data; for instance an insurance company or a bank that provides an escrow account can act as an auditor. Every time the delivery passes from one hand to another, the operations are automatically, accurately (and unaltered) documented in the distributed ledger of the blockchain, reducing processing time and added cost, and eliminating the risk of human error. From a technical point of view, the system is a blockchain itself deployed on the company's servers, and client SOFTWARE for interaction with a distributed ledger. The system is closely intertwined with existing systems (e.g.: 1C, SAP, Oracle). According to Traft developers, it is possible for large carriers of the platform to deploy a part of the system on their side, which will increase confidence and speed of processing, without reducing the overall reliability. Rapid development of systems and technologies for e-wallets, money and transactions based on blockchain technology will lead to their widespread use. Given the real possibilities of legalizing the issue of electronic currency in Russian Federation, the system becomes promising from the point of view of the financial component of the interaction of the participants in the process. One example is the automatic charge-off when the controlled parameters of the smart contract are violated.

Processes automated using smart contracts

First of all, the execution of payment can be automated. The company checked it and according to their experience, it works properly. Payment is automated with smart contracts as the delivery is conducted. Smart contact in this case is used as a "deposit account" where the client transfers money in advance. This deposit account opens up only when certain conditions are met in the smart contract. In the case of Traft, this deposit account opens up only after the smart contract gets a series of signals. First of all, a signal from satellite that the driver arrived at the destination, through GPS connection which is installed in the software of the mobile application that each driver has installed on their phone. When the back office of Traft sees that the truck arrived at the point necessary and the driver took certain actions accordingly, e.g. he unloaded the truck and pressed the appropriate button in the application and uploaded a photo of the transport documents which was given by the employee of the warehouse, finally employees of Traft validate the document. This way they can be sure that there was no fraud with documentation, that the driver arrived where necessary and unloaded the cargo, for which he received the confirmation document. When all conditions met, the smart contract opens the deposit account. The company expects that in the future with the help of smart contracts they will be able to automate the process of cargo insurance, as it is also a very important issue. For that they will need more sensors in order to understand all the conditions. Demonstrating with an example, in case of long-distant transportation between the two cities the company cannot always understand what happened with the truck, for instance, the driver says that the accident occurred, and in the area there are no security cameras, just with GPS sensors we are not always able to understand what really happened – a flat tire or an indeed serious accident.

In the future smart contracts help to read this information more accurately. In order to get extra information for efficiently work with insurers, additional tachometers must be installed in the vehicle. In other words, devices that record additional parameters about the vehicle. If, for instance, sensors record that the truck is 90% tilted, it is likely that the truck fell, in this case tachometer should make a request to the system about what is necessary to do further. In case of fruit-vegetables, the issue must be solved one way, in case of petrol, oil and lubricants (POL), the situation is even more critical and may need call the fire brigade to the point of the accident. Even such complex tasks the company plans to solve with the help of smart contracts, and automate it.

The most important thing in addition to payment is of course the process of document exchange_between parties. In Russia, much is being done on this issue at the legislative level. In early February, Prime Minister Medvedev signed a special law by which Russia enters into the

so-called "international Convention on electronic document management". This gives a new legislative framework for electronic documents, and enables accountants to recognize electronic documents as legal documents. Until now, it was impossible, thus accountants had to work with the original paper copies, with blockchain technology, accountants can receive the same legal, legitimate copy, only digital, encrypted, so that nor customers nor accountants would doubt their safety. Digital documents on blockchain are much better protected, their forgery is simply unrealistic.

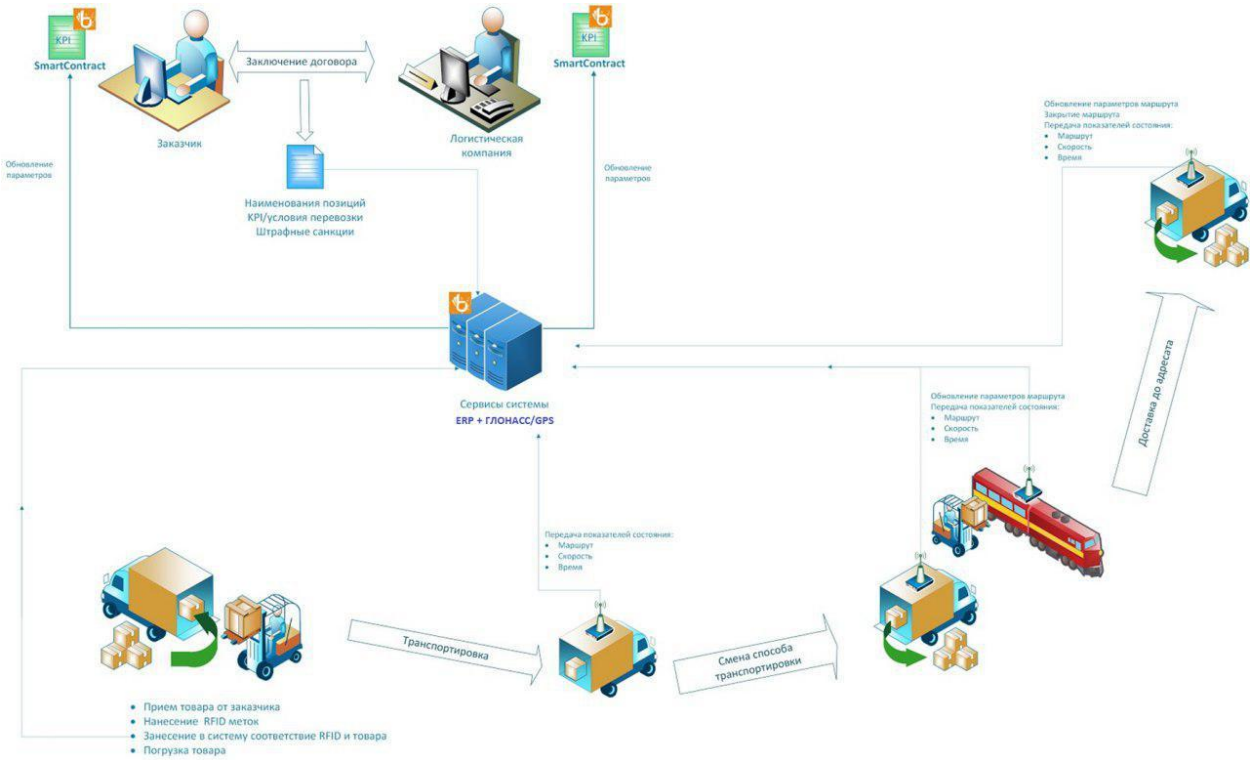


Figure 5 Blockchain system of Traft

Blockchain connected to IoT

Traft plans to connect IoT applications to blockchain. As already mentioned earlier, the company plans to install so called “tachographs”, which will permanently record all changes that occur with the truck, or with the cargo inside, which data will be used for insurance matters. The company also plans to conduct an experiment with perishable products in the near future. For this so-called "isothermal" trucks will be used, in other words trucks with special temperature regime will deliver frozen products, and special temperature sensors will be placed in the truck. In the case of perishable products a special condition can be to the smart contract, where the company guarantees the customer that during delivery the agreed upon temperature regime will be in place. For instance, a satisfactory condition can be added to the smart contract, that temperature must be kept as -20 (plus-minus 1-2 degrees), if condition is met, the smart contract

opens the deposit. In case the sensor records higher temperature (e.g. -5), condition is not met, a certain system signal is triggered which notifies the customer that a situation has arisen on the way of delivery, when the goods were in danger, as a result there is ground for refusing on payment, or at least to apply some sanctions. Cases for refusal of payment and/or penalties can also be written in the smart contract code.

Benefits of implementation – Improved logistic processes

The company had a trial project in 2017 where the developers encrypted the conditions of carriage using Blockchain technology in such a way, that it excludes the possibility for drivers to assign additional time to themselves. I was a long-standing problem, when drivers used paper waybills, that the driver arrived at the landing and knowing that no one was watching him was assign more time. When introducing software products, the company completely excluded the possibility to assign time, thus fraud with time assignment and inefficient use of delivery time is eliminated.

It became necessary to observe one more aspect, it is turnover of documents, and their processing time. On one hand when drivers get documents from the warehouse, they do not bring them immediately, thus documents were received by the office occasionally even after two weeks, as a result tradition paper based processes had a disadvantage for document processing time, and invoicing. On the other hand the issue of security of documents and their confidentiality remained open. The company decided to target this problem with encrypting some parts of the document, so that one part of this document was at the client, and the other part of it at the driver. After the delivery, both parts are automatically checked and if they correspond to each other, the carrier automatically receives the money in his account from the deposit account (which is actually a smart contract on blockchain). This happens in real time, when the client received the goods in his warehouse.

Furthermore, with using smart contracts idle trips has definitely decreased, thus as a result load levels increased. This is one of the goals of blockchain technology implementation at the company. Traft's own software is built on the principle of Airbnb (renting out not used houses), that is renting out unused capacities. Any large company with any fleet loses huge money for empty and inefficient loading of vehicles. This is especially true among intercity transportation, when the truck goes 300 km with the goods, after it is unloaded, then on the way back he has no order so the driver spends his time, fuel, capacity of the truck and at the same time he does not earn money. As reported by Traft, the situation on the market today is chaotic and far from ideal. This is shown by the high percentage of idle traffic — according to expert estimates it is 10-15%

of all trips. Moreover, incomplete loading of trucks the vehicle is loaded on average 70-75%. Also there is an uneven distribution of flows - 70% of the goods from the center. This non-optimal use of resources ultimately affects the prices in the store. In order to mitigate this phenomena Traft created the Vezubr system, which is a platform similar to Uber, just for Trucks. The company directly connects cargo owners with drivers within the framework of this platform, so that the driver can manually control his load. The main goal of the application is to maximize the performance of each truck

To sum up, economic effect cannot be measured yet, as the company started the implementation just a year ago, however the company foresees a large decrease in the expenditure part in accounting support. They will be able to exchange documents faster, receive money faster from the client. With the use of blockchain and smart contracts the company accelerated the processing speed of all orders, thus the speed of processing documents by decreased by several hours. For demonstration, if we take one client, where we save three hours of processing, it means a huge time saving if we take into account hundreds of clients. Secondly, the organization increased the level of security and transparency of customers. The customers can track the entire chain of movement of goods under the contract in real time, monitoring the routes of the vehicles, disclose documents in a secure way, and the truck drivers can maximize their load level. The delivery time is optimized, the dispatchers' efficiency is increased. Material and financial accounting is based on smart contracts, which brings with itself a transparency of operations and full trust of all participants in the system. The higher level of efficiency, transparency and security offered by blockchain technology helped Traft to justify its tariff policy, given the fact that it is not the cheapest company (the price level is above average). Thus from a business point of view, blockchain technology gives the organization not only security, but also some marketing advantages. Traft sees these technologies as a competitive advantage.

Type of blockchain used by the company

The company chose Ethereum as a blockchain platform for its smart contracts, because they needed a solution what can be implemented fast and fits the expectation of their business model. Hyperledger is a solution for large-scale projects where it is clear that this is a project for many years, in our case, the task was minimal effort and in a fairly short time. Developers of the organization have studied the software environment of Ethereum, the programming language "solidity", wrote a small basic smart contract and began testing. Within a month the developers of the company managed to check a demo version, and the management recognized that they

will be sufficient to use the opportunities offered by the Ethereum. Finally, the company decided to use Ethereum as the most accessible platform.

The company does not use cryptocurrency function of Ethereum as a mode of payment. However, in the future the organizations plans to introduce cryptocurrencies as a system of accumulation of certain bonuses-points for clients. Moreover, in the future, the company wants to introduce its own internal corporate and intra-sectoral currency, although the only big barrier remains the legislation. The law on cryptocurrencies adopted in Russian Federation needs to be finalized. Until that this experiment cannot be scaled officially, just as a private initiative within the company. Earlier, the company used special Tokens in their pilot project (not cryptocurrencies). Traft issued a conditional token, which was an internal settlement unit for which the company determined whether or not the transportation occurred, Traft sent this token to the client's e-wallet and as soon as the transportation was confirmed this token returned and the fact of its return meant that the transportation was carried out.

Case 2 – VTB Bank

Company overview

VTB Group is a global provider of financial services. The group consists of over 20 credit institutions and financial companies, which operate in all key areas of the financial markets. VTB Group is a holding company with a strategically aligned development model, which includes centralized financial and risk management, a common brand, and integrated compliance systems. VTB Group also has a wide global network, which makes it a major player in the Russian banking industry. It enables the group to facilitate international partnerships and promote Russian companies aiming to engage with global markets. VTB Group encompass a large international network across CIS countries; Armenia, Ukraine, Belarus, Kazakhstan and Azerbaijan. VTB also has banks across the world. Banks in Austria and Germany are part of the European sub-holding - VTB Bank (Europe) SE. The Group has subsidiary and affiliated banks in the United Kingdom, Georgia, Serbia, Cyprus, Angola, branches in China and India, and VTB Capital has a branch in Singapore.

The Russian Federation is the bank’s majority shareholder, the government owns 60.93% of the bank’s ordinary shares through the Federal Agency for State Property Management. The Ministry of Finance of the Russian Federation holds 100% of Type 1 preference shares, and the Deposit Insurance Agency holds 100% of Type 2 preference shares of the Bank. The aggregate stake of the Russian Federation (through the Federal Agency for State Property Management and

the Ministry of Finance), and the Deposit Insurance Agency is 92.23% of the Bank's share capital.

VTB bank is a member of Russian Fintech Association, which was established in January 2017. Their mission is designing and implementing new technological solutions, including blockchain technology, to support the Russian financial market. The founders of the association are the Russian Central Bank plus top players of Russian Bank sector. (VTB, Sberbank, Alpha Bank, Reifeisen, Gazprombank, and others) The main idea of the association is to build up an interbank in terms of blockchain.

Business use of Blockchain and Smart Contracts

The Bank's activities in terms of blockchain are focused on 3 main projects. All projects are interbank projects (VTB is collaborating with a range of Banks which are members of Fintech Association). The collaborating members arrived at the decision that that it is not reasonable to build blockchain projects which are focused only on a few banks, they try to build up a platform which could operate on wider interbank level, and join at least 60-100 banks in Russia, which will be interested in the platform. The undergoing three projects are in development stage. The areas of the projects are the following:

- Banking Guarantees (to make them paperless, and to make the operations for bank guarantees much easier and convenient for banks and clients, has some importance to the field of research, as it is a part of trade finance)
- Letter of credits (also part of trade finance, this field has more importance for the field of research, more related to current topic, going to be discussed in detail)
- Mortgages (to make them paperless, first for natural persons, next step will be for legal entities, not so much importance for the research, it won't be taken into account)

Banking guarantees and letter of credits are the part of trade finance, and trade finance is one of the most popular area for blockchain. VTB focused on the second project during the interview, since it is more connected to logistics and SCM. Letter of credits is strongly related to logistics of goods, and the documentation it brings with itself. They do not use the cryptocurrency functionality of blockchain at all, in all these projects they use blockchain for the documentation flow. Trade finance is still mostly based on paper, such as bills of lading or letters of credit being sent by fax or post around the world. VTB believes that hat blockchain is the obvious solution for revolutionizing financial supply chains, especially since in a trade deal numerous parties need access to the same information. Trade finance is a very important element

of the supply chain and blockchain can offer a several elements in this area, including distributed ledgers and smart contracts. However, banks will be unable to achieve blockchain benefits, if they act alone. It is useless to digitize trade finance without also digitizing trade. In order to work properly, the blockchain network should include not only the banks and shipping companies, but also the agents, the freight providers, the ports, the customs and the insurers. Besides letter of credits, bill of lading and other necessary documents should be also digitized.

Trade Finance - Letter of credits as smart contracts

A letter of credit is a special Bank account to which money is put with an obligation — to transfer it to another account under certain conditions. This is usually done in order to obtain firm guarantees of payment, to exclude the possibility of unfair partnership. If we talk about transactions with some goods, the supplier in this case is sure that his goods will be paid immediately upon receipt. It is not difficult to notice that the letter of credit is something like a smart contract, that is, a guaranteed transaction in the performance of certain conditions. Only a letter of credit is a smart contract of the pre-blockchain era. Blockchain can make it easier and more convenient. The supplier's and buyer's banks conclude a smart contract to create a letter of credit. Having received confirmation from the transport company about the delivery of the goods, the buyer's Bank automatically issues a letter of credit to the supplier's Bank. This can be called a transitional scheme from traditional business to blockchain-based business. In the future, probably not need the actual letters of credit, and smart contracts can be concluded not between banks, and between the direct participants in the transaction. But so far, blockchain architecture in Russia is being implemented primarily in banks, and they are running on the deals of the future.

Trade finance solution – the way VTB is planning to implement the system:

The implementation of the technology is in the development and planning stage, in the following the implementation plans will be described. The parties of a usual trade deal are: supplier, buyer, transport companies or 3rd party logistics companies, bank of supplier, bank of buyer, ports, custom services (in case of cross-border supply), and special agencies (e.g. if goods has special regulation by country of destination). In a usual trade deal it takes at least 4 up to 10-12 parties involved, depending on different aspects, such as transportation mode, domestic or international trade deal, special regulations. Current supply chain problem is that bureaucratic, paper based processes are slowing down the physical movement of the products, and data stored

in different database can cause differences in accounting and invoicing. With utilizing blockchain network and smart contract, goods will be able to flow without bottlenecks caused by insufficient documentation. Each deal will be a smart contract on the blockchain with several entry points, starting with the creation of the trade deal, then providing some additional documents (e.g. certificate of quality), and signals from the parties when supply chain events are happening. Considering an example of an international supplier deal with 8 participants, first a smart contract is created between the bank of the supplier and the bank of the buyer. To initiate a smart contract the bank of the buyer initiates a letter of credit (to provide a guarantee of payment for suppliers), than the supplier collects all the documents which are required for the buyer (for custom and special agencies). When all documents are prepared which are going to be shipped, they are placed on the smart contracts and all participants receive a signal. Participants such as customs, port and special agencies should accept the documents, agree on the information, and the goods can be shipped with the original documents. If the same documents will be accompanying the goods as uploaded into the smart contract, shipment will get a fast and easy pass. In the future the aim is to keep only electronic documentation on the smart contract (excluding paper variants). On the physical way of the goods every participant (like: port, transportation company etc.) signals to the blockchain when they received the goods and when they sent it to the next participant, so that all participants can track the route of the shipment. (when are they loaded to trucks, when are they loaded to a ship, where the vehicles are moving, when the ship arrives at the port, customs, port administration and special agency reviews the documents which are with the goods.) Finally when the buyer receives the goods, and has the quality checks, it signals to the buyer's bank in order to make a payment to the bank of the supplier. Thus, on the first stage when shipping documents are on paper it works with regular approval by authorities connected to the electronic system, when the system which has electronic shipping document will be trusted from the international trade finance point of view, this signals will be accepted automatically with this smart contracts, and push the view for the next stage to the next status.

Type of blockchain used by the company

The company will use a blockchain platform developed in Russia by developers of Fintech Association. This platform is called Masterchain, which is basically a private version of Ethereum. The code is based on Ethereum blockchain, however the cryptography is replaced by a local cryptography. Solidity (programming language) is used for writing smart contracts. Proof-of-Work (PoW) consensus is used now, which would be legally accepted shortly (3-4

month timeframe) by the Russian Government. However, PoW will be most probably replaced by Proof-of.Stake (PoS) in 12 months. Prone to the heavy utilization of computational resources involved in mining, PoW is considered to be costly, wasteful and inefficient. Under the PoS algorithm, tokens are issued to the validating nodes in the network from the very beginning of the network's existence, which means that unlike PoW, tokens are not concurrently mined as new blocks are added to the ledger, thus it does not require so much energy as PoW. Another influencing factor is the time period that coins have been held by users. It indicates whether they are invested for the long-term into the platform, which is clearly a more desirable position than someone who just purchased their coins yesterday. Those with more stake in the network are deemed to be more trustworthy and considered less likely to attack the network. VTB is working with Masterchain because it is important to make the deals legal. In order to meet the legal obligations of the Russian Government a local encryption was created. In any other aspects Masterchain is equivalent to a private version of Ethereum. VTB and the FTA is looking into the possibilities of Hyperledger also. "Masterchain" is implemented within the framework of Russian legal field. AFT is the administrator of the network who grants access to new members, among which may be both natural and legal persons. The most important factor is that all the participants of "Masterchain" network accept the rules of distributed data in the sense that any electronic document in the network has equal legal force as a physical document with stamp and signature. When the Russian law require a signed paper, the participants could be do business without it, because they agreed on it beforehand and because this decision is recognized by the AFT. This way, contracts, data and information flow in the "Masterchain" are included in the Russian legal system. Participants are protected by law and can enjoy the benefits of technology without having to worry about its legal purity. This is the first and only legally pure blockchain in Russia. For now projects of "Masterchain" live solely within the Association. The members of the association expect that the platform will be available to a wide range of users until the year of 2019. A pilot is expected to be released until 1st November 2018.

Another type of blockchain VTB is looking at is Hyperledger, because of two things: its options for private channels and its more flexible smart contracts (less isolation than in Solidity). Most probably both platform will be used for different types of systems. Each platform has pros and cons. It is also under heavy discussion to use Corda in the future. Corda is distributed ledger, but technologically not blockchain, also it is quite expensive solution in terms of licenses and cost of implementation. The company made a decision to use Ethereum as a base of Masterchain as Hyperledger was at that time in beta (v0.6) and Corda was in alpha (v0.4) level, thus Ethereum was the only stable solution.

Case 3 – M.Video in collaboration with Sberbank Factoring and Alpha Bank

Company Overview

M.Video is the largest Russian consumer electronic retail chain by revenue. The Company started its operations in 1993, today it runs 424 brand name stores in 169 Russian cities. The selling space of its stores accounts to 693,000 sq. m while the total space accounts to 937,000 sq. m. The Company's annual turnover exceeds 230 billion Russian Rubles. M.Video is the first Russian retail chain that had implemented fully-fledged OMNI-channel business model meaning a unified assortment, price and client service for both in-store and online sales. The retailer offers its clients over 20,000 SKUs of audio/video and digital products, large and small home appliance, media and entertainment products, as well as complementing accessories. The company operates its stores under a uniform format and a specially designed store concept. The areas are equipped with own check-out points, wide range of innovative products displayed, and aim to offer an integrated solution to satisfy customers' needs at the best price possible. In 2016, M.Video was included in Top-50 most expensive Russian brands by British consulting agency Brand Finance. In 2017, the organization was recognized among Top-10 best employers and the best HR-brand in retail in Russia. The Company is dedicated to its clients' needs, constantly seeks innovative solutions and operational efficiencies. In November 2007, M.Video became the first and the only publicly traded company in the domestic consumer electronic retail sector. The Company is listed on Moscow Stock Exchange (ticker: MVID).

M. Video, Alfa-Bank and Sberbank Factoring have created a consortium to use blockchain technologies in the financial sector in 2017. Partners believe that as a result, market participants will be able to save hundreds of millions of rubles by reducing the role of the human factor.

Business use of Blockchain and Smart Contracts

M. Video with alpha Bank and "Sberbank Factoring" launched a blockchain platform for factoring operations. The platform allows to connect to unlimited number of suppliers and banks while maintaining the confidentiality of information about transactions. They use for this a permissioned blockchain platform, a private version of Ethereum. The platform is only available for professional participants of the factoring market and their clients.

The organization found blockchain an ideal tool to optimize its factoring operations. When electronic importers, manufacturers and partners use factoring, the company needs to confirm receipt of merchandise to reduce the factors' risks. Previously, the whole confirmation process

has been done via correspondence or phone calls, which lead to time losses and confidentiality risks inevitably. With the help of the pilot blockchain platform, which the company is developing in collaboration with Sberbank Factoring, each party creates their own database and the data being encrypted and synchronized between them automatically. The use of blockchain automates the reconciliation of shipping documentation and eliminates the risks of fraud and loss of confidentiality, reduces operating costs, increases the speed and convenience of factoring payments.

The new platform is based on Ethereum smart contracts, which will perform verification of information. If the hashed information in the documents matches and the delivery of the goods is confirmed, the Bank will be notified that the supplier can be paid. The public network consists of each participant's servers. The platform allows you to connect an unlimited number of suppliers and banks while maintaining the confidentiality of information about transactions. It has nothing to do with payments for now, it is used as means of recording information about commodity and monetary transactions between the participants of the transaction.

Uploaded to the network smart contracts use at the entrance accounting documents in the form of Excel files: "M. Video" and the factor agree on the number of fields, separators, the use of symbols, etc. Smart contract contains hashed information (mathematically compressed source data) about the supplier and the volume of goods, the amount, the date of accounting transactions. If M.Video and the factor have encrypted the same document and the resulting hashes match, the delivery of the goods is confirmed and the Bank may pay the supplier.

In the following figure (Figure 6) the factoring process is demonstrated. Client sends the supply data to Sberbank Factoring, combines the data of the supplier and its supply and takes a hash from them. The process of combining and taking a hash can be from anything, such as an Excel table (should be additionally implemented) or an intermediate database. Sberbank Factoring publishes the hash of the supplies via web interface and validation begins. Blockchain system displays the hash status:

Status OK – if they are available both at Sberbank-Factoring and M.Video

Status Bad – if some of the participants do not have hash

Figure 6 Blockchain System of M.Video and Sberbank

Trade Finance – Factoring

Factoring is one of the financial tools for financing working capital. The great part of M.Video's (and generally all retailer's) working capital is goods that are in warehouses and in stores and are waiting for their new owner.

Generally the factoring process works as the following: There are three participants in the deal, the bank, the supplier of the goods and the retailer. The supplier ships the goods to the retailer, the bank took over the liabilities, thus when the supply arrives it pays to the supplier. For that the bank needs to receive confirmation from the retailer that he indeed received the goods in complete and of proper quality.

M.Video actively uses factoring with several hundreds of its suppliers. Previously, all the operations of confirming supplies were made by M.Video manually: after receiving the goods from the supplier, specially trained employees checked the delivery and uploaded data to our system. Than the bank had a request for validation from the accounting department of the company, the request took place by post or by phone. The experts of the company specified the information inside the company and verified the information to the bank, in order for them to be able to pay. The process was rather inefficient and long, containing an excessive amount of manual labor resulting in human mistakes and the multiple participants in the process were not contributing to confidentiality.

M.video does not limit its suppliers in choosing a bank or factor, the company works with around 12 financial organizations, the usual aggregated amount of open limits under contracts is around 50 billion rubles. Each of the factors use their own IT solution to verify the supply. Therefore, M.Video was frequently approached with a proposal of integration their systems to some Banks' IT system, however, since M.Video uses SAP, it is rather difficult and expensive for the company to integrate. According to M.Video's estimates, each of the integrations would cost around one million rubles, which should be than followed by constant support of each system, as they are developed and updated. However M.Video was interested in the opportunity to somehow simplify the procedure for factoring, integration was not a viable option for the company. When the IT community began to talk a lot about the use of blockchain technology, an idea arose to try this technology for factoring operations. It is safe, simple and open to all participants. The process can be traced from the beginning to the end of the whole chain of operations. As a result of implementing blockchain technology, there is no need to transfer confidential data to a third-party expensive storage, because at each moment of time each participant has a local database of all operations in the distributed ledger. Every event is stored on the blockchain, we know what goods the supplier shipped, which of them M.Video accepted, for which of them has the bank already payed. It is only necessary to establish an information exchange between these registries, the issue of information security was extremely important for the company.

The decision was made for a pilot blockchain solution, however M.Video had no IT specialist with blockchain experience, thus they connected their partner Sberbank, in order to collaborate regarding this issue. Sberbank had the resource, M.Video had an idea, as a result a joint project was created for piloting blockchain platform for factoring.

Type of Blockchain used by the company

For their smart contracts the company decided to use Ethereum blockchain platform. With smart contracts the company can specify different information for each transaction. The company's blockchain development has nothing to do with payments, they use the technology for a tool for fixing information about commodity-money transactions between the parties in the factoring scheme (bank, supplier, retailer). Ethereum as an open-source platform has no restriction of access to smart contracts and transaction data records. M.Video decided to build a private version of Ethereum, since it offers several advantages. First, transactions are written in a chain that has nothing to do with the public network Ethereum. Secondly, blocks of transactions (records in the decentralized ledger) can be created and data can be obtained from the ledger for

a limited number of participants. The private network is technically not different from the public Ethereum network, but its privacy allows the peers to monitor the network and quickly update functionality, as well as change the logic of data recording and reconciliation. Moreover, a private network reduces the cost of transactions, since they are verified for validity by trusted and high-performance nodes. The network is consisting of node miner-servers that are on each network member. At any time new miners can be added to the network, the new participating companies can freely join the platform. The miners are the clients of the Ethereum network, on which mining is started. They participate in the procedure for confirming incoming transactions and adding them to new blocks. The network works such as the "classic" Ethereum, the company did not change either hashing algorithms or transaction block records. It was important for the company that all participants could create their own smart contracts on the network, and receive the data of other participants. Ethereum algorithms provide decentralized data storage and execution of a smart contract. Hashing is performed locally, the already hashed documents become public in the network. Hashing is done for improving security. Each node contains a copy of the database and information to connect to other nodes – public key, IP address and port.

Smart contracts downloaded to the network use the accounting documents in the form of Excel files on the input. The format of the data is harmonized: agreed on the number of fields, separators and symbols. For each delivery of goods based on key fields, a hash is generated using the SHA-3 algorithm. The smart contract records:

- hash of delivery;
- all amounts in the document currency for the given hash;
- posting dates corresponding to amounts.

If M.Video and the factor have encrypted the same document, and the hashes correspond to each other, then successful delivery of the goods is confirmed. The bank has a record of confirmation, and ultimately payment can be done to the supplier.

Occasionally, overheads from suppliers and from us do not match by the amount. This is caused by typos when filling out the documents, as mistakes are possible due to some level of human contribution. The platform provides a mechanism for handling such situations: a smart contract first hashes only the requisites of the document, and the amount remains open. If M.Video and the provider have different hashes of attributes, then access to the sum is opened. If the supplier has less, then the bank will pay less, since for this the risk is lower. If the amount of the supplier is significantly greater, the bank can additionally contact M.Video and clarify the information. However, this happens rarely, for half a year two or three times.

Benefits of the technology

The blockchain platform allows us to get rid of a number of shortcomings inherent in the usual pattern of interaction with factors. One of the advantages of the technology is cost reduction: because it eliminates the need of a single unified database, the company saves on its building, integration and maintenance. Banks and factors do not need to create or customize their systems in order to exchange data with M.Video. They are able to use ready-made tools to quickly create a node-miner and connect it to their information system for data exchange with a common network. The blockchain platform prototype was developed by Sberbank's Centre for Technological Innovations with the help of IT experts from Sberbank Technology. M.Video was responsible for the unification of the data format. Another benefit is that secure automated data exchange and delivery confirmation reduce financial risks for factor companies and speed up settlements with suppliers. The platform excludes from the factoring operations a number of intermediaries and various "manual" operations, so that data exchange between the participants is faster, and most importantly, much safer. This is highly relevant for M.Video because financial comfort and confidence of its partners is their top priority. Consequently, blockchain has reduced the time of data confirmation and processing of factoring payments from three days to several hours. Annual savings on the use of the blockchain in the factoring may be about 150-200 million rubles per year according to the company's expectations.

The platform has already has significantly reduced operating costs, increased speed and enhanced security of factoring payments. Thus, the use of blockchain has reduced the time for verification of deliveries from one to two days to several seconds, due to smart contracts (computer algorithms) that perform verification of information on deliveries in real time. The supplier's shipment data is uploaded to the system by the Bank or Factor, encrypted and automatically matched with the retailer's data on receipt of the goods. The coincidence of the "data chain" for a particular transaction serves as a basis for confirmation and financing of delivery.

To sum up, the use of blockchain allowed to automate the reconciliation of shipping documents and thus eliminate the risks of loss of confidentiality and fraud, reduce operating costs, improve the speed and convenience of factoring payments. Blockchain technologies is known for its accessibility and ease of integration, which is beneficial for the company's suppliers – already every fifth partner of M. Video uses blockchain for factoring.

3.2. Cross case study

In the following cross case study several dimensions were created accordingly to the use cases, where the interviewees' opinions were displayed on the following issues.

Characteristic	Traft	VTB	M.Video
Industry	Logistics provider	Bank	Retailer
BCT implementation	2017	Pilot should be implemented until 1st Nov 2018 Platform will be ready +6 months after (Q2 2019)	2017
Type of BCT	Ethereum (private version)	Masterchain (looking at Hyperledger, heavy discussions about Corda)	Ethereum (private version)
Reason for choosing the particular BCT	Fast implementation Fit to business model	Ethereum was the only stable solution 2 years ago, developers used it as a base for developing Masterchain	Ethereum has an opened source code Readily available solution Reliable, low-cost of implementation, transparent However: observing unstable productivity with Ethereum, SberTech team is testing Hyperledger
Reasons for implementation	Competitive advantage Cost and time efficiency Transparency Marketing reasons	Cost and time efficiency Meet clients' need (e.g. optimized financial supply chain)	Cost and time efficiency Speed and transparency of process Reliability, stability and scalability
Supply Chain processes suitable for SCs	Payments – automated transactions Logistics – Track and trace Future plans: Insurance	Trade finance – Letter of credits Future plans: Payments Track and Trace Procurement	Trade finance – Factoring Future plans: Procurement – Proof of origin (Loyalty programs)
IoT applications	GPS appliance, sensors, tachographs	Not considered yet	Not considered yet
Success criteria for Smart contract design	GPS device on each truck and containers for tracking Sensors (e.g. temperature) in order to gain data for special conditions	In order to digitize trade finance it is necessary to digitize trade itself All trade partners should connect to the network	Using of one technology for all partners The verification of 80% of suppliers who prefer factoring for financing It will work if the process is simple
Benefits of implementation	Decrease of accounting support expenditure, accelerated order processes, track the entire chain of goods movement, optimized delivery time and load level, less idle trips, faster document exchange,	Less paper, less people involvement, faster and less expensive processes, less reporting to regulators (regulators will use Reg Tech approach)	Pilot project showed the viability of the system Validation process is simplified Reduced operating costs, increased speed and enhanced security of factoring payments Higher confidentiality

Table 3 Cross-case comparison

Company Traft and M.Video has implemented the technology in 2017. Traft is using smart contract in their logistics processes and M.Video for their factoring processes. VTB Bank is in the planning stage of the implementation, they intend to pilot their platform (in collaboration with RFTA) until the first of November in 2018, and a wider implementation should be ready until six month after the pilot project.

As for choosing the right fit to their processes among existing blockchain technologies all of them used the Etherium open source code as a base, and created a private, permissioned version of the public network. Traft and M.Video are using the exact duplicate of the "standard" Etherium blockchain, they use the same coding language and the same consensus protocol, however VTB Bank uses a new type of platform created by the Russian Fintech Association, called Masterchain, which kept the code of Etherium, however introduced a new consensus mechanism, which allows a better fit to the Russian legal environment.

The reason of choosing Etherium was similar by all three companies: it is an open-source code already available for the public, at the time when developers started to look into Blockchain, Ethereum was the only stable, readily available solution on the market. Etherium is reliable, it can be implemented low-cost and in a relatively short period of time. However all three company uses a private version of Etherium, with permissioned access to the network. Traft is perfectly satisfied with the platform, it fits their business model exactly. M.Video is also using their private version of Etherium, it has successfully improved the factoring processes, however the company experienced some unstable productivity with Ethereum, so SberTech team (tech-team of Sberbank) is testing Hyperledger at present time. VTB is on one hand using a newly developed platform called Masterchain on the base of Etherium code with a Russian consensus mechanism, and on the other hand also looking into Hyperledger at the moment as a possibly better solution for supply chain processes, since it has its private channels and more flexible smart contracts. VTB also has currently hard discussions about Corda, however not for supply chain processes but other financial services, according to them it is a rather expensive solution due to its high license price. All in all, Ethereum is proved to be a very good platform for gaining experience with blockchain, and getting started with smart contract development. It provides an open-source code, with minimal effort and in fairly short time a company can implement the technology successfully. However, according to the interviewees for long term, high scale projects such as utilization of smart contracts and blockchain technology for whole supply chains, which include several different processes, a tailor-made Hyperledger project is more of a fit.

For the reasons of implementation the companies had similar answers. First of all, they were expecting cost and time reduction in their operations, with the aim to transform from paper based documentation flow to digitized one. Moreover all of them expected more transparency of the processes and higher confidentiality and less financial risks. Two of the companies – Traft and VTB companies – also mentioned the satisfaction of their clients/customers with more optimized services. The technology can mean competitive advantage among competitors and can have an influence on the price decision: the company can offer lower prices allowed by higher cost efficiency, or higher prices for services, since the technology can be used as a tool for differentiation and positioning yourself in a higher price segment due to enhanced security, convenience and transparency. Traft and M.Video also mentioned their incentive to use tokens in loyalty programs.

Investigating the actual supply chain processes which could be improved and automated by smart contracts, the following processes were discovered during the interviews.

- Payments – Automated transactions
- Logistics – Track and trace and insurance
- Trade Finance – Letter of Credits and Factoring
- Procurement – Proof of Origin

Similarly to each other, in all cases blockchain technology is mainly used for improving and digitizing document flow for the supplies, for instance: invoices, bill of lading, letter of credits, etc. With the help of smart contracts human factor is reduced in the activities of physical, financial and information flow, in the future probably even entirely eliminated from certain processes with the help of different sensors. Blockchain is used for payments just in case of Traft, who claims that it works successfully in their system. Future plans with the use of smart contracts encompass automated insurance deals for cargo, and proof of origin for procurement. VTB and M.Video have not yet considered to link blockchain technology to IoT, however Traft is already using GPS appliance for tracking the route of vehicles, and worked out smart contract schemes for transporting perishable products (sensors for monitoring temperature) and for insurance (installed tachographs).

According to Traft the ultimate success criteria for smart contracts are the installation of several sensors and GPS appliances in order that smart contracts could work solely from data retrieved from the blockchain itself, and so monitor and trace the route of the goods from suppliers to customers. In VTB's opinion, in order to digitize and automate Trade Finance, there is a need of digitizing trade itself. According to M.Video, for smart contracts to work effectively it is necessary that all the supply chain partners start to use the technology. They set a requirement for their own project, that at least 80% of their suppliers, who prefer factoring as a financial

mode, verifies the interest for using the technology, this can be achievable if the system offers a simpler more convenient process.

While investigating the three business case, the following general improvements can be obtained from the conducted interviews:

- Accelerated processes
- Exclusion/reduction of confidentiality risks
- Reduced financial Risk
- Synchronized transaction data
- Real-time transparency
- Automation of reconciliation of shipping documentation
- Increased convenience
- Cost reduction
- Safe, simple and open to all participants

By smart contracts supply chain processes can be accelerated, order processing time, lead times and delivery times can be reduced, for instance by faster information exchange, less bottle necks due to waiting times between supply chain events, reduced time for data confirmation and for processing payments. If payments are automated by smart contracts then in a matter of minutes the payment can be done, almost in real time, however payment processing is also reduced when smart contracts are not used concretely for them, as the accelerated document and information exchange itself results in time reduction, thus from few days to several hours payments are done.

With blockchain technology confidentiality risks can time excluded by end-to-end encryption, or be reduced by simply eliminating some of the intermediaries and various "manual" operations from the process, thus there is no need to transfer confidential data to a third-party storage, which is also expensive at the same time.

Since smart contracts work as "deposit accounts", "letter of credits" or "factoring agreements" in the use cases discussed in the research, financial risk is reduced, suppliers can be sure that they will get payed when all conditions of the smart contract is met, and customers can be sure that payment is made just in case all prerequisite is fulfilled and all the goods arrived.

By the distributed ledger system data about all transactions are synchronized with consensus protocol, every participant in the transaction agrees on the one version of truth. Blockchain technology provides real-time transparency, thus it allows to see all the processes in real time, trace the supply chain events from the beginning to the end, and track the location and state of the shipment. By automation of confirmation of shipment documents inefficiency of

manual mistakes and risk for fraud is eliminated, which brings itself an increased convenience of managing the processes. Regarding cost reduction, on one hand smart contracts contribute to optimizing processes, thus decreasing operating costs (e.g. decreased idle trips and increased load levels at Traft), on the other hand by eliminating the need of a single unified database across the supply chain, the company saves on building, integration and maintenance of a central database. Blockchain is a less expensive solution for integrating the supply chain processes, since it does not need the difficulty of integrating whole IT systems, thus every participant can work with their own IT solution to verify the information of the supply. Every transaction data is stored on the distributed ledgers, it is only necessary to establish an information exchange between the ledgers. Finally, the technology is safe, simple and open to all participants. Companies prefer platforms which allows you to connect unlimited number of participants into the system while maintaining the confidentiality of information about transactions.

3.3. Comparison of Blockchain technologies regarding their fit for supply chains

In the following paragraphs blockchain technologies, which has already wide acceptance among businesses, financial institutions, Fintech Associations, experts and academics, will be compared with each other according to some aspects, such as architecture, use cases, and fit to supply chain. The following platforms are compared: Ethereum, Corda (R3), Fabric (Hyperledger) and Masterchain (FTA). Analyzing white papers of different Blockchain technologies it became clear that all these frameworks have quite distinct visions of application of their platform. In terms of Ethereum the standard public platform will be compared, however in real use cases it frequently happens, that taking the open source code of Etherium private versions are built, some comment will be concluded on that issue. While Ethereum presents itself as independent from any specific field application, Masterchain, Corda and Fabric development is mostly driven by specific use cases. Corda's use cases are exclusively related to financial services industry, Masterchain's current applications are also focused mostly on financial services industry, however it has a generic character, also it offers solution for trade finance, which is a connection point to logistics and supply chain management. Fabric proposes a modular and extendable architecture that can be employed in various industries, from banking and healthcare to supply chains. To compare just Fabric and Ethereum, the main difference of the two platform that even though both of them propose a universal use, Fabric solves that with a modular approach (you choose what you need for your field, depending on your business), Ethereum however offers a generic platform for every type of business use.

Characteristic	Ethereum	Hyperledger Fabric	R3 Corda	FTA Masterchain
Description of platform	Generic blockchain platform	Modular blockchain platform	Specialized distributed ledger platform for financial industry	Generic blockchain platform, primary use of financial deals
Governance	Ethereum Developers	Linux Foundation	R3	Russian Fintech Association
Mode of operation	Permissionless, public (or private)	Permissioned, private	Permissioned, private	Permissioned, private
Consensus	- Mining based on Proof of Work (PoW) - Ledger level	- Broad understanding of consensus that allows multiple approaches - Transaction level	- Specific understanding of consensus (i.e. notary nodes) - Transaction level	-Proof of Work is used now -POS will be most probably used in 12 month
Smart contracts	Smart contract code (e.g. Solidity)	Smart contract code (e.g., Go, Java)	Smart contracts code (e.g. Kotlin, Java) Smart legal contract (legal prose)	Smart contract code (Solidity)
Currency	Ether Tokens via smart contract	None Tokens via chaincode	None	None
Fit to supply chains	Due to generic design applicable to wide range of processes, however privacy issues because of public mode of operation Strong smart contract machine, but not so flexible	Modular platform enables a range of application, channels provide privacy, just parties of transactions see the data involved. Flexible smart contracts	It designed solely for finance processes, might be used for financial aspects of supply chain, although licensing is expensive	It has a focus on trade finance and letter of credits, which is closely connected with financial supply chain. Smart contracts are less flexible.

Table 4 Comparison of blockchain technologies

As we discussed in the literature review, with conventional central data storage, a single entity keeps a copy of the underlying database (e.g. a ledger), consequently, this entity controls what data is contributed. With distributed ledger technologies multiple entities hold a copy of the database and control together what data is contributed. The entities that participate in the blockchain network are the so called nodes or peers. Due to the distributed character of the data

storage the difficulty arise that all nodes has to agree upon a single truth, this is called consensus. Regarding participating in consensus, there are two modes of operation: permissionless and permissioned. If the participation is permissionless, everybody can become a node in the network, this is true for Ethereum. If the participation is permissioned, peers are selected in advance and access to the network is restricted to these only. This is true for Fabric, Masterchain and Corda. Whether a blockchain has a permissioned or permissionless character, it has an impact on the mode of how consensus is reached among peers. In case of Ethereum all peers have to reach a consensus over the order of all transactions that have taken place (does not matter it the peer took part in the transactions or not). The order of the transactions is crucial for the consistent state of the ledger. As the network might involve mutually distrusting and anonymous parties, a consensus mechanism has to be taken place, which protects dishonest participants that attempt double-spends. (Sandner, 2017) In Ethereum this consensus is established with Proof of Work (PoW) mechanism. All nods have to agree upon a common ledger and all nods have access to all entries ever recorded. As a result PoW unfavorably affects the performance of transactions processing (in variables like time and energy). Prone to the heavy utilization of computational resources involved in mining, PoW is considered to be costly, wasteful and inefficient. However, the required expensive computation is necessary in a public blockchain to reach a higher cost to attack the system. On the other hand private Etherium platforms has the potential to transform the consensus mechanism from PoW to Proof of Stake protocol (PoS) and there are less members in the network, and any new node are verified to access to the system. Concerning the data stored on the ledger, even though there records are anonym, they are accessible to all peers, which can be problematic for applications that require higher degree of privacy. (Although with some certain cryptography measures it can be managed in private versions) Contrary to Ethereum, Fabric, Corda and Masterchain has a more refined definition of consensus. Due to operating in a permissioned mode, Masterchain, Corda and Fabric provide access control to records and this enhance privacy. As a result for validating transactions it is enough if the parties taking part in the transaction reach a consensus. While in Ethereum you have to pay for transactions with cryptocurrency, in Masterchain, Fabric and Corda, the transactions are free. When IBM talks about blockchain they talk about blockchain for business. For them this is a permissioned private blockchain (e.g.: Fabric), it means it is not public and it is not anonymous. There are roles associated who can do what on the blockchain. The different participants of the network are the validators as well (they do not have miners) Fabric's understanding of consensus is broad and contains the whole transaction flow, starting from requesting a transaction to the network to allocate it into the ledger. In Fabric, the consensus algorithm is "pluggable" which means that depending on application specific requirements various algorithms can be used.

Nodes have different roles and tasks in the consensus process and consensus is reached at a transaction level. (This contradicts to Ethereum where all the nodes has the same role and task to participate in consensus, and consensus is reached at a ledger level.) In Fabric nodes are differentiated, whether they are clients, peers, endorsers or orderers. As mentioned, Fabric offers a pluggable architecture, where you can define consensus algorithm yourself. Smart Contracts can be written, in any language and allow keeping the ledger in a consistent state according to our needs, however for now the most supported programming language is Go. In Fabric when we write smart contracts one thing we have got to do is to be clear about the consensus requirement. We have to write a solution with an appropriate consensus requirement. For example: what is the requirement when someone wants to post an event to the blockchain. Do we require half of the participants on the blockchain to validate that participant's identity? Do we require a fourth of the participants or do we only require four? We can create that consensus requirement as strict as we want to, based on a business solution. All the participants has to agree on what a consensus requirement should be. The permissioned and private operation and the pluggable architecture makes Fabric more flexible for business use and supply chains, it is more a fit for large supply chains, which worry to use Ethereum due to confidentiality issues, and for supply chains who already are in partnership for a long time so there is no need for an online marketplace for finding new suppliers. Regarding confidentiality issues interviewees claim that with encryption on the private Etherium blockchain confidentiality risks can be also eliminated. Similar to Fabric, in Corda consensus is also reached on a transaction level by involving parties only. Validity is ensured by running the smart contract code associated with the transaction, by checking all required signatures and by assuring that the transactions that are referred to are also valid. Uniqueness concerns the input states of the transaction, it has to be ensured the transaction in question is the unique consumer of all its input states. (Thus, there is no other transaction existing that consumes any of the same state) The reason of this is avoiding double spending. Consensus over uniqueness is reached with so called notary nodes, while the employed algorithm is "pluggable" just like in Fabric. (Sandner 2017) Moving on to comparison of smart contracts, we need to lay it down as a principle that, as it was discussed in literature review, smart contract are not "smart" in the sense that they are not intelligently act on your behalf, driven by artificial intelligence for example (at least not yet), and also they are generally not legally binding contracts like traditional ones. Sometimes a Smart Contract means, just a *smart contract code*, sometimes it means a *smart legal contract*. This gives us the opportunity for comparison in this two aspects. All distributed ledger technologies feature smart contracts in the sense of a smart contract code, that can be written in Go or Java for Fabric, in Solidity for Ethereum and in Java or Kotlin for Corda. In Fabric a term for chaincode is used as a synonym

for smart contract. There is a difference between Ethereum and Fabric on one hand, and Corda and Masterchain on another hand in terms of the second way smart contract term is used. Masterchain is addressing the question of the legal aspect by operating a legally accepted (in Russia) consensus protocol, moreover, when you access the blockchain network, you agree that you will be legally bonded with all other participants, thus smart contracts you enter with other peers will be backed by Russian laws. In Corda the issue is addressed otherwise: in Corda smart contracts consists not only from code but additionally legal prose that are formulated in a way that they can be expressed and implemented in smart contract code. The rationale behind this is to give the code legitimacy that is rooted in the associated legal prose. (Sandner 2017) Both Fabric and Ethereum lacks these features of legitimacy. Another notable difference that Ethereum features a built-in currency called Ether, it is used to pay rewards to nodes that contribute to reach consensus by mining blocks as well as to pay transaction fees. Also tokens can be created by developing smart contracts. Masterchain is based on Ethereum coding however it does not use the currency function, as it has other consensus mechanism. Fabric and Corda also do not require a build-in currency as consensus is not reached via mining. With Fabric, however it is possible to develop digital token with chaincode (smart contract code). With Corda, the creation of tokens are not intended.

To sum up, Fabric and Ethereum are both highly flexible, but in different aspects. Ethereum's powerful smart contract engine makes it a generic platform for literally any kind of application. The code is open source, any developer team can create their own private blockchain in a relatively short time period and relatively low cost. However, Ethereum's permissionless mode of operation and its total transparency comes at a cost of privacy and performance scalability. Even though most of the selected companies use a private version of Ethereum because of the availability due to its open source code, some of them are observing unstable productivity with Ethereum and as a result looking into Hyperledger.

3.4. Methodology of smart contract development

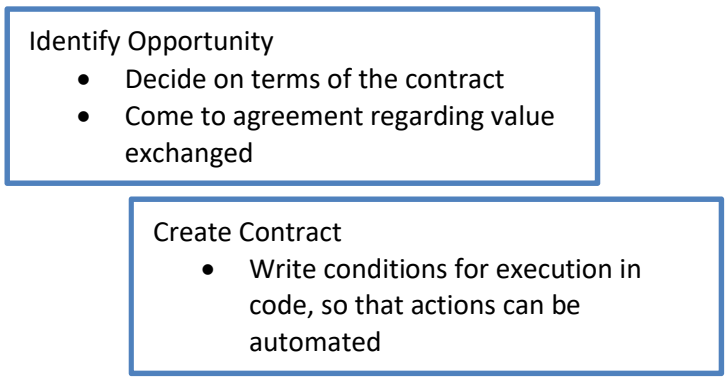
The key concern related to developing smart contracts is that it requires an understanding of programming. First thing a company must do to build a blockchain solution for its business to hire a team of skilled developers who know how to deal with distributed ledgers, or to collaborate with IT Company who can assist the implementation. The expertise of the developers is crucial, since smart contracts should be developed without mistakes. As already discussed in the first chapter, smart contracts are computer codes with predefined set of rules, which run on the blockchain based on conditions all parties agree, executes automatically when the latter

mentioned conditions are met. Any contract deployed would be performed automatically, and in a case it contains a mistake, there would be no chance to correct it, since all the results are registered on a blockchain for eternity and cannot be changed anymore. Therefore, in order to do not encounter the risk of mistakes in the programming, companies should work with team which do not lack experience and knowledge of smart contracts development.

Management together with a group of IT professionals can take care of the technical side of contract preparation, deciding on the following aspects:

- Choose a blockchain platform that suits your supply chain's need
- Design the nodes, APIs (application programming interface), take care of hardware and all the required configurations
- Define the roles of the nodes (reader, writer, validator)
- Define the rules and conditions that must be outlined in smart contracts
- Test the contracts to make sure they contain no mistakes and vulnerabilities

To create a smart contract parties has to first identify the opportunity for them to collaborate and agree on the desired outcomes for each party. This could include any exchange of value, such as goods or services. Next, they might set the terms and the conditions that have to be met in order for the exchange to occur. This could be triggered by the parties themselves or by external event or certain milestones which are given by the parties. All the requirements and contractual agreements are then programmatically written using computer logic and code. The smart contract then can be deployed to the blockchain where they self-execute when initiated by specific conditions. In order to initiate a smart contract users must use their account on the blockchain to carry out a transaction with the deployed contract's account. This is encrypted with the initiator's private key and transmitted to the other nodes on the blockchain. Other nodes can verify the transaction using their public key, to ensure that the initiator was indeed the one who triggered the transaction. Once consensus has been obtained by the majority, the transaction is added to the blockchain. The smart contract is successfully executed and the outcomes are recorded on the distributed ledger and updated across all nodes in case of a public chain or just the ones participating in the transaction in case of private blockchain.



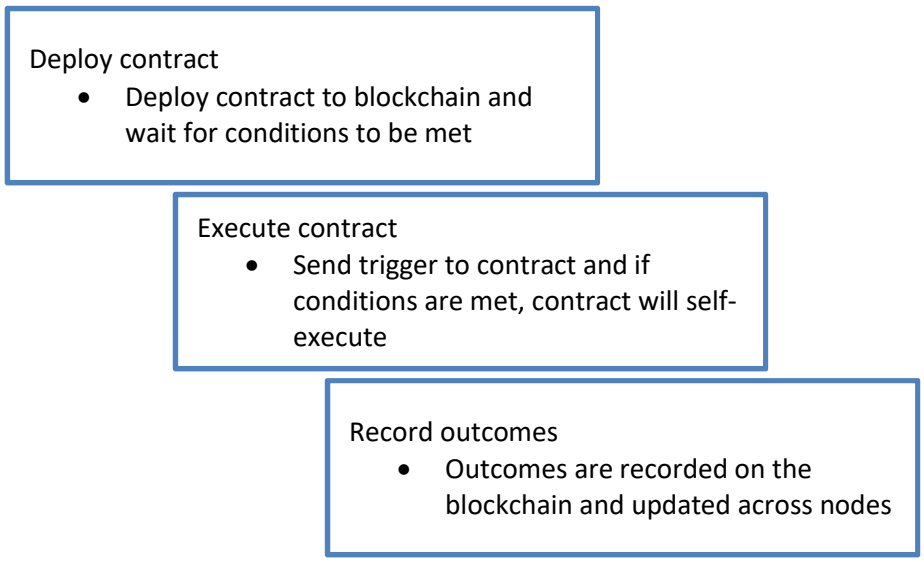


Figure 7 Methodology for smart contract development

Stages of implementation of Blockchain technology

In the following, stages of implementations are generated based on the analysis of the interviews.

1st stage: Use cases that brings value to the business has to be identified, meanwhile making a plan for scoping the required technology. According to use case, blockchain technologies need to be studied and appropriate BCT needs to be chosen.

2nd stage: When use case is identified, the architecture of the project needs to be decided. IT needs to determine the budget, deadline and whether the work can be done solely with internal resources, or whether outside help is needed. Traft made it without help, since the company was an early mover, no one had better knowledge in the market about blockchain at that time, however today there are more use cases in Russian market which is done as a result of collaboration. In current and future use cases the author predicts a collaboration with banks who are members of RFTA.

3rd stage: Proof of concept - using not real data. Whether accomplishing blockchain implementation independently or with outside assistance, it is important for companies to gain internal expertise with the technology since it is both new and complex. Proof of concept provides stakeholders an opportunity to identify challenges and risks associated with the new technology before going live.

4rd stage: Field trials/Pilot projects for testing the technology in real environment with real data on a part of the supply chain with a few parties involved. This is the top stage, where most of the use cases are at current moment.

5th stage: Full-scale implementation for whole supply chain follows successful field trials. A full-scale system requires a much greater commitment to the blockchain application than the prior stages, as they are going to be followed by several changes in business processes. As of first part of the year 2018, very few organizations have reached full-scale blockchain implementation in Russia and also globally. Generally enterprises implementing blockchain technology in their supply chain management are either in the use case, proof of concept or field trial stages.

3.5. Discussion and findings - Answers to research questions

During the research it became clear that the driving force of blockchain transformation in the Russian market will be most probably lead by banks collaborating with IT and Fintech companies. This is not a great surprise however, for the following reasons. A crucial part of their business is threatened by the new technology, some range of financial services could soon become unnecessary if companies start develop blockchains themselves. In order to have a competitive advantage it is necessary to look at a new phenomenon both as a threat and an opportunity, that is why the biggest Russian Banks including the Central Bank created a Fintech Association focusing on several matters including blockchain, in order to make their client's payments and finance more effective. The other reason why Banks has an advantage to become a leader of change, that the financial services industry (which blockchain touches upon) is highly regulated, smart contracts has the limitation of not being legally binding at the moment. The Fintech Association however can play a role in influencing government decisions in order to create a legal environment which enables the wide implementation of the technology. A transformation lead by banks can be a win-win situation, as banks can keep their clients as business partners, and supply chains will have assistance in the transformation, and still become less depending on central authorities, since the technology enables peer-to-peer agreements without large dependence on any intermediary. Another reason why the financial services industry got a head start on developing use cases for blockchain technology is because it had early awareness of Bitcoin. Considering that Banks understood Bitcoin before other industries they have the advantage to understand the underlying technology as well.

Furthermore we can conclude from the research that currently and also in the future of blockchain utilization and digitization collaboration is a key feature. The research results show

that full width digitalization and blockchain application through the supply chain cannot be reached without cooperation between banks, corporates, and industry players.

From the interviews it became clear that the utilization of smart contracts on blockchain brings a wide range of benefits to the supply chain. First of all, all the activities automated by the technology enables shorter processing time at each stage of the product and financial flow in the supply chain, which together with information transparency and digital document handling results in shorter lead times, thus lower inventories, and has a positive effect on tied up capital, as materials and products do not have to stand-by waiting for paper documentation. The supply chain becomes more agile, thus it is more responsive in a volatile market. Accuracy is also a great advantage, automated transactions are not just quicker but also less subject to mistakes. Smart contracts require less human factor in the processes, and fewer intermediaries, which results in a higher cost efficiency regarding administrative costs and also brings with itself a higher confidentiality. Transparency provided by blockchain creates an environment of trust as the logic and information in the smart contract is visible for all participants taking part in the transaction. Contracting parties can view and track the contract in real time, and checking upon the events occurred and conditions already met. As the distributed ledger is impossible to alter and tamper with, it is secure, there is no risk of default. Moreover, since identical copies of the contract are kept across the blockchain and additional amendments to the contract has to be verified by all parties involved, there is no problem of version control, no need of running comparison software over documents.

Research Question 1: Which supply chain processes are suitable for smart contracts?

After connecting several companies, the following smart contract implementations were collected as examples:

- Payments – Automated procession of business transactions
- Supply Chain Finance/ Trade finance – Letter of credits, Factoring
- Logistics – Track and Trace automatization
- Procurement – Proof of origin

While conducting the research it became obvious that the first emphasis was placed on the reduction of paper based systems, both in finance and logistics aspects. Traditional paper processing across supply chain processes is a significant burden to businesses, the industry has been looking for solutions to simplify and digitize trade, making supply chain welcoming the prospected benefits of blockchain technology. Companies try to decrease time spend with different administration processes by digitizing all kind of documents: contracts, letter of credits,

bill of lading, certificates etc. One aim of these attempts is to bring together physical and financial supply chains. In today's supply chains there is a time lag between the two. The payment for the goods can be delayed for several weeks after the physical delivery of the goods. With the help of smart contract several steps of administration can be automated (invoicing, payments etc.).

In the Russian industry several companies piloting blockchain platforms in collaboration with Banks usually concerning different trade finance solutions. Alpha Bank had conducted an experiment regarding blockchain solution for letter of credit in 2016. VTB in cooperation with other banks is currently working on letter of credit solutions involving a range of banks, ports, logistics and manufacturing companies, also considering to use smart contracts for payments. The Russian metallurgic company Severstal and Sberbank declared about a blockchain project for transactions with foreign partners in 2017. The retailer M.Video had a pilot project recently in collaboration with Sberbank regarding factoring and also intends to use blockchain for proof of origin in the future. The Russian retailer Ulmart is also looking into possible solutions regarding proof of origin in order to fight counterfeit products. Company Traft developed a system for payment and track and trace automatization, which works successfully, and they explore further opportunities in order to connect IoT applications with blockchain technology. Also Russian Railways (RZD) is working on digitizing and automating trade documentation with the help of the technology.

If we analyze the processes we can conclude that they have different complexity of realization. Payments and digitizing trade finance documentation is less complex, than track and trace automation and proof of origin. It is easier to find real life examples of successful implementation. For track and trace solutions a range of different sensors are necessary install in order to collect information about state and place of the shipment. This makes blockchain implementation more sophisticated, since the solution is combined with IoT applications, thus there are fewer examples of these type of solutions to be find. The most difficulty brings itself the application of blockchain technology for proof of origin and bill of lading. In order to be able to check the products origin, it is necessary to tag every piece of goods, make sure tags cannot be tricked with, and record every stage of their production and delivery, which is a rather complex task. As a result, already working models in real business environment are hardly any to find at the moment. Globally it was tested on proof of origin of diamonds, within Everledger project, however with identical products the identification is a more difficult task than with unique products such as diamonds. Globally, Wallmart is working on proof of origin projects regarding food safety at the moment.

Research Question 2: What are the requirements (success criteria) out of the supply chain for smart contract design?

The first requirement is a business network, blockchain does not really make sense unless multiple entities are collaborating around shared information (e.g. suppliers, customers, regulatory forces, special agencies). Smart contracts can be used for use cases involving multiple parties using transactions (e.g. EDI). Supply chains by nature meet this requirement.

Secondly, a key concern regarding smart contract development is that it requires an understanding of programming. There is a need for certain level of digitization and an IT-team familiar with smart contract codes, or in case we do not have skilled developer team, we should collaborate with IT companies, or other companies who has a qualified team. Expertise in writing smart contracts is a must, as they act on conditions automatically, thus bugs or errors in code could cause serious issues. Also a certain level of digitization of supply chain processes are required, resources for server hardware, configuration and training is necessary. The respondent from VTB pointed out that in order to digitize and automate trade finance there is a need of digitizing trade itself. By the level of digitization not only the existence of appropriate resources is significant, but also employees have to use digital tools extensively in their daily activities, thus paper based work should transform to fully computer-based work. According to experts the greatest differentiation nowadays is the possession of a digitally empowered workforce. Although blockchain technology requires some level of digitization, it is a lean software solution with easy integration of users and quick implementation of application, and if compared with the option of integrating the ERP systems of supply chain members, distributed ledger system is much less cost intensive.

Moreover, in order to be able to design specific types of smart contracts there is a need of standard operating procedures across the supply chain regarding trade documents. M.Video highlighted that for smart contracts to work effectively it is necessary that supply chain wide partners start to use the technology, for that simple processes are preferable. In order to help forward the shift from paper-based trade to paper-less trade, clearly defined rules and minimum standards are necessary to allow banks and corporates to connect more easily to digital platforms. Furthermore, set standards between legal- , security- and liability service providers can facilitate the removal of legal uncertainty. Thus, clear standards are ensuring enforceability of documentation (contracts) and facilitate the digitalization process of the supply chain members.

The company experts were all on the same page regarding permissions to enter the network, thus in order to exclude malicious actors from the network, they all suggest a need of

authorization of the new trade partner. In blockchain networks every member has a digital identity, and in permissioned type of networks other members has to confirm that identity in order to become a verified peer. This is a critical issue in order to ensure that the source of information is trustworthy.

From the interviews with Traft the researcher concluded that the ultimate success criteria for smart contracts are the installation of several sensors and GPS appliances in order that smart contracts could work solely from data retrieved from the blockchain itself (not from outside data bases), and so monitor and trace the route of the goods from suppliers to customers. It would be important as data from blockchain is eternal and non-editable, however from other data bases date can be easier to tamper with. It also would allow further automation and M2M transactions. Integrating Blockchain technology with IoT could open a new way of supply chain management, e.g. shelves in a warehouse could order their own supplies, containers could organize their own cargo etc.

Research question 3: Which technologies are appropriate for smart contract modelling in Supply Chain environment?

According to case studies permissioned and private, consortium type blockchain platforms fit the most the integrated supply chain purposes. Hyperledger Fabric is created as a permissioned, private, consortium blockchain, although Ethereum is also widely used in its private form. Ethereum offers a general platform for any type of smart contract. Ethereum has the disadvantage of less privacy of transactions, however it is faster to implement. According to case study of Traft it is successful in implementing payment and track and trace processes, also documents can be encrypted with exclusive access of the transaction parties. For logistics companies it is fairly easy to implement it for an additional service to offer to their clients. The transportation company Traft chose Ethereum, because their aim was to implement blockchain technology with minimal effort and in a fairly short time, they succeeded within a month to test these features just in demo mode, they realized that it is sufficient to use the opportunities offered by the Ethereum. Hyperledger implementation usually takes longer time and more planning due to the larger range of modules business can choose from in order to tailor-make to a specific supply chain need. Usually companies implementing Hyperledger target a solution for large-scale projects where it is clear that this is a project for many years. An example for Hyperledger implementation on Russian market is Russian Railways. According to expert opinions, it looks like that from today's existing blockchain technologies Hyperledger fits the

most all supply chain purposes, as it has wide variety of modules which can be chosen for different purposes. It can be an effective solution regarding management of a whole supply network offering on one hand transparency on the other hand necessary privacy. However, with any type of Blockchain companies have the possibility to store sensitive information off chain in their own database and hash it to the distributed ledger. Corda is more financial oriented, it was invited for financial service industries, without any considerations of supply chain use, as a result it has limited opportunities for supply chain utilization.

To sum up, choosing the appropriate blockchain technology for our business is a matter of perspective. On one hand Hyperledger's utility is creating private blockchains to be used by approved companies and individuals in a trusted network, with the possibility of using channels for increased confidentiality, with the opportunity for binding together and several processes using its modular approach with the potential of tailor-made systems. Long supply chains and integrated solutions come to mind, when looking at this solution. On the other hand Ethereum can be used as a totally transparent network with fast implementation for separate supply chain processes, for instance cargo logistics, where cargo owners can find easily the optimal solution for their cargo transportation, or letter of credits and factoring as processes of financial supply chain.

How blockchain solves trust issues?

First of all we should state that each type of blockchain solves trust issues on a different level. When we look at Ethereum, it plays a role of connecting parties with smart contracts, without the need of knowing each other. Since it is a public blockchain, everyone can enter into transaction with anyone else in the network, the trust is in-built in the network itself. The idea behind is that with the technology there is no need of trusting or knowing the other parties, smart contracts are the assurance that in order to get paid job has to be done while all conditions met stated in the contract. This anonymity brings itself that one party wants to make sure that the job will be done, the other party wants to make sure that he/she will be played for his/her work. In the case study of company Traft, they use Ethereum to ensure clients about automatic execution of contracts. If they step into a smart contract through Traft-online, they will be able to track their performance, and pay for their services just if all stated obligation is met in the smart contract, taking responsibility of the quality of the delivery and the service. This provides client with additional trust towards the 3rd party logistic company, which eliminates any type of fraught (e.g. drivers assigning more time). To conclude, Ethereum platform can work as an online

supply-demand platform, where cargo owners can find truck drivers, or sellers can find buyers and make deals purely with trusting the system itself, without entering into a legal contract, leaving out banks or other institutions from the transaction. This solution fits well startup companies, small carrier companies, and logistic companies who are ready to coordinate the system. In case of Ethereum trust is inbuilt in the system in the way that, all nodes has to agree on the state of the network, consensus is made by mining, and in the case of Fabric consensus mechanism is about a number of nodes agreeing on a certain transaction. Ethereum is fully transparent, however, even though it works anonym, as it is a public platform, anyone can see all the transactions and information on the ledger, which could result in privacy and confidentiality issues. This is what Hyperledger and Masterchain and other permissioned platforms solve. When comparing a public blockchain network with a permission blockchain such as Hyperledger Fabric, we can see that sacrificing some of decentralization greatly improves scalability and performance. Sacrificing some decentralization means we need more trust on the validating nodes and the authority and trust has to come from outside the network. And since trust is already achieved from outside the network, we do not need much computational power to support that trust. This allows us to use different consensus mechanism, such as BFT protocols (Byzantine fault tolerance), and almost all of the issues public blockchains have, disappears. The governing body can ensure data access to participants in the channel and only allow them to view sensitive transaction data. Thus, Hyperledger Fabric has the features required for modern enterprise security standards, which are difficult to achieve in public blockchains. In a permissioned network the members of your supply chain and additional institution (such as a bank, some special agency, customs service etc) included, you already know these organizations and you have some level of trust as you work with them most probably for years. Derived from this structure these type of blockchains are frequently called consortium blockchains. Earlier in literature review it is stated, that according to several studies trust issues still exists nowadays towards business partners. Moving from the first level of trust, when we solely care about whether we will be paid or not for the job done, on the second level trust issues are rooted in confidentiality and opportunistic behavior. The questions rise, how much of the information I should share with my supply chain partner? This can be solved by channels offered by Fabric. Invoicing disputes are also common in the industry because of separate ledgers, quality disputes, contrasting data about the same transactions are common problems blockchain can solve. The current developed communications systems and the support of legal contracts are not comprehensive solutions for all these trust issues. According to experts and investigated market players as a result of implementing blockchain technology high level of trust can created by the consensus mechanism and encryption, we can be sure of secure, untampered data storage. Smart

contract ruled activities can enhance automation, thus support smart processes in the supply chain. Smart contracts on blockchains are a source of trust, since data on the contract is unable to be deleted, it increases transparency, and execute themselves when conditions are met. All in all blockchain is a good tool for enhancing supply chain visibility while also taking care about confidentiality issues and privacy. It is a lean solution with easy integration of the users, and relatively quick implementation and application. Trust is also created from the fact that parties has to agree according the consensus protocol, and data is stored in various computers (distributed ledgers), so parties can share one variant of truth.

3.6. Theoretical contribution and practical implication

This master thesis can contribute to existing theory in several ways. From the theoretical perspective this thesis contributes to the sphere of digital solutions in supply chain management, which is quite uninvestigated. Blockchain case studies on Russian market were revealed, reviewed and investigated.

Currently there are several challenges to the widespread use of permissionless and permissioned distributed ledger technologies. Key among them are regulatory challenges, challenges around the lack of standards, and the lack of knowledge about distributed ledger technologies. These challenges are general to any new technological infrastructure that replaces an older infrastructure. This master thesis aims to decrease the third challenge, i.e. to provide knowledge for supply chain professionals about the technology.

As for practical implications it can be concluded, that the master thesis can provide assistance in order to plan the blockchain implementation and figure out what kind of processes smart contracts could work for effectively. After the analysis of cases a methodology of smart contract development was created and the steps for blockchain implementations were summarized in a framework. The study holds value for supply chain managers, IT managers and other employees, who are involved in implementation of digital solutions in supply chain management. The findings of the thesis demonstrate that on a firm level smart contracts provide cost benefits on administration costs, speed up transactions, reduce confidentiality risks and risk of default. Blockchain technology plays a role in integrating supply chain processes, with increasing visibility of complete audit trail of events, improves real-time transparency, confidence and trust across the supply chain.

The findings of current research also indicate that smart contracts on blockchain platform has a potential to revolutionize traditional practices in logistics and supply chain management, thus the study has global implications. On a global level blockchain technology can decrease

barriers of global trade, by the trust, transparency, and efficiency built into the blockchain solution. It breaks down many of the barriers that small businesses has to face entering the global market. The cost of paperwork decreases, proof of origin and identification is managed by the blockchain, and the volume of communications among parties decreases as each step in the chain is visible and verified. After wide implementation of the technology, blockchain can enable more companies to participate in the global economy, thus enhance global trade. One more consequence of blockchain technology will be bringing together the physical and financial supply chain, as payments and financial documentation will happen simultaneously with the products receipt, there will be no delays such as due to traditional invoicing and payment practicing.

3.7. Limitations and prospects for future research

The research has several limitations, which has to be taken into consideration. First of all, limitations derived from the chosen research strategy in the thesis. Since case study strategy is applied, there are limitations connected to generalizations of the findings (Yin, 2003) as the was limited number of analyzed case studies exploring a number of use cases of the technology in the field of supply chain, which might be not the only business solutions possible for utilizing Blockchain technology. However the aim of a case study analysis is not a representative generalization, but the generalization of an idea, in current study, the possibility of using smart contracts to automate certain supply chain processes in order to make it more agile and transparent in real time. As a result of the master thesis supply chain cases were explored and analyzed in deep details.

Further limitation is, that the phenomenon investigated in current research is highly innovative and new. Since blockchain technology is an innovative topic, there is an absence of scientific theory behind the phenomenon, active implementations of the technology started around a year ago, thus there is only limited amount of companies in Russia who already implemented it. Therefore, it was difficult to find companies who are ready to share their experiences. The few number of cases can raise some bias in terms of creating a methodology for smart contract development, therefore, further research can expand number of case studies in order to obtain more relevant and objective results and improve the methodology. Moreover, due to the novelty of the implementations any time series data is not yet available to measure the actual benefits of the technology implementation we have to solely depend on the managers' opinion. However as the research is focusing on exploring, not measuring the effect of the

implementation on supply chain processes, the latter can be left for future research in the field, when the technology will be more mature.

Despite all the mentioned limitations the master thesis holds both theoretical and practical value and it was possible to reveal requirements and potentials of utilization of Blockchain technology regarding Smart Contract functionality.

3.8. Summary of chapter 3

The third chapter of the thesis consists of the analysis of best practices of implementing Blockchain technology in supply chain management in the Russian market. For the analysis primary and secondary sources were used. The researcher conducted four interviews with industry professionals and collected further information from articles of mass media and company websites. Existing blockchain solutions in supply chain management of the companies are identified.

For a starting point for each case study within-case analysis was accomplished, each of the cases were analyzed according to certain dimensions set by the author of the master thesis. Within-case studies were structured as follows. Firstly, overview of the company was given, then business use of blockchain and smart contracts at the company was described, followed by the descriptions of the processes smart contracts are used for, and the improvements experienced by the implementation, finally type of blockchain technology the company is using is investigated. In case of VTB the only difference is that instead of improvements experienced, the way VTB plans the implementation is discussed, since the company is in the planning stage with blockchain implementation.

Within-case analysis was followed by cross-case analysis, during which a comparison was conducted by the researcher according to some aspects investigated. The aspects of comparison were the followings: time of implementation of the technology, type of BCT used, reasons for choosing that particular platform, reasons for BCT implementation, supply chain processes suitable for smart contracts (here the researcher were interested in already used smart contract solutions and future plans), the existence of IoT applications connected to BCT, the success criteria for smart contract design and finally the experienced benefits of the implementation of the technology.

Cross-case analysis is followed by a comparison of blockchain technologies regarding their fit to supply chains. With the help of a cross-table analysis four technologies were chosen for analysis. The technologies were compared under the following aspects: description of the

platform, governance of the platform mode of operation, consensus protocol, smart contracts, currency, and fit to supply chains.

Comparison of the blockchain platforms is followed by a generated methodology of smart contract development and stages of implementation of the technology itself. This part of the research includes practical recommendations and an algorithm of steps to be done when implementing the technology and developing the smart contract.

The third chapter ends with “Discussions and findings”, “Theoretical contribution and practical implication”, and “Limitations and prospects for future research”. In the part “Discussions and findings” all research questions are answered, moreover the way how the technology contributes to create additional trust is defined.

The results of the research can be summarized by the list of processes smart contracts are suitable for, which are the followings: Payments, Trade Finance, Track and Trace and Proof of Origin. As suitable platform for smart contracts most of the questioned experts answered Hyperledger Fabric, as it offers channels for private transactions, and more flexible smart contracts. However, currently most of the assessed companies use Ethereum or Masterchain in their blockchain projects. As success criteria several requirements were mentioned, such as IT requirements, multiple entities, common standards and verified trade partners (digital identity),

Conclusion

The aim of the master thesis was to analyze how smart contracts could solve recent supply chain issues, such as lack of trust and real-time transparency, accompanied by a comparison of blockchain technologies as a platform for smart contracts, and to generate a methodology for smart contract development in supply chain management for managerial implications. Technologies were analyzed, best practices were identified in the Russian market, research questions were answered, and a methodology was created for smart contract design, thus a theoretical and practical contribution is added to existing research and the research gap was addressed. In order to achieve the research goal stated above, literature review was conducted to define the state of the art, then in the empirical study multiple case study analysis was conducted. Both within-case and cross-case analyses were carried out during the research. Data was collected with the help of semi-structured interviews and an investigation of secondary data. Supply chain use cases of three Russian companies were explored during the research.

During the interviews and secondary data analysis existing processes suitable for smart contracts were identified, blockchain technologies suitable for smart contracts in supply chain

environment were listed and compared, and success criteria for smart contract design were determined. In order to conduct within-case and cross-case study analyses certain dimensions were chosen by the researcher guided by the three research question as research objectives.

During the research several limitations were identified, which refer mostly to the research sample. Moreover, some limitations were revealed, which were connected with the opportunity to provide generalization of the findings since as the limited number of analyzed case studies.

As for summarizing the results of the master thesis, derived from the research it can be concluded, that physical and financial flows can be streamlined to a greater extend using blockchain, where all involved partners are able to share and monitor trade and finance related information such as bill of lading, latest invoice status etc, and check transactions in a transparent manner. This new digital infrastructure allows every participant to have easy access to real-time supply chain information. Peers are able to continuously monitor the details of goods and transactions digitally. Every member of the network has a digital identity, which is verified by other members and their digital signature, which improves the trustworthiness of the data source. Such an inclusive infrastructure, which relies on distributed ledgers, ensures global validity and security for data and information. This reduces significantly the costs and complexity of today´s systems.

By addressing the first research question, several supply chain processes were identified, for which smart contracts are suitable solutions for optimization. During the research four use cases were found: payments (automated transactions), logistics (track and trace), trade finance (reducing finance documentation) and procurement (proof of origin).

With the created methodology we address the second research question about the requirements and success criteria form smart contract design. The main points from the finding are the followings. Multiple entities should collaborate as smart contracts are useful only in use cases involving multiple parties transacting with each other. Supply chains by nature meet this requirement. There is a need for certain level of digitization and an IT-team familiar with smart contract, or in case we do not have a qualified IT team, we should collaborate with IT companies, or other companies who has a qualified team. Expertise in writing smart contracts is a must, as they act on conditions automatically, thus bugs or errors in code could cause serious issues. By the level of digitization not only the existence of appropriate resources such as computers, servers, networks and software is significant, but also employees have to use intensively digital tools in their activities, and transform from paper based to computer-based work. The company experts were all on the same page regarding permissions to enter the network, thus in order to exclude malicious actors there is a need of authorization of the trade partner. This is an important issue in order to ensure that the source of information is

trustworthy. According to experts, there is a need of standard operating procedures across the supply chain in order to design successful smart contracts.

As a result of a comparison of a number of blockchain technologies, benefits and drawbacks of all technologies were discussed in detail. The companies investigated are using permissioned blockchain platforms for their smart contracts. Two of the companies use a private version of Ethereum, VTB uses Masterchain, a Russian blockchain platform on the basis of Etherium code. Traft is absolutely satisfied with their platform, do not plan to use other platform, the other two companies are getting familiar with Hyperledger fabric at the moment, they believe that Fabric could offer them more flexible solutions for supply chain utilization.

To sum up, from the practical examples examined, it can be deduced, that blockchain technology and smart contracts provides several gains to supply chains and contributes to solving long-standing problems in supply chains, such as bottlenecks at stages of the supply's physical movement, high tied up capital in the supply chain, lack of trust and real time transparency.

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