UNIVERSITY OF TURKU

ABSTRACT

	Bachelor's thesis
X	Master's thesis
	Licentiate's thesis
	Doctor's thesis

Subject	Information Systems Science	Date	10.6.2019
Author(s)	Sofia Mäkivaara	Student number	508394
		Number of pages	68 p.
Title	Blockchain in Energy Transfer Management		
Supervisor(s)	Ph.D. Jani Koskinen, Jani Hautaluoma		

Abstract

Blockchain is a distributed ledger technology that was first introduced a decade ago as pseudonym Satoshi Nakamoto launched Bitcoin, peer-to-peer electronic cash system to public audience. Blockchain's inherent characteristics are decentralization, immutability, trust and transparency. Deriving from the world of cryptocurrencies, blockchains have been for a long time associated only with financial industry, but nowadays enterprises from various fields are increasingly showing interest towards the technology and investigating how they can benefit from it in their business and products. Compared to Bitcoin, enterprises have different needs regarding privacy and security and therefore enterprise blockchains emphasize different approaches in e.g. identification of members, consensus mechanism and customizability of the system structure. This thesis studies the specific field of LNG supply chains and how blockchain can contribute to energy transfer management, having the focus on the user perspective.

The study was conducted as a qualitative research. In data collection phase altogether 8 semi-structured interviews were conducted with various professionals from the field of LNG, including participants from terminals, trading companies and the automation provider. The interview results helped in understanding the challenges of LNG supply chains, recognizing the supply chain participants, communication methods that are used, interconnectivity and the big picture. The relevant information in energy transfers is related to technical data, documentation and the general overview over the inventories. One of the major themes occurring in the interviews was the uncertainty about blockchain technology, how it works and what are its key benefits over more mature technologies.

The key findings of this study include that there is a need for a system that increases visibility within LNG supply chains, and blockchain is a potential technology for interconnecting the different parties. There is also however need for further research on blockchain's benefits and exploration of practical use cases. The market still needs to be educated about blockchains, and training and increasing knowledge about the topic will be in a major role in the adoption of the new technology. Because blockchains are decentralized systems, it seems more likely that enterprise blockchains are a collective effort, and not provided only by a single central entity.

Key words	Blockchain, LNG, energy transfer management, supply chains
Further information	

TURUN YLIOPISTO

TIIVISTELMÄ

☐	Kandidaatintutkielma
X	Pro gradu -tutkielma
☐	Lisensiaatintutkielma
☐	Väitöskirja

Oppiaine	Tietojärjestelmätiede	Päivämäärä	10.6.2019
Tekijä(t)	Sofia Mäkivaara	Matrikkelinumero	508394
		Sivumäärä	68 s.
Otsikko	Lohkoketjun käyttö energiansiirtojen hallinnassa		
Ohjaaja(t)	FT Jani Koskinen, Jani Hautaluoma		

Tiivistelmä

Lohkoketju on hajautettu tilikirja sekä tietokanta, joka alun perin esiteltiin Bitcoin-kryptovaluutan julkaisun yhteydessä vuonna 2008. Lohkoketjujen tärkeimpiä ominaisuuksia ovat desentralisaatio, muuttumattomuus, luottamus sekä läpinäkyvyys. Sillä lohkoketjut ovat lähtöisin kryptovaluutoista, on ne pitkään yhdistetty vain pankkeihin ja rahoitusalaan, mutta nykyään monet yritykset myös muilta aloilta ovat alkaneet kiinnostua teknologiasta ja sen mahdollisuuksista liiketoiminnassaan. Täysin avoimeen kryptovaluuttaan verrattuna yrityksillä on paljon erilaisia tarpeita liittyen yksityisyyteen ja turvallisuuteen, ja siksi yritysten hyödyntämiltä lohkoketjuilta vaaditaan käyttäjien tunnistamista, kevyempiä konsensusprotokollia sekä järjetelmän rakenteen muokattavuutta. Tässä tutkielmassa tarkastellaan pääasiassa nesteytetyn maakaasun toimitusketjuja ja kuinka lohkoketjuja voitaisiin hyödyntää niissä tapahtuvissa energiansiirtojen hallinnassa.

Tutkimus toteutettiin laadullisena tutkimuksena ja aineistonkeruussa hyödynnettiin puolistrukturoituja haastatteluita. Haastatteluihin osallistui yhteensä kahdeksan henkilöä LNG toimitusketjujen eri osa-alueilta. Haastatteluiden tulokset avarsivat toimitusketjujen haasteita, eri osapuolten tunnistamista, käytettyjä viestintämenetelmiä, sekä auttoivat hahmottamaan toimitusketjussa saavutettavaa kokonaiskuvaa. LNG toimitusketjuissa oleellinen tieto liittyy tekniseen dataan, dokumentaatioon sekä yleiskuvaan varastojen tilasta. Yksi selkeimmistä teemoista, joka haastatteluista oli havaittavissa, oli lohkoketjujen tuntemattomuus alalla. Haastateltavia kiinnosti kuulla lohkoketjujen toiminnasta sekä siitä, mitkä on niiden edut verrattuna perinteisiin tietokantoihin.

Johtopäätöksinä voidaan todeta, että LNG toimitusketjuissa on tarve suuren kuvan hahmottamiselle ja lohkoketjut tarjoavat potentiaalisen teknologian toimitusketjun eri osapuolten yhdistämiseen. Lohkoketjujen etuja verrattuna perinteisiin menetelmiin täytyy kuitenkin vielä tutkia ja saada enemmän näyttöä käytännön toteutusten toimivuudesta. Yritysten, jotka pyrkivät hyödyntämään lohkoketjuja, tarvitsee lisätä teknologiaan liittyvää tietoutta joko koulutuksilla tai rekrytoinneilla. Sillä lohkoketjut perustuvat desentralisaatioon, tulevat myös yritysten hyödyntämät lohkoketjut olemaan todennäköisimmin useamman toimijan välisen yhteistyön, kuin yksittäisen yrityksen ponnisteluiden tulosta.

Asiasanat	lohkoketjut, nesteytetty maakaasu, energiansiirtojen hallinta, toimitusketjut
Muita tietoja	

UNIVERSITY
OF TURKU
Turku School of
Economics

BLOCKCHAIN IN ENERGY TRANSFER MANAGEMENT

Master´s Thesis
in Information Systems Science

Author:
Sofia Mäkivaara

Supervisors:
Ph.D. Jani Koskinen
Jani Hautaluoma

10.6.2019
Turku/Tampere

The originality of this thesis has been checked in accordance with the University of Turku quality assurance system using the Turnitin OriginalityCheck service.

Table of contents

List of figures

List of tables

1 INTRODUCTION

1.1 Background and motivation

In 2008 an anonymous person or a group called Satoshi Nakamoto published a whitepaper describing Bitcoin, a peer-to-peer electronic cash system, and the technology behind it called blockchain. The whitepaper describes how blockchain solves the double spending problem and transferring assets between network participants without an intermediary (Nakamoto 2008). Since their introduction, blockchains have intrigued researchers and business practitioners alike in the race to find out about their viable uses. In 2017 Bitcoin's price skyrocketed and after that many innovative projects have been launched in order to explore the different uses of blockchain. Currently medias are claiming that from 2019 onwards blockchain will become more and more mundane and normalized part of a wide range of business applications and that it has a big potential in becoming an invisible and ubiquitous technology unnoticeable to the users, such as electricity and the Internet (Orcutt 2019, Mougayar 2016).

At an abstract level, blockchain can be described as digital rails that move assets from one network member to another (Mougayar 2016). It differs from previous Internet based technologies in that one doesn't need a central entity or trusted intermediary in between the transfers while making sure, that the assets are not replicated, reversed or modified by the sender or other network members. In short, blockchain offers trust embedded in its structure. Blockchain may be observed from several perspectives. Technically, it is an open, distributed database that contains an append-only ledger. From business perspective it is a peer-to-peer network for exchanging value. From the legal perspective, blockchain can be utilized in validating transactions (Mougayar 2016). To use blockchain to its fullest potential, it is important to observe it holistically from all these perspectives.

Blockchain is a foundational technology that has several potential uses extending outside cryptocurrencies. It features many important properties, as it enables new computing infrastructures, transaction platforms, decentralized databases, distributed ledgers, development platforms, open source software, marketplaces, peer-to-peer networks and trust layer services to name a few (Mougayar 2016). By understanding the flexibility and versatility of the technology it is possible to experiment with it and start seeing new use cases outside traditional cryptocurrency implementations.

Supply chains, just as blockchains, are about networks. They generally consist of a network of companies working towards the common goal of creation and delivery of a good or a service all the way to the customer. Hugos (2018) defines the five major supply chain drivers to be production, inventory, location, transportation, and information. Supply chain management coordinates the actions of these drivers in the network. Supply chain management acknowledges the same activities as logistics, but in addition involves marketing, product development, finance and customer service. The goal of supply chain management is to coordinate the activities in a way that optimal balance between responsiveness and efficiency regarding market demand is achieved. Essentially supply chain management aims to ensure the satisfaction of end customers. (Hugos 2018, Drake 2012.)

Small-scale LNG (Liquefied Natural Gas) supply chains are as well networks consisting of energy producers, LNG terminals, transportation trucks, bunkering vessels, process plants, LNG fueled ships and the end users. The changing quality of LNG poses challenges to supply chain participants, making forecasting and storing much more difficult than in the case of traditional fossil fuels like oil. Critical information may also get stuck to the participant possessing it, instead of being evenly distributed to designated network members. For small-scale LNG supply chains, blockchain has a potential to offer a way to map out demand, follow transfers and trends, and create a platform for information exchange. The aim is to map out the whole supply chain and make it transparent for all network members.

The motivation for this research comes from the lack of the general big picture in the small-scale LNG supply chains, and the aim is to find out can blockchains add visibility, transparency and security to them. The aim is also to support the development of the LNG infrastructure and the adaptation of renewable energy in future. The final product of LNG and Biogas are the same, but the ways of production are different. Therefore, the same infrastructure can be used for both.

In a practical sense this study examines the utilization of blockchain in connection with the Valmet Integrated Operations software. The aim is to explore the challenges and opportunities of the technology in the product. Valmet Integrated Operations combines, monitors and controls information for all participants in the small-scale LNG supply chains. It enables the optimization and efficient management of the logistics and easy communications and sharing of data between participants.

1.2 Research gap

The main research topics related to this study are the blockchain technology, supply chain management (SCM) and LNG. Each of these research areas have been studied widely, but the intersection of the three remains yet an academically unexplored area (figure 1).

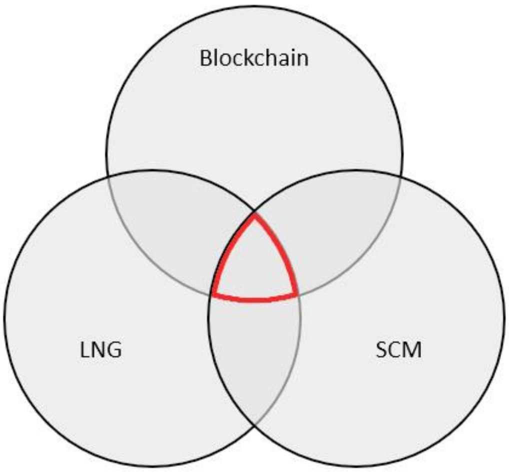


Figure 1 The research gap.

Blockchain is the most recent research area out of the three and has been actively studied since 2013. Blockchain integration to supply chain management has been studied by Korpela et al. (2017), Li et al. (2018), and O'Leary (2017) among others. Blockchain for IoT has been studied by Christidis and Devetsikiotis (2016), Dorri et al. (2017), and Samaniego et al. (2016). The book by Mougayar (2016) discusses blockchain generally in the business context. Ethereum founder Vitalik Buterin's blog posts and white papers offer insights on blockchain and the Ethereum platform, which is part of the blockchain 2.0 phase. Several overviews on are conducted by Zheng et al. (2018) and Zhao et al. (2016) and a recent literature review by Casino et al. (2019). The personal data privacy in blockchain has been studied by Zyskind et al. (2015).

Out of the three areas, supply chains and supply chain management are the most extensively researched areas. Entering the keyword "supply chain*" on Scopus returns 86,177 documents in total. In this study, supply chains and supply chain management are based in the literature by Hugos (2018), Drake (2012) and Chopra & Meindl (2015). A conceptual theory on supply chains developed by Carter et al. (2015) has been used to form a basis of understanding. The future research themes of supply chain management have been studied by Wieland et al. (2016), supply network innovations by Narasimhan and Narayanan (2013) and cloud integration by Shee et al. (2018) and Wu et al. (2013).

LNG has been researched for decades and there are large amounts of literature available. LNG value and process chain has been discussed in a book by Sakmar (2013). The optimal design for a small-scale LNG supply chain has been studied by Bittante et al. (2017).

The intersection of these areas is where the research gap lies. Blockchain integration to supply chains and energy sector have both been studied, but the perspective of LNG supply chain has not been covered comprehensively. Blockchain is also a constantly evolving subject, which requires further research especially in the exploration of new proofs of concepts. Therefore, the aim of this thesis is to contribute theory and practice in following ways:

- Filling in the research gap of blockchain in LNG supply chains
- Drafting the steps needed for business blockchain implementation
- Strong practical contribution by offering the industry information about latest developments in LNG supply chains and the blockchain technology

1.3 Research problem

The implementation of blockchain in Valmet Integrated Operations seeks to solve Valmet's customers' problems, such as the lack of supply chain transparency and visibility, the challenges in forecasting, information exchange, and making transfers and contracts in the network. The aim is to explore the use of a cloud based blockchain to guarantee data security and integrity, and to support the use of renewable energy (Wind/Solar/Biogas) in the future, since it is possible to utilize the same infrastructure as for LNG. As a result, this thesis will draft the steps for implementing blockchain in LNG supply chain management. The research questions are following:

- How to utilize blockchain in supply chain management in a way that it solves the stated challenges faced by end-users and customers?
- What are the main challenges and obstacles in implementing blockchain in the product and how to overcome them?

In this thesis, blockchain is observed from supply chain management and enterprise perspective. Therefore, the research will emphasize private and permissioned blockchains over public blockchains. The use of cryptocurrencies or tokens in the model is minimized, and the network-aspect, exchange of documents and tracking physical transfers is focused instead.

1.4 Thesis structure

This thesis consists of six chapters, which are organized as follows. The first chapter introduces the research topic to the reader and describes the background, motivation, research gap, research questions and the scope of the study. It offers an overview of the purpose of the thesis, limitations and the structure. The second chapter consists of the literature review, which builds the theoretical background needed to comprehensively understand the studied topic and later chapters. The topics covered in the literature review include the blockchain technology, its different types and challenges, supply chain management and LNG. The third chapter forms the empirical part of the study. It presents the research methodology used, and describes the semi-structured interviews conducted. Chapter three also includes an introduction to organizational context and reliability and evaluation of the study. In chapter four the results are presented and the interrelations between the categories occurring in the data are explained. Chapter five discusses the key findings derived from the results and blockchain's potential in the context of LNG supply chains and energy transfer management. Chapter six draws conclusions from the discussion and summarizes the thesis.

2 LITERATURE REVIEW

The aim of the literature review is to form a solid grounding on the research areas related to this study. Because the body of literature is significant in each research area, several methods have been used to reach a comprehensive selection. For more general material most-cited articles and highly ranked journals were emphasized. For more specific material recent articles were emphasized in searches and snowballing relevant articles. Materials were searched via Scopus and other article databases with keywords such as "blockchain*" "smart contract*" "Supply chain*" and "LNG". Because the field of blockchains is constantly being shaped, some grey material has been chosen to support the literature selection. The topics covered in this review include blockchain architecture and concepts, different types of blockchains, blockchain challenges, supply chains, supply chain management and supply chains from the perspective of LNG.

2.1 Blockchain overview and concepts

Blockchain technology, which is a form of a distributed ledger technology (DLT), is a growing record of transactions that enables a peer-to-peer network for exchanging value. Blockchain's structure offers important advantages, such as immutability, transparency and trust. Similar approaches have been studied before, one being described by Haber and Stornetta (1991) in their article called "How to timestamp a digital document". Blockchain first emerged when a pseudonym Satoshi Nakamoto published a whitepaper entitled "Bitcoin: A Peer-to-Peer Electronic Cash System" (Nakamoto 2008). Bitcoin's core technology managed to solve common issues associated with cryptocurrencies, such as the double spending problem and transacting value non-reversibly from one person to another without an interference of a third party. These properties are important features of blockchains: eliminating intermediaries and ensuring that a digital asset is not copied or manipulated by a malicious party.

The key characteristics of blockchain technology are *decentralization* across peer-to-peer network formed by computers (nodes), *immutability* once the blocks have been validated and permanently chained together, *trust* enabled by a synchronized copy of the blockchain ledger that everyone in the network holds, and *authentication* enabled by the chosen consensus mechanism that defines how the transactions are validated in the network. User's privacy and security is ensured with cryptographic techniques. (Li et al. 2019, Wüst & Gervais 2018, Antonopoulos 2018.)

A generalized blockchain transaction operation progresses as follows: as a new transaction is requested, it is first broadcasted to the entire network and sent to all nodes pointed as validators (miners in Bitcoin). Validators run the transactions through pre-defined checks that make sure that their structure and activities are correct, thus verifying the transactions. A validator collects several transactions and forms them into a new block, which is accepted when over 51% of the network nodes agree that it is valid (the network reaches a consensus). In Bitcoin blockchain, this is the point where a new block is mined. After a new block is accepted, it is added to the blockchain ledger held by each network participant, and everyone will have an up-to-date copy of made transactions. The distributed blockchain ledger is append only, and the further in the history a block has been formed, the more difficult it is to change as it would require changing the same block (and all blocks that were added after it) in every network participant's copy of the ledger. (Li et al. 2019, Tschorsch & Scheuermann 2016.)

The data structure of blockchain is a back-linked list of blocks that contain transactions. Blockchains are often visualized as vertical stacks of blocks, the one on the top representing the freshly mined block and the one on the bottom representing the foundation of the chain, the genesis block. This visualization also illustrates well the history-aspect of blockchain, and how the bottom blocks become more and more permanent as the chain grows. (Antonopoulos 2018, Nakamoto 2008).

Regarding industrial and business implementations, one of the most interesting features of blockchains are smart contracts. The concept was first introduced by Nick Szabo in 1994, who defined smart contract as "a computerized transaction protocol that executes the terms of a contract" (Szabo 1994). Once successfully implemented, smart contracts could be used in automating paper-based processes and contracts involving human input. It should be however considered, that currently smart contracts have barriers such as interoperability, storage constraints and problems with confidentiality. (Li et al. 2019.)

The following subchapters go further into detail about the architecture and concepts of blockchain. For clarity the concepts are explained as they are defined in the Bitcoin blockchain, but slight variations may occur depending on the chosen blockchain platform.

2.1.1 Transactions

Transactions are transfers of value from one network participant to another. They contain the information about a recipient's address, a sender's address and an amount sent. Once a transaction is submitted, it is broadcasted to the network, confirmed by the active nodes, collected into a block and again sent to all nodes. In public blockchains anyone can view all the transactions ever made in a given blockchain's history. (Tschorsch & Scheuermann 2016, Nakamoto 2008.)

Transactions may contain one or multiple inputs and outputs. Input is always a reference to the previous transaction's output and it contains the sender's signature and a public key (figure 2). Output defines the amount and address the transaction is sent to. The linked inputs and outputs create a continuous stream of value that is verifiable. Once a transaction is confirmed to the block, it is irreversible, and becomes a part of the blockchain ledger.

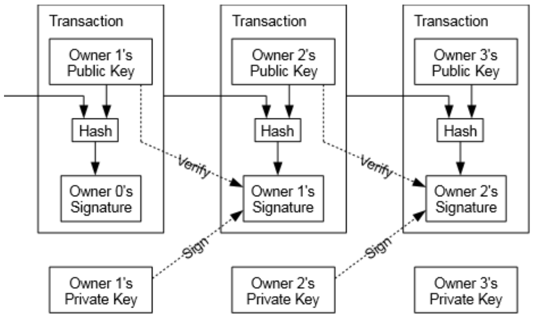


Figure 2 **Blockchain transactions (Nakamoto 2008).**

2.1.2 Blocks

A block consists of the header and the block body. The header includes all metadata and information that identifies the block and ties it to the chain, such as the block version, reference to the previous block's hash (parent block hash), merkle tree root hash (hash identifying the block), timestamp, current difficulty used to create a block and a nonce. The block body consists of transactions that have been confirmed as valid by the network and a coinbase transaction (reward for the miner). Once a transaction is confirmed, it is permanently recorded in a new block (Tschorsch & Scheuermann 2016, Zheng et al. 2017). New blocks are then added to the end of the chain in a chronological order.

Each block is identified by its cryptographic hash, and each block references to the previous block's hash, as illustrated in figure 3. This creates a link between the two blocks, thus resulting in a chain of blocks after several transactions. Every computer node in the network has the right to read this back-linked list and figure out the current and past transactions made in the network. (Christidis & Devetsiokiotis 2016.)

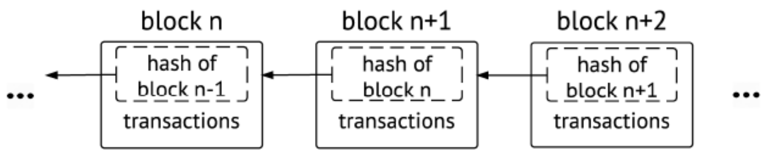


Figure 3 Back-linked list of blocks (Christidis & Devetsiokiotis 2016).

In addition to general blocks, a blockchain always has one genesis block that is the first block in the chain. The genesis block differs from the rest in that it doesn't reference a previous block's hash and is only created to begin a new chain.

2.1.3 Consensus

Reaching consensus among the untrusting peers is one of the main functionalities in blockchain. Because of the distributed structure and no central entity to make sure all nodes have the same information, there needs to be a consensus protocol. Consensus protocol should not be confused with the social consensus of most participants agreeing on a certain matter or a blockchain's consensus rules. Several consensus algorithms exist for different types of blockchains, and the strictness of a consensus mechanism depends on whether the network is public or permissioned, and what is the level of trust in the network.

Proof of work (PoW) is the consensus protocol used in Bitcoin. The concept of Bitcoin mining is closely related to proof of work since it means putting real world work of maintaining the ledger in a form of electricity. PoW is a resource- and time-consuming process of solving the next block's hash. The miner nodes in the network compete against each other in who can calculate the hash value first. The hash value is not supposed to exceed a given maximum value. The network participants make calculations of the hash value by trying different nonce values until they reach the target. The hash is demanding to calculate but easy to verify as valid by the peers. The miner or a group of miners who calculate the hash get rewarded with bitcoins for their effort.

In a decentralized network, there is a possibility that two valid new blocks are created when several miners find a working solution for a hash calculation. In this scenario, the blockchain creates a fork, where there are two truths about the state of the chain (figure 4). The branches of the fork will compete against each other, and eventually the longer branch takes over and the shorter will be discarded. (Zheng et al. 2018.)

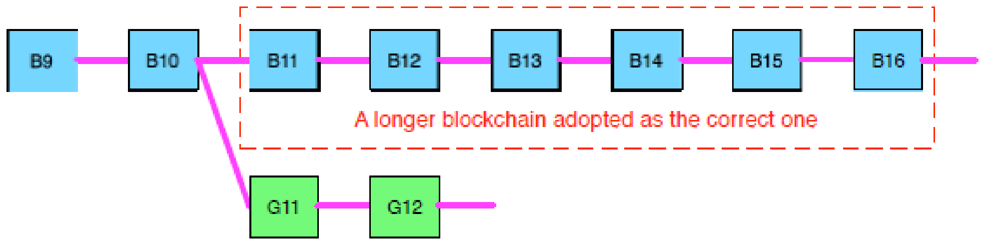


Figure 4 Blockchain fork (Zheng et al. 2018).

Proof of Work has been criticized for wasting too much energy and resources on the heavy computer calculations required. To put the energy consumption in scale, according to Digieconomist (2019) and Casino et al. (2019) Bitcoin network alone exceeds the energy consumption of many countries in the world and if it itself was a country, would it rank right by Singapore in energy usage. Therefore, less energy-consuming consensus protocols are highly requested and searched for.

Proof of Stake (PoS) is one of the protocols suggested to be used instead of PoW. It's an energy-saving option that doesn't require as powerful hardware as PoW. In Proof of Stake a person who gets to validate the next block is based on the amount of coins they own and their age of ownership. The idea is that people who are more engaged with the network (own most currency) are less likely to attack it. However, the protocol can't be entirely depending on the amount of currency people own, because it would result in the richest person on the network dominating it. Therefore, different formulas are used to calculate the size of stake of each network participant, upon which the selection process is based. Most blockchains start with PoW but many of them, including Ethereum, are planning to shift to proof of stake in near future. (Zheng et al. 2018, Casino et al. 2019.)

Practical Byzantine Fault Tolerance (PBFT), introduced by Castro and Liskov in 1999, is a state-machine replication protocol used to tolerate independent node failures and faulty messages sent by malicious nodes. Compared to PoW, PBFT has excellent performance and low energy consumption but is limited in scalability (Vucolic 2015). PBFT requires multiple voting rounds in groups of nodes. One node is chosen as the leader, or the primary node, of the group based on a chosen election system. The voting rounds of PBFT include pre-prepare, prepare and commit phases. During these phases the primary node informs replicas about the requests made and their identification numbers, replicas share the messages they have received among each other and agree on the state of the request. The next phase is entered when votes have been received from over 2/3 of the participants. (Zheng et al. 2018, Zoican et al. 2018.)

In addition to mentioned consensus protocols, also several other “proof-of-X” protocols with slight variation exist and are under development but are not included in this review.

2.1.4 Smart contracts

The concept of smart contracts was introduced in 1994 by Nick Szabo. Smart contracts embed contractual clauses into hardware and software. According to Szabo (1997), traditional contracts are a way to formalize a relationship, and similarly smart contracts can be used to formalize and secure a relationship digitally over public networks using existing protocols and user interfaces. In blockchains, smart contracts could be used to make transactions faster and more efficient by automating the triggering of transactions (Casado-Vara et al. 2019). Smart contracts may require some human control and input, but to a big extent they can be automatable by computers. Blockchain’s distributed architecture and immutability offer a platform where smart contracts can be enforced and verified (Clack et al. 2017).

2.2 Types of blockchains

The most common way to differentiate between different types of blockchains is to separate them to public (permissionless) and private (permissioned) blockchains. The first blockchains to emerge, such as Bitcoin and Ethereum are examples of permissionless blockchains that are fully public. Once blockchains began attracting parties outside cryptocurrency, different types were developed to meet their privacy and governance needs. For example, businesses and organizations that have confidential information may benefit more on the use of permissioned blockchains that do not share the ledger information publicly, such as Hyperledger Fabric.

The major difference between public and private blockchains is the distinction in who is allowed to participate in the network and act as a transaction validator (O’Leary 2017). Even though there is a rough categorization of public and private blockchains, public blockchains can be either permissionless or permissioned and similarly private blockchains can be permissioned or permissionless (figure 5). To clarify the difference between the types, this chapter focuses on fully permissionless public blockchains and permissioned private blockchains.

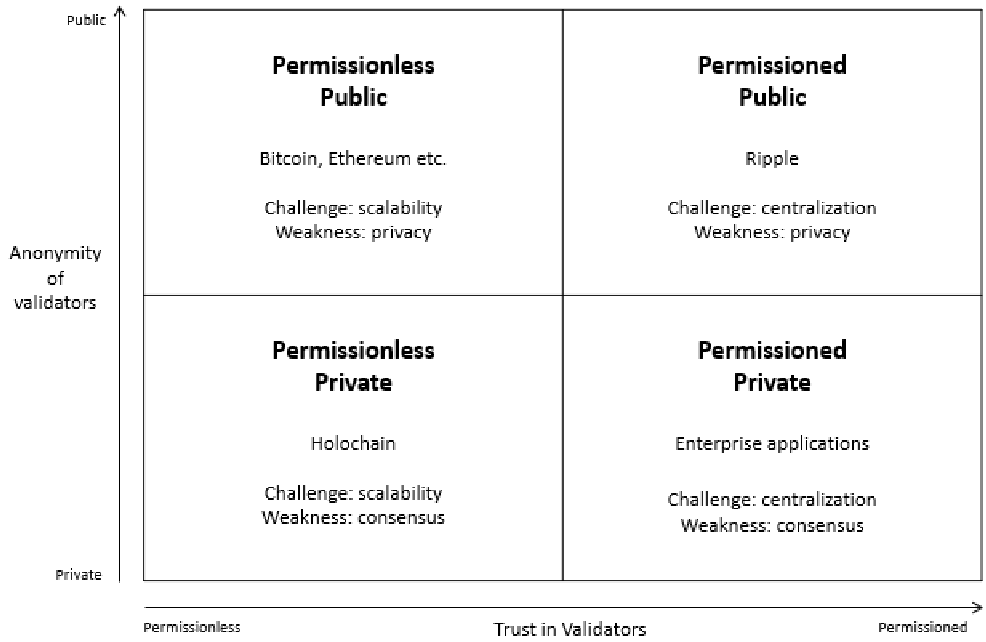


Figure 5 Different types of blockchains, examples and characteristics (BlockchainHub 2019).

2.2.1 Public blockchains

Public blockchains, such as Bitcoin and Ethereum, are permissionless, meaning that anyone can become a member of the network and have read and write rights to it. The network is truly open and decentralized and there is no central entity to manage and maintain it. The network as a whole agrees on the consensus by verifying the state of the distributed ledger and validating transactions. Every node holds their own copy of the ledger. The blockchain ledger is completely transparent and open for anyone, even outside the network, to download and examine. The bigger the network grows the more secure it becomes, because everyone is endorsing the same rules. Because the transaction information is public, the network participants' privacy must be protected with cryptography. Common consensus protocols for public blockchains are proof of work and proof of stake.

Public blockchains are based on the idea that there is no trust between the network members. This means that the members do not have to know each other in advance to be able to transfer assets from one person to another. The trust is achieved by establishing it in the platform's structure and code. Public blockchains benefits include public ownership, decentralization, transparency and robustness. The drawback of public blockchains is that to date they require a heavy consensus system, which is why they are not optimal to be used in this study.

2.2.2 Private blockchains

Private blockchains only allow permissioned, pre-selected members to participate in the blockchain network. Therefore, there needs to be a central entity to manage the memberships and read and write rights of the network. Because the network members are known, the consensus protocol does not need to be as heavy as in public blockchains. The assumption is that there is a certain degree of trust between the participants. A common consensus protocol for private blockchains is the Practical Byzantine Fault Tolerance.

The access to transaction information is limited and depending on the use of blockchain, some pieces of information can be kept private. Private blockchains are not transparent in the same manner as public blockchains, but the transparency depends on who are granted access to information.

2.2.3 Justifying the use of blockchain

When considering using a blockchain the first and foremost question is when and where is it useful. Wüst and Gervais (2018) have researched the matter and created a flow chart for recognizing viable blockchain use cases (figure 6). Blockchain is a form of database architecture, so it makes sense to use it when there is a need to store data. On the other hand, data could be stored in a traditional centralized database as well. Whether to use a decentralized database (blockchain) or a centralized database depends on how many writers need to use it and how it is meant to be governed. If there are several writers forming a network of nodes, choosing a blockchain makes sense. It is also reasonable to consider that regular, centralized databases are faster and more efficient whereas decentralized databases provide data integrity and therefore security and immutability. According to Wüst and Gervais (2018) the use of blockchains should be reconsidered if there is an online trusted third party available. If an online trusted third party exists, the data verification process could be delegated to them. If there is no online trusted third party available, and the writers don't trust or know each other, a private permissioned blockchain could be used.

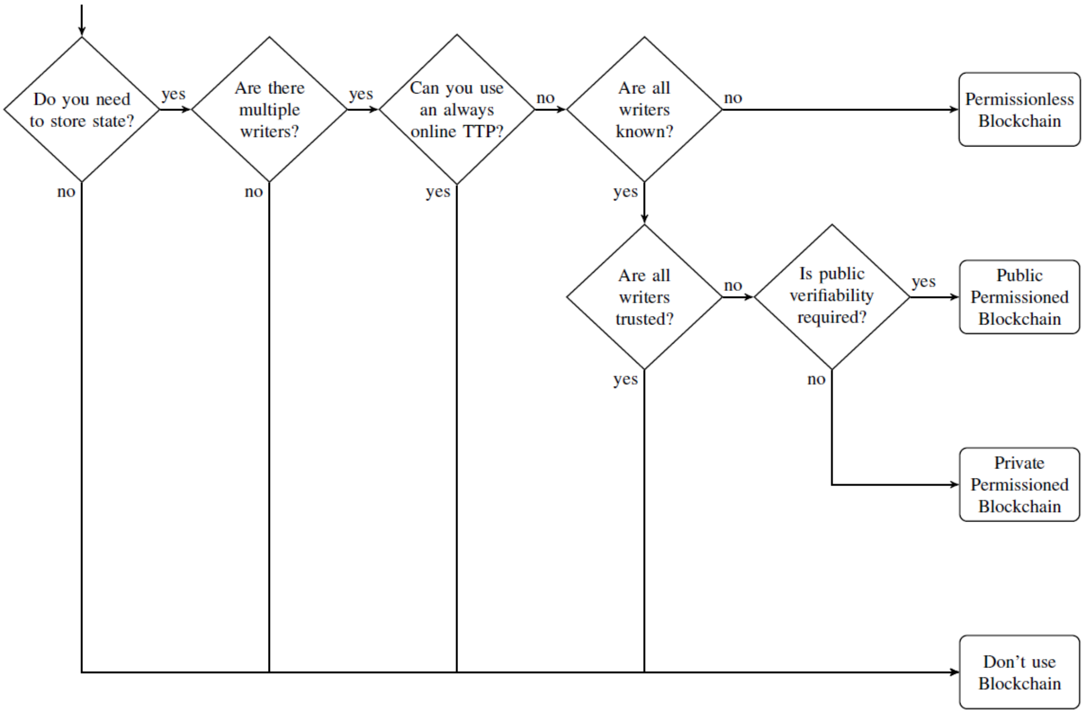


Figure 6 Flow chart for identifying blockchain uses (Wüst & Gervais 2018).

Choosing between permissionless or private permissioned blockchains and traditional centralized databases depends on the needs of a business. What kind of database to use depends on several factors: throughput, latency, the number of readers, writers and untrusted members, consensus and management style (Wüst & Gervais 2018).

Permissionless blockchains are open for anyone to join and allow a high number of nodes. Anyone joining the network can read and write to it, and the identification of the network participants is not required. To reach integrity of data in such a network requires a heavy consensus algorithm such as proof of work, which results in low throughput and high latency. The advantages of permissionless blockchains are true decentralization and transparency, gaining network effects and eliminating third parties. (Buterin 2015, Wüst & Gervais 2018.)

Permissioned blockchains are more likely to provide advantages for institutions and organizations. They allow a central entity to choose who can join the network as a writer and validator, whereas reading rights could be open or permissioned. The reader number in permissioned blockchain can be high but the number of writers is limited. Because the network participants are identified, permissioned blockchains don't need as heavy consensus algorithm as permissionless blockchains, enabling high throughput and medium latency. Permissioned blockchains allow central entities to modify the network rules and the level of privacy, as it may be necessary.

Compared to blockchains, centralized databases have a very high throughput and are fast while allowing a high number of readers and writers. There is no mechanism to check the integrity and immutability of the information. Centralized databases always have an administrator who can create, delete or modify records, create new user accounts and change the rules of a database. The downsides of regular databases are that they are highly dependent on the central entity maintaining them and are prone to downtime in a case of a server crash (Table 1).

Table 1 A comparison between permissionless blockchain, permissioned blockchain and a central database (Wüst & Gervais 2018).

	Permissionless Blockchain	Permissioned Blockchain	Central Database
Throughput	Low	High	Very High
Latency	Slow	Medium	Fast
Number of readers	High	High	High
Number of writers	High	Low	High
Number of untrusted writers	High	Low	0
Consensus mechanism	Mainly PoW, some PoS	BFT protocols (e.g. PBFT [5])	None
Centrally managed	No	Yes	Yes

2.3 Enterprise blockchain platforms and frameworks

Currently there exists various blockchain platforms, a lot of which extend on the original Bitcoin Core and are targeted for the financial industry. Most blockchain platforms also rely on a cryptocurrency or a token partially as an incentive method, which might make a platform inflexible for enterprise use. Since it is difficult to provide an exhaustive list of all blockchain platforms, it was necessary to narrow down the selection in this review. From an enterprise perspective, the platform should support private blockchains and the creation of smart contracts. Several technical aspects also can be used in classifying the platforms, such as consensus protocol, transaction validation method and targeted functionality of the application.

When looking up enterprise blockchains, three platforms stand out from the rest currently: Ethereum, Hyperledger Fabric and R3 Corda. These platforms have most existing implementations and most active communities behind them. The platforms differ in their characteristics, which helps in choosing the most appropriate option for one's business. (Teslya & Ryabchikov 2018, Androulaki et al. 2018, Vucolic 2017.)

2.3.1 *Ethereum*

Ethereum, founded by Russian-Canadian programmer Vitalik Buterin in 2013, is one of the first blockchain platforms after Bitcoin that aimed at extending beyond financial industry to decentralized applications and more generalized blockchain use cases. Ethereum was also pioneer in the inclusion of smart contract functionality to blockchains. Ethereum is programmable and Turing-complete. The smart contracts are programmed with Solidity language, which is similar to JavaScript and C++. An important element of the platform is the Ethereum Virtual Machine (EVM), which can execute code, such as smart contracts.

Due to generalized nature of the applications, Ethereum is mostly used in peer-to-peer or business-to-consumer operations. Ethereum is an open source public blockchain, meaning that anyone can join the network and maintain it. The network is governed by Ethereum developers. Because the consensus protocol Ethereum uses currently is proof of work, it faces similar scalability issues as Bitcoin. In the future as the platform develops, it is planned to use proof of stake as its consensus. Ethereum has its own cryptocurrency called Ether (ETH), which is used in fueling the network and paying the validators. (Buterin 2013, Reyna et al. 2018.)

2.3.2 *Hyperledger*

Hyperledger is an open-source project hosted by Linux Foundation. More than just a single platform or a product, Hyperledger is a hub incubating several blockchain-focused projects called Burrow, Caliper, Cello, Composer, Explorer, Fabric, Grid, Indy, Iroha, Quilt, Sawtooth and Ursa. Hyperledger is a collective effort to accelerate the development of blockchain technologies across industries. Instead of striving for a single standardized blockchain approach, Hyperledger encourages customizability and modularity.

All Hyperledger frameworks and tools are developed to meet a specific need, for example Burrow is specialized in smart contracts, Fabric enables building enterprise applications with modular architecture, Indy specializes in decentralized identity and Sawtooth is a modular platform aiming at resource minimizing with its special consensus algorithm Proof of Elapsed Time (PoET) and a large distribution of validator rights. The frameworks are mainly developed to support B2B operations and permissioned blockchain networks. Hyperledger projects emphasize less energy consuming consensus mechanisms, such as Practical Byzantine Fault Tolerance (PBFT).

Among the Hyperledger projects, Fabric has the most existing implementations and research on it, partially due to IBM’s efforts. Fabric is completely permission based, modular and its functioning does not rely on any cryptocurrency or token. Distributed applications can be written in standard general-purpose programming languages. Currently Fabric officially supports Node.js and Java, and languages available for testing include Python, Go and REST. One of Hyperledger's most important features for businesses is the ability to create private channels within designated members. As of 2018, Fabric had been used in more than 400 prototypes including cases in logistics, food and diamond provenance and contract management. (Androulaki et al. 2018.)

2.3.3 Corda

Developed by company R3, Corda is a permissioned distributed ledger platform targeted mainly for financial transactions and agreements between peers and organizations. Corda has been open sourced since 2016. The long-term vision of Corda is to create a shared global logical ledger for varying actors, such as organizations, individuals and in the future even machines to interact, transact and make agreements with each other.

Corda is a permissioned platform, and contrary to traditional blockchains has higher emphasis on privacy and the transaction data is only visible within actors or groups participating in it. Information about agreements is documented in a state object which is shared between transacting participants and global consistency of the ledger ensured with cryptographic hashing. Corda has pluggable options regarding scalability, privacy and legal regulations compatibility. In Corda, smart contracts are used in linking business logic to legal processes and as a functionality accepting or rejecting proposed transactions. Corda supports Kotlin programming language and uses Java Virtual Machine (JVM) in the execution and validation of smart contracts. Corda does not have any native cryptocurrency. (Teslya & Ryabchikov 2018.)

2.4 Blockchain challenges

It is common for an emerging technology such as blockchain to face several challenges. The further adaptation depends highly on how these technical, business, educational and legal challenges are managed to be solved in the future. The challenges listed in this part are based on current state of blockchain platforms and are continuously worked on by researchers, startups and companies around the world.

Blockchains have been a very hyped topic during the past couple of years. Hype may be however more damaging than beneficial to the new technology, since it tends to create unrealistic expectations to parties interested but not yet deeply knowledgeable about the concept. Critically examining blockchain and learning about its challenges and opportunities will result in a more realistic perception on it.

2.4.1 Scalability

Scalability continue to be one of the main challenges of blockchain and it affects both public and private blockchains. To a large extent, the scalability of blockchains is about tradeoffs between desired properties. Public blockchains such as Bitcoin trade the fast speed of transactions to security and a high number of nodes in the network. Bitcoin's seven transactions per second can hardly compete with current systems such as Visa's thousands of transactions per second (Casino et al. 2019). The consensus algorithm in public blockchain in usually more secure, but also more energy-consuming compared to the consensus algorithms used in private blockchains. The creation of one block takes around 10 to 60 minutes on Bitcoin blockchain resulting in worse latency issues as the network grows bigger.

Private blockchains on the other hand are faster and more energy-efficient but lack many core characteristics of blockchain such as transparency and decentralization. Private blockchains also usually don't have the capacity to manage as large networks as public blockchains (Vucolic 2015). Some argue that private blockchains cannot be called blockchains to begin with, because they are not truly decentralized but require a central entity to assign transaction validators and manage trust in the network.

One more challenge with scalability is the data storage. One characteristic of blockchain is that once a block is created, it will always exist in the chain and can be checked on at any time. Therefore, on the course of time, the chain will become heavier and heavier. Storage optimization is yet an open issue in many blockchain platforms, but new approaches are under development according to Zheng et al. (2018) and Casino et al. (2019).

2.4.2 Security and privacy

Security and privacy in blockchains are achieved in different ways we are used to. Security in blockchain is achieved by redundancy of data (data distributed across many nodes) and the nodes collectively agreeing on the validity of transactions. Blockchain becomes more secure the bigger the network grows, since it will be more difficult to modify or delete information within a consistent and all-agreeing network. Whereas decentralized networks can prevent the attacks commonplace for centralized databases, such as Distributed Denial of Service (DDoS) attacks, they are vulnerable to other types of attacks.

In blockchain literature the most discussed attack against blockchains is the 51%-attack, which means that if several nodes together manage to maintain over 51% of the computing power in the network, they can reverse and modify transactions by ruling over the whole network's consensus. Zheng et al. (2018) call this selfish mining, as the untrustworthy nodes may get to mine more new blocks and make more revenue. Honest miners might feel tempted to join selfish miners, resulting in one or several groups overpowering the rest of the network.

Privacy is one of the main properties of public blockchains, and it is ensured by anonymity of the users and the capability to generate several new addresses where the transactions can be sent. Public blockchains have an interesting relationship between transparency and privacy, because even though all transactions are public, the identities of senders and receivers of the transactions can be protected or are kept completely anonymous. Information leakages are however possible, and by analyzing and comparing the ledger data to real-world events some party's identity may be linked to certain transactions (Zheng et al. 2018).

2.4.3 Education and human factor

The acceptance of a new technology relies considerably on the education and training of different stakeholder groups, such as the personnel and management of an organization or an enterprise and the users of an application. The management's knowledge and support are crucial when deciding whether a new technology will be adopted or not. The personnel's understanding is important when deploying the technology. The lack of understanding about a new technology leads to an organization not getting the management's support and therefore not being able to take fully advantage of it. Therefore, the capabilities of blockchains must be gradually educated to all groups using it. The concept will remain complex if there are no information and training available about the issue. (Mougayar 2016.)

Accumulation of the user base as well as the knowledge of the users is crucial for the wider acceptance of the technology, especially in network-based technologies such as blockchain. Introducing the new technology to users is always challenging and requires adapting to a new mindset. Because blockchain is a backend technology, the users won't necessarily know they are dealing with blockchain: the technology itself is not visible to the users. The user experience might be com-promised at first, because there is no standardized way to make user interfaces for blockchain and the users need to be trained about the new technology before they will fully be able to utilize it. Even though the user experience might be compromised at first, once the technology is fully integrated to existing applications, it may become unnoticeable to users and not so different from the applications that are used today.

2.4.4 Disrupting one's own business

What businesses may find challenging in blockchains in the beginning is disrupting their own business models in the early implementations. This partly relates to the lack of knowledge about the technology and to the lack of standards. It is more likely that the early implementations replicate existing processes, but don't take full advantage of the technology's benefits. On the other hand, in the beginning it might be better that the projects are smaller and help in getting familiar with the technology. In the beginning, the targets should be relatively easy to reach, but gradually as the knowledge and concrete skills build up, it is easier to jump into more ambitious projects. But as the projects grow and become more ambitious, it will require the businesses to question the status quo and for example look into business process reengineering. (Mougayar 2016.)

2.5 Supply chains

Supply chains have existed for centuries and gradually evolved into the form and concepts we are familiar with today. As before supply chains were mostly internal within a single company, today more and more supply chains are networks comprising of several parties that participate in the process of designing, producing and delivering a good or a service from a point of origin to the point of consumption (Hugos 2018, Prater & Whitehead 2012). Supply chains provide a business with what it needs in order to thrive. Every company is part of one or more supply chains and plays a specific role in them. There are several definitions out there for supply chains, one by Chopra and Meindl (2015) being:

> *"Supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers and the customers themselves." (Chopra & Meindl 2015).*

Before supply chain management became a popularized concept, businesses used terms such as logistics and operations management. Traditional logistics differ from supply chain management in that it refers to activities taking place within a single organization, such as inventory management, material acquisition, production, transportation, packaging and delivery. Supply chain management coordinates the actions of network of companies in producing and delivering a good or a service to the market. Supply chain management acknowledges the same activities as logistics, but in addition involves marketing, product development, finance and customer service. (Hugos 2018, Gunasekaran & Ngai 2004.)

Hugos (2018) defines the five major supply chain drivers to be production, inventory, location, transportation, and information. Production refers to the supply chain's capacity to produce and store goods. Inventory occurs in multiple spots in the supply chain and includes products of many stages: raw materials, unfinished and finished products. Inventory can be constituted for example by manufacturers, distributors and retailers. Location driver is based on the geographical whereabouts of the supply chain network. Transportation driver, closely related to location, refers to the movement of products of every stage between supply chain locations. Transportation can be organized in several different ways, most common ones being ship, rail pipelines, trucks, airplanes or electronic transport. Transportation means are organized starting from the most efficient and ending in the most responsive way. Location and transportation drivers both balance between responsiveness and efficiency. In location planning efficiency may be emphasized by centralizing and having less facilities or on the contrary responsiveness can be emphasized by decentralizing and having more locations near customers and suppliers. Supply chain routes are then planned based on the chosen transportation means and the location of supply chain facilities.

The information driver in supply chains is the basis for decision-making relating to other four drivers. Information connects activities and operations in all the areas together. The stronger the information connection between the areas is, the better is the ability of a certain supply chain participant to make decisions on their own operations. The better the decision-making ability of a single supply chain party, the better tend to be the effectiveness of the entire supply chain. Information has two main purposes in supply chains: the coordination of daily activities and forecasting and planning for the future. (Hugos 2018, 10-18.)

The structure of supply chains has changed considerably over time. In the industrial age, when markets used to move much slower, companies attempted to own as much of their supply chains as possible. This kind of vertical integration is efficient, but slow in reacting to the varying customer demands. In today’s fast-paced and fragmented markets many companies aim to concentrate on their core competencies in the supply chain management and outsource the rest. This approach lets the company do what it knows best and react to changing customer demands swiftly. Focus in a specific area helps in remaining competent. Supply chains in fast-paced markets resemble more of ecosystems of companies working together and performing the activities needed in supply chains. Figure 7 illustrates the structures of vertically and virtually integrated supply chains. (Hugos 2018, 21-23.)

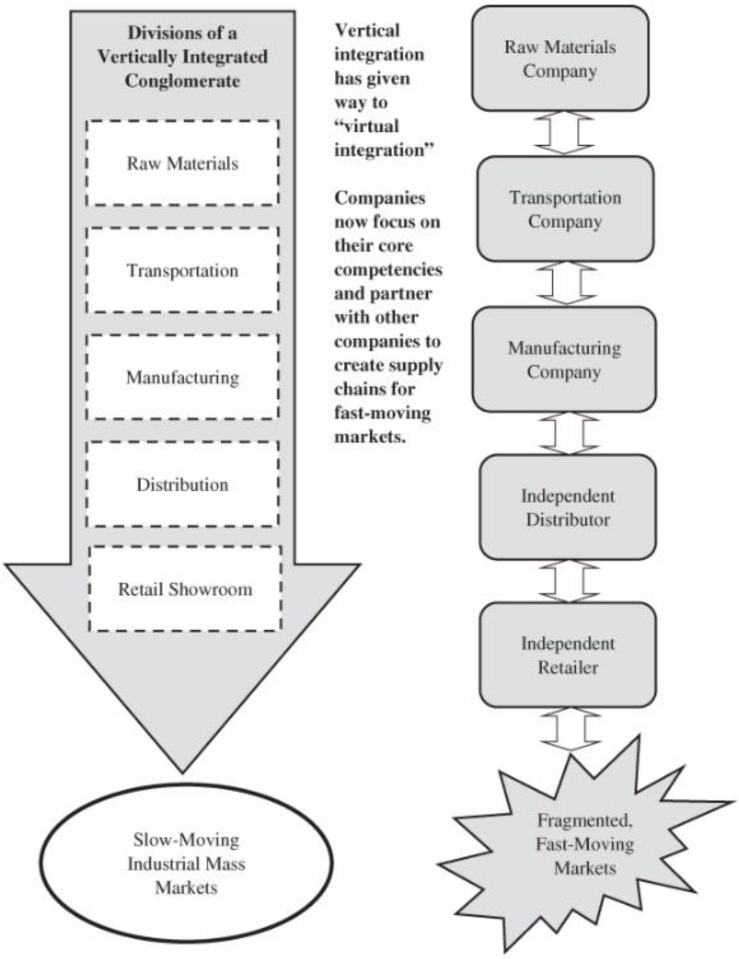


Figure 7 Supply chains in the slow-moving markets versus fast-moving markets (Hugos 2018, 21).

2.5.1 Supply chain management and the bullwhip effect

If supply chains are influenced by the five supply chain drivers, then supply chain management is the coordination of these drivers and activities they involve. The goal of supply chain management is to coordinate the activities in a way that optimal balance between responsiveness and efficiency regarding market demand is achieved. (Hugos 2018). Essentially supply chain management aims to ensure the satisfaction of end customers (Drake 2012).

The coordinative actions of supply chains derive from the bullwhip effect which has been recognized in many supply chains and different types of markets. The phenomenon has been recognized and studied in supply chain management research since the 1960's (Lee et al. 1997). In the bullwhip effect the changes in customer behavior and fluctuations in demand at the downstream supply chain (supply chain participants that are closer to the customer) tend to lead to exaggerated demand forecasts at the upstream supply chain (supply chain participants in the back of the supply chain) (Lee et al. 1997, Hugos 2018, Drake 2012). This effect leads to a distortion in a supply chain's information. The five major factors contributing to the bullwhip effect are demand forecasting, order batching, rationing game, pricing and performance incentives (Hugos 2018, Lee et al. 1997). The understanding of these factors is required to effectively coordinate the supply chain.

Demand forecasting based on a single participant's order data will result in a distorted demand picture, and therefore it should be done using a single source of demand information shared with all participants. Point-of-Sales data is an important indicator and by sharing with all participating companies makes forecasting easier and more accurate for everyone.

Order batching occurs when companies order large amounts in longer intervals to cut order and transportation costs, but this way the inventory won't meet the actual demand. Therefore, it is more beneficial to order in smaller and more accurate amounts in shorter intervals. In many cases ordering costs can be cut by using relevant information systems and transportation costs by outsourcing to a third-party logistics company.

Rationing game results from a situation where demand exceeds supply and manufacturers must choose how to allocate the available supply between the distributors. To have their product demand fully covered, distributors and retailers may order larger quantities than in reality is necessary. To avoid rationing game the manufacturers can make rationing decisions based on past orders instead of present ones. Distributors can also inform their customers about upcoming shortage, preventing product shortage from surprising the customers.

Varying prices also affect the demand fluctuations and add to the bullwhip effect. Special prices and sales lead to customers making purchases earlier than they would without a discount (forward-buying). When the customer feels they can get the lowest optimal price for the product at any time, their purchasing behavior is not based on the frequent promotions.

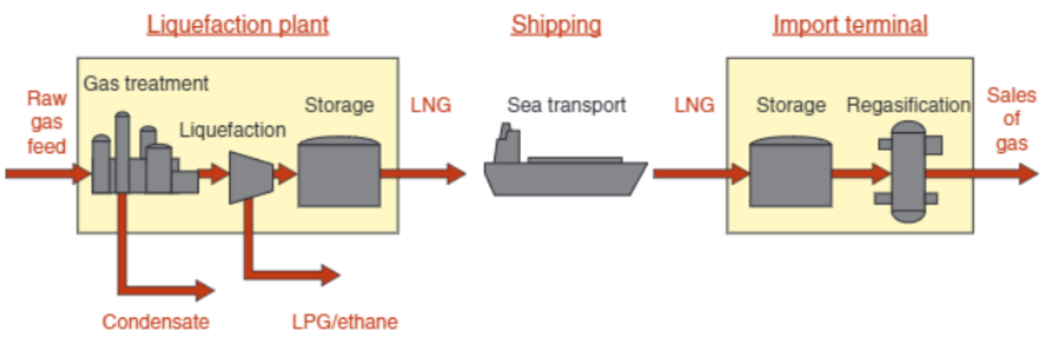
Performance incentives vary depending on a company. The problem with performance incentives is that individual companies and workers may see their job separate from the rest of the supply chain while reaching for the targets. If certain objectives are rewarded, they may be reached at the expense of other company or supply chain objectives. Sales related objectives may be reached by additional discounts, which also relate to the above-mentioned price variance factor.

All of the factors causing the bullwhip effect stem from a participant trying to be as efficient and effective as it can be as a single unit, and the supply chain as a whole ends up becoming ineffective. This can also happen with a single business line within a company. The information distortion especially affects the manufacturers and the upstream supply chain parties. The key to the efficiency of the entire supply chain is in the collaboration of all parties and the integrity of data (Lee et al. 1997, Hugos 2018).

2.5.2 LNG supply chains

There are many kinds of supply chains and LNG supply chains are very different compared to those focusing on the creation of consumer goods. LNG supply chains can be roughly divided into two categories: large-scale and small-scale supply chains. Large-scale LNG supply chains refer to the global LNG supply chain and to the big size of the transportation means, such as ships and pipes. Small-scale LNG supply chain on the other hand refers to the local supply chains and ships and transportation means smaller in size.

The LNG supply chain consists of three main phases illustrated in figure 8: liquefaction, shipping and regasification. The LNG supply chain begins at the offshore gas reservoirs where the natural gas is drilled and produced. From the offshore reservoir the natural gas is piped to an onshore treatment plant where impurities and liquids are removed from the product. Liquefaction phase includes the cooling down of the gas to the temperature of -162°C, causing it to condense into a liquid form. Liquefaction is an important phase, because in a liquid form natural gas takes up 1/600th of the space compared to the gaseous form, making it easier to store and transport. Transportation of LNG requires specific LNG carriers, which can be for example ships and trucks. Before being distributed to consumers, LNG passes through regasification terminal where it is turned back to its original gaseous form. (Sakmar 2013, 32.)



Source: GIIGNL, Information Paper 2 – "The LNG Process Chain"

Figure 8 LNG process chain (Sakmar 2013, 33).

The liquefaction process starts with purifying the natural gas from several compounds and gases such as ethane, butane, propane, carbon dioxide, sulfur, water, oil and other substances. Because the composition and the characteristics of natural gas around the world vary a lot, the buyers of LNG usually need to specify ranges for different components and heating values they can allow in use. Liquefaction takes place when the natural gas is cooled down to the temperature of -162°C, allowing easier storing and transportation. Because pipelines can't possibly reach some difficult or remote locations, or geopolitical tensions prevent their construction, different transportation methods are needed in the distribution of LNG. Shipping of LNG is made by carriers like ships and trucks especially made for the LNG transportation that can maintain its cryogenic temperature. Ships and trucks allow more flexibility in the transportation and accessibility from and to harsh or remote locations. The last phase of the LNG supply chain is regasification, during which the transported liquefied natural gas is returned to its gaseous state and delivered to the end users via domestic pipelines. (Sakmar 2013.)

3 RESEARCH METHODOLOGY

This chapter describes the empirical part of the study, which includes the introduction to the research process, use case description, data collection and analyzing methods, organizational context where the study has been conducted and reliability, validity and ethics of the study.

The structure of this chapter has been partially adapted from Saunders et al. (2003). The research design is explained using a research process 'onion' (figure 9), which assesses layer by layer the approach to how the research questions are answered. The first layer on the outer edge is the research philosophy, which defines the way the researcher understands the development of knowledge. The second layer, the research approach, indicates the way theory is defined. The third layer, research strategy, offers a general plan or guidelines on how to carry out the research. The fourth layer indicates the time horizon of the study, whether it is a snapshot-like cross-sectional study or diary-like longitudinal study. Finally, in the center is the last layer, that assesses the data collection methods. Justifying each layer in relation to each other, the whole research process can be appropriately aligned. (Saunders et al. 2003.)

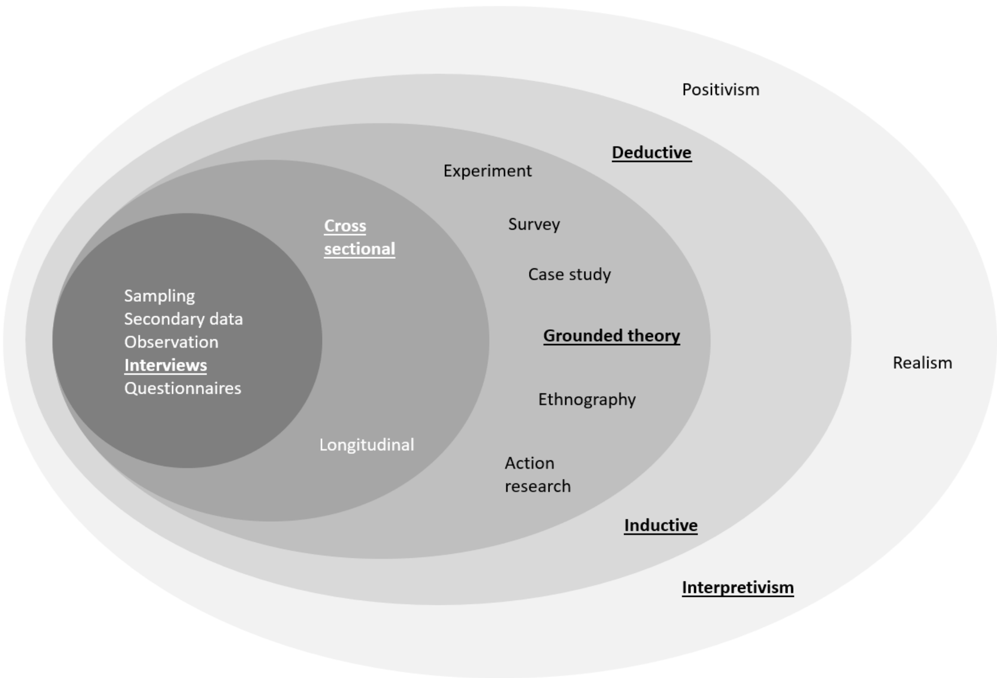


Figure 9 Research design based on Saunders et al. (2003).

3.1 Research philosophy

In research literature, the epistemology underlying the research process often falls under three views: positivism, interpretivism or realism. All of these research philosophies are distinct from each other and affect the way knowledge is being constructed and evaluated during the research. (Saunders et al. 2003, 83.)

Positivism has its roots in natural science and therefore emphasizes observing the social reality in an objective manner. The end product of positivist research may be generalizations from a sample to a population or increasing predictive understanding. In order to reach replicable results, positivist research emphasizes highly structured methodologies, quantifiable measures, formal propositions and hypothesis testing. (Orlikowski & Baroudi 1991, Saunders et al. 2003, 83-84.)

Interpretivism on the other hand views phenomena as complex and unique, and that the richness of detailed insights is lost if complex issues are being reduced to a generalized level. Interpretivism recognizes that people have different interpretations of different situations and interactions which motivate them in their actions. Interpretivist research aims to make sense of phenomena through the subjective insights of the research participants. (Saunders et al. 2003, 84.)

Realism assumes that reality exists independent from human thoughts and beliefs but there are social forces and practices that influence people's behavior without them noticing it. Although realism shares some of the objective views of positivism, it also recognizes that human behavior can't be purely studied and observed from the external point of view. Therefore, in addition to objective reality, realist studies also emphasize subjective reality in understanding of phenomena.

In practice, the research does not necessarily follow only one specific philosophy, but can have a mix of positivist, interpretivist and realist stances. Before it used to be more common for information systems science research to lean towards positivist view but nowadays the interest is more in interpretivism and studying information system complexities in a nuanced and open way (Goldkuhl 2012). Because the business environments are comprised of humans and their interactions with information systems, subjective reality and complex cultural contexts are also important to consider. This study emphasizes interpretivism but acknowledges how the objective reality influences and constrains the human behavior and the perceived subjective reality.

3.2 Research approach

The research approach is often classified as either deductive or inductive. The difference between deductive and inductive approaches are distinguished by the way the theory is defined in the research. Deductive approach begins with the development of theory and hypotheses, and the hypotheses are tested through the empirical data collected and analyzed. Inductive approach, contrary to the deductive, begins with data collection and the theory is developed based on the empirical data collected and analyzed. Deductive approach is usually associated with positivism and inductive approach with interpretivism, but there are no clear boundaries defining the underlying philosophies. (Saunders et al. 2003.)

Research approach can also be classified as quantitative or qualitative. Quantitative research emphasizes earlier theories and results of research, hypotheses testing, concept definition, quantifiable data collection methods, sampling and statistical analysis. Qualitative research on the other hand emphasizes the comprehensive description of a complex real-life situations and phenomena and the subjective views people have on it. Both qualitative and quantitative research methods can be used in answering 'what' and 'why' questions, but qualitative research puts also more emphasis in answering 'why' questions. (Hirsjärvi et al. 2004, Myers & Avison 2002. Saunders et al. 2003, 248.)

Qualitative and quantitative approaches are often compared with each other and some might argue that quantitative research is more scientific and generalizable and therefore more reliable than qualitative research. Both approaches however have their distinct uses and no approach is better than the other. Quantitative and qualitative approaches can also be used within a single research to complement each other and increase reliability.

For the purpose of this study, it is meaningful to emphasize a hybrid approach of both inductive and deductive paradigms and the qualitative approach in data collection and analysis. The research topic of blockchains in business environments is fairly new, and no single standardized model or theory exists yet. It is also necessary to map out and find the characteristics of the specific field of LNG supply chain management. The research also emphasizes the perspective of end-users, clarifying why blockchain would benefit LNG supply chain management and propose a model how it could be implemented. Therefore, by observing the objective reality and gathering data that represents the subjective experience of the users, new model is developed partially inductively, partially deductively.

3.3 Research strategy

The research strategy employed in this study is grounded theory. Although grounded theory is often referred to as a purely inductive approach, it actually combines both inductive and deductive approaches. Research based on grounded theory begins with data collection and theory and hypotheses will follow that data. The collected data generates predictions or interpretations, that will be tested and confirmed again through subsequent data. This continual checking between empirical data and theory allows the researcher to construct and ground the new theory systematically in data gathered. Grounded theory acknowledges theoretical background related to the topic, but the researcher is able to set them aside if necessary to give more emphasis for the data from the field. (Charmaz & Belgrave 2015, Locke 2001, Martin & Turner 1986, Saunders et al. 2003, 93.)

Regarding the research topic of blockchains, grounded theory enables the theory building upon real-life observations and interpretations. In order to settle the right hypotheses, it is important to first comprehensively understand the field studied and the complex real-life situations the potential end-users face in their business. This way the developed model also responds more effectively to the needs of the specific field of business.

Due to the limited time-horizon for data collection and the novelty of the technology, this study is cross-sectional, meaning that it studies a specific phenomenon in a specific moment in time. This study provides a snapshot of the current state of both blockchain technology and LNG supply chains and aims to describe how the phenomenon affects the field. Furthermore, this study is exploratory, meaning that the aim is to explore the research topic to find out what is happening, ask questions from experts and designated interviewees, and based on gathered information assess the phenomenon in a new light. (Saunders et al. 2003.)

3.4 Use case

Assuming not all interviewees participating in the research are familiar with the blockchain technology or its application in industrial settings, a preliminary use case was created to support the interviews. The use case was intentionally crafted as a loose framework that could be tailored for each participant’s industry and allows adding and detaching functions. The use case was presented, and concepts introduced in the beginning of each interview session. The use case is based on material gathered and examined during the literature review and current blockchain technologies available. Figure 10 illustrates the system on a high level. The blockchain network described in the use case has following features:

- In this outline the network only shares data about physical energy transfers, no financial information. The information about energy transfers contains fiscal volume and energy value. The network is its own separate and secure process for sharing data between companies.
- LNG blockchain network consists of 3-6 companies being constantly connected to the network and sharing energy transfer data between each other.
- Companies could be each other's customers, competitors, or part of the different stages in the same supply chain.
- The data companies disclose with each other includes energy volume, quality and value. Once a new transfer is proposed, it is collectively validated by the network (with digital signatures) and included in a new block, that is then included in the blockchain ledger.
- The blockchain ledger is distributed to all participants and always kept up to date. Information tampering is prevented, because change in one piece of information would require changing every participant's copy of the ledger.
- Smart contracts will be used to define business processes and transaction logic between participants.
- The platform enables communication between participants.
- Light clients, such as mobile devices can be added to the network. They interact with the blockchain via connection with the full nodes.
- As a result, transparent and secure supply chain is achieved within designated network members. Private data is possible to protect using channels and cryptography.
- Network-effect enhances the roles and trust building between participants.

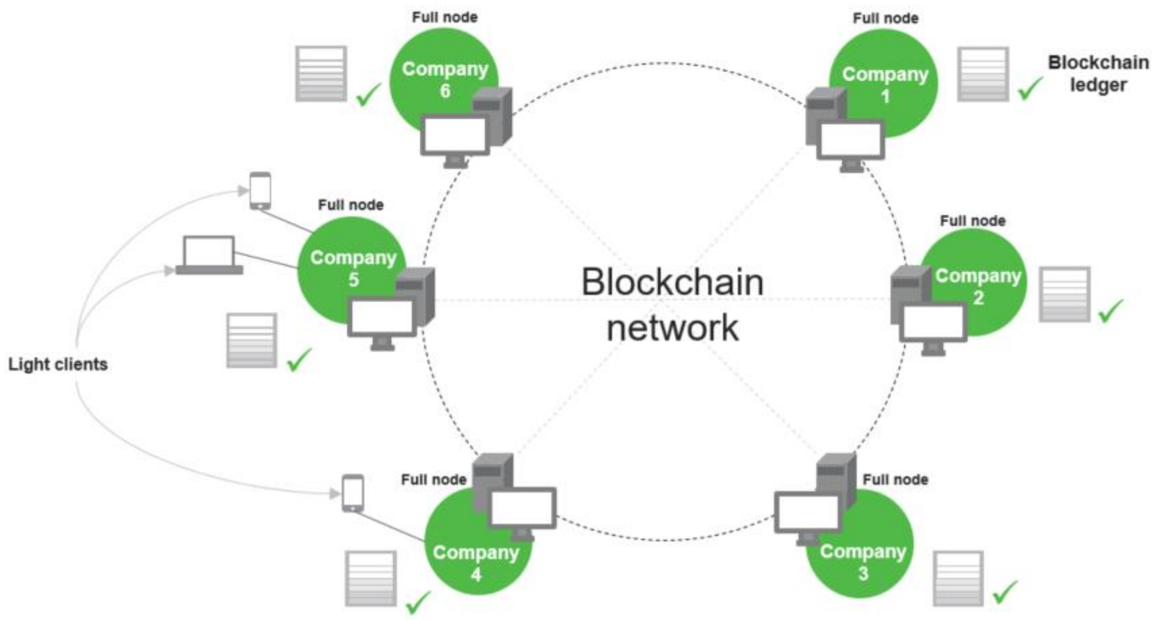


Figure 10 Preliminary use case created to support the interviews.

3.5 Data collection and analysis

3.5.1 Data collection

Semi-structured interviews were chosen as a data collection method, because they allow a partly structured framework, but it is possible to delve deeper in topics and let the interviewee add in their own experiences at any point of the interview. The participants were chosen based on their knowledge on the field and the software product used in this study. The purpose of the sample was to represent participants that are intentionally chosen, knowledgeable about the field of LNG and have diverse perspectives on the topic. Due to the prerequisite of knowledge and expertise on the field, a random sample was not appropriate to use in this study. (Hirsjärvi et al. 2004, Kallio et al. 2016.)

The data used in this study consists of interviews from 8 experts. The first three were internal interviews and the rest were from external participants. The interviews were conducted during the end of April and the beginning of May. The length of interviews varied from around 20 minutes to two hours. Almost all interviews were conducted face-to-face, either at a Valmet office or at an LNG conference organized in May 2019. Exceptionally interview number 4 was conducted on a Skype call. Two group interviews were conducted with participants 5 and 6, and participants 7 and 8.

The persons interviewed for this study are listed in table 2 and referred to as Interviewees 1-8 (I1-I8). The first three interviews were internal Valmet participants, and the rest were participants from an Eastern European terminal and different trading companies operating in the Nordics and the Baltic countries. Out of all eight interviewees, one is female, and the rest are males. Participants' gender was not perceived to have a significant effect in the answers.

Interviewee 1 is a product architect at Valmet. He is a designer and a problem-solver that sees as one of his most important skills, that he can go to previously unknown spaces and business environments and find suitable solutions for the customer's problems. He believes that every existing solution can be improved, and problems should always be observed from the end-user's perspective. He believes that the added value in business comes from customizing the solutions to fit the customer's business model.

Interviewee 2 is a project manager at Valmet. He has worked in his current position since November 2018. He has made a long career in paper business and quality reporting systems as a R&D project manager. Before joining his current team, he has lead development projects related to Valmet DNA automation system and internal virtual platforms for R&D, operations and services.

Interviewee 3's title is a lead engineer, but he hasn't started working in the described position yet at Valmet. To date he has been working with projects related to Integrated Operations software, because he has experience of similar development projects from the past. The current tasks have been related to investigation of project integrations and securing connections between AWS cloud and Valmet's process calculations and reporting system.

Interviewee 4 is a production engineer working at a gas distributing company in Finland. His business unit is concerned with the traffic and distributing compressed biogas to the gas stations that are used by both trucks and passenger cars. Even though his business unit is mostly concerned with compressed biogas, LNG is also distributed in their infrastructure and some of the stations.

Interviewee 5 is a head of commerce at a trading company operating in Eastern Europe. He was simultaneously interviewed with the interviewee 6, who is a head of business development division at a terminal operator that also resides in Eastern Europe. The trading company is also a user of terminal's services.

Interviewee 7 works as a business development project manager at the same terminal and infrastructure operator as the interviewee 6. He develops all commercial activities for the terminals and works directly with gas traders. Simultaneously interviewed Interviewee 8 is a sales director at a trading company that operates in the Nordics and the Baltics. Interviewee 7 and 8 are also each other's customers, when the trading company needs to use the terminal for gas trading.

Table 2 List of interviewees.

	Participant title	Background	Date
I1	Product architect	Automation provider	25.4.2019
I2	Project manager	Automation provider	26.4.2019
I3	Lead Engineer	Automation provider	29.4.2019
I4	Production engineer	Distributor	3.5.2019
I5	Head of commerce	Trading company	7.5.2019
I6	Head of business development division	Terminal operator	7.5.2019
I7	Project manager	Terminal operator	8.5.2019
I8	Head of business unit	Trading company	8.5.2019

During the interviews the question guide (Appendix 1) and follow-up questions were modified slightly depending on the interviewee's background and perspectives they chose to emphasize. In the beginning of the first interviews the participant's own supply chain perspective was focused, but it soon was noticed that it is better to begin with the introduction to blockchain, because it gave the interviewees more time to digest, most of the time, a new topic for them and then reflect it on their own experiences. After all the eight interviews provided a rich and detailed data, collectively approximately 90 pages of text from transcribed audio records.

3.5.2 Data analysis

After the interviews were conducted, the data was analyzed with qualitative analysis methods. The research themes had been already drafted for the semi-structured interviews, but they were further defined in the analysis stage. The analysis began with carefully reading through and studying the interview results. After internalizing the collected material, the data was coded and organized around emerging concepts. Based on the emergent concepts, relevant categories were formed. The final steps in the analysis included recognizing patterns and linkages between the categories and finally based on them interpreting the data and drawing conclusions from it. Characteristic for the grounded theory, every phase of the analysis included constant comparison between the data and developed concepts, categories and models. Figure 11 illustrates the steps taken in the data analysis.

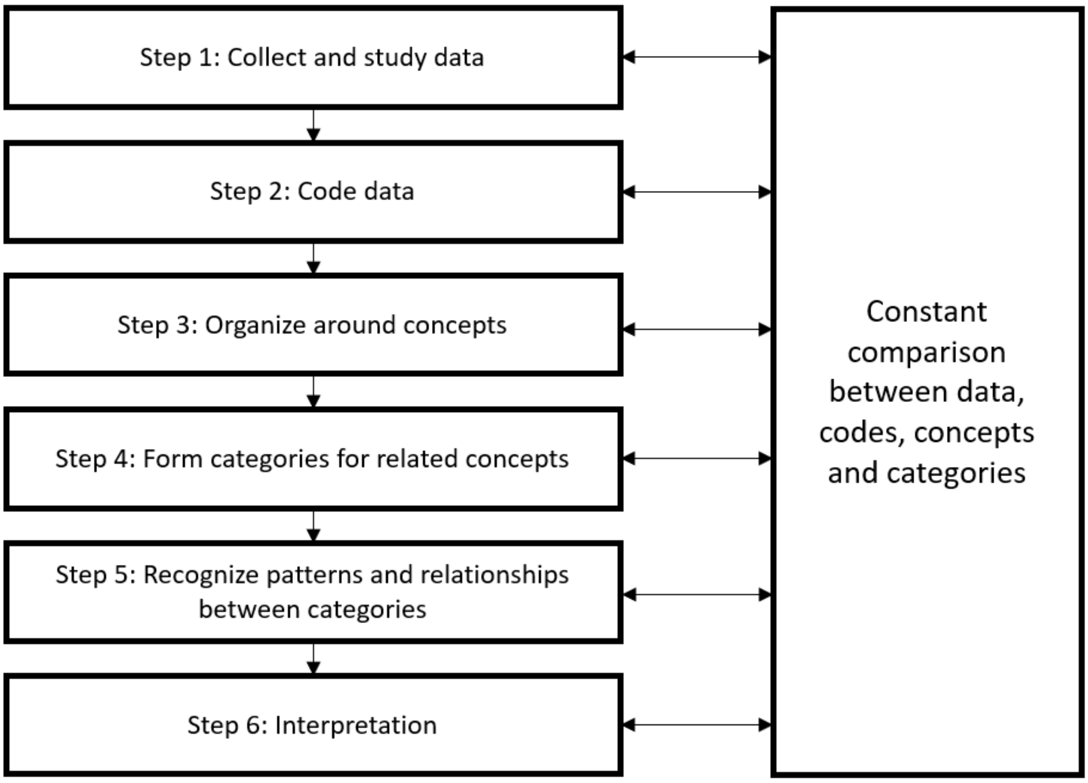


Figure 11 Steps included in the data analysis.

3.6 Organizational context

This study was conducted as a commission for Valmet, a global developer and supplier of technologies, automation and services for the pulp, paper and energy industries. Valmet has a head office is located in Keilaniemi, Espoo, Finland, and there are approximately 13,000 of Valmet's employees around the world. Valmet's automation solutions range from single measurements to mill wide turnkey automation projects.

The software product examined in this study is called Valmet DNA Integrated Operations, which combines, controls and monitors information for all LNG supply chain members. Integrated Operations covers the entire LNG supply chain, including terminals, bunker vessels, cargo ships, industrial terminals, loading and unloading. (Valmet Oyj 2019.)

3.7 Reliability, validity and ethics

This research aims to take into account reliability and validity during the entire research process. Reliability and validity indicate that the research is designed, and the conclusions laid out in a manner that bear close scrutiny. Reliability of a research or a measurement means its ability to give repeatable and precise results. Reliability can be enforced by several external observers coming to same conclusions as the researcher, or for example repeating the research process several times successfully with equivalent results. Validity of research means that the measurements and findings are correct and correspond to their intended purpose and reality. Validity can be observed from several different perspectives including validity of predictions, research design or structure. (Saunders et al. 2003, 100-104, Hirsjärvi et al. 2004, 216-218.)

The evaluation of reliability and validity were originally developed within quantitative research, and therefore cannot be adapted as they are in the evaluation of qualitative research. Reliability and validity of qualitative research is usually seen more complicated, as many qualitative research strategies include unique situations and subjective portrayals that are not necessarily replicable. The flexibility of semi-structured interviews also poses challenges to reliability and validity. In qualitative research reliability is enhanced by the detailed description that takes place in all stages of the research process. The author has attempted to be precise in describing the circumstances in which the data is collected, locations and conditions in which interviews are conducted, timeframes, possible distractions, misinterpretations in the interviews, and self-evaluation. All information gathered during the interviews has been systematically recorded and stored. (Hirsjärvi et al. 2004, 216-218.)

Ethics and trustworthiness have been considered throughout the whole research process, from research design to data collection and analysis. Participant privacy and confidentiality have been guaranteed by anonymizing and removing personally identifying information from the collected and stored material. The participant’s approval to participate in the study was requested face-to-face or in advance either by an email invitation. For the author the whole research process has required staying objective and avoiding any personal or professional bias during data collection and analysis, by making sure no subjective intentions constrain what kind of data is collected and objectivity is maintained while analyzing the data and reporting the conclusions.

4 RESULTS

4.1 Overview of the results

The interviews opened up the reality of LNG supply chains in many different ways. The interviewees' insights are representations of their subjective views over their businesses, but after the analysis and examining the material all together, it was possible to recognize interrelations between the topics that emerged during the interviews. Overall, three specific themes could be recognized from the data: the current state of LNG supply chains, the relevant information in the network, and knowledge on blockchains. The relationships between categories are illustrated in figure 12.

Each interview provided a lot of new insights in the current state of LNG supply chains. The interviewees described the supply chain participants and challenges, communication methods, interconnectivity and the big picture. The relevant information for LNG supply chains was also explored during the interviews. Even though technical data was considered useful, also other blockchain uses were suggested such as provenance tracking and documentation handling. One of the stronger themes that was possible to recognize from the data was the scarce understanding of blockchain technology and concerns relating to it. Overall the topic raised many questions from the interviewees and doubts whether they can discuss it in detail or consider its potential. Many interviewees however had an idea about the basics of blockchain and its principles.

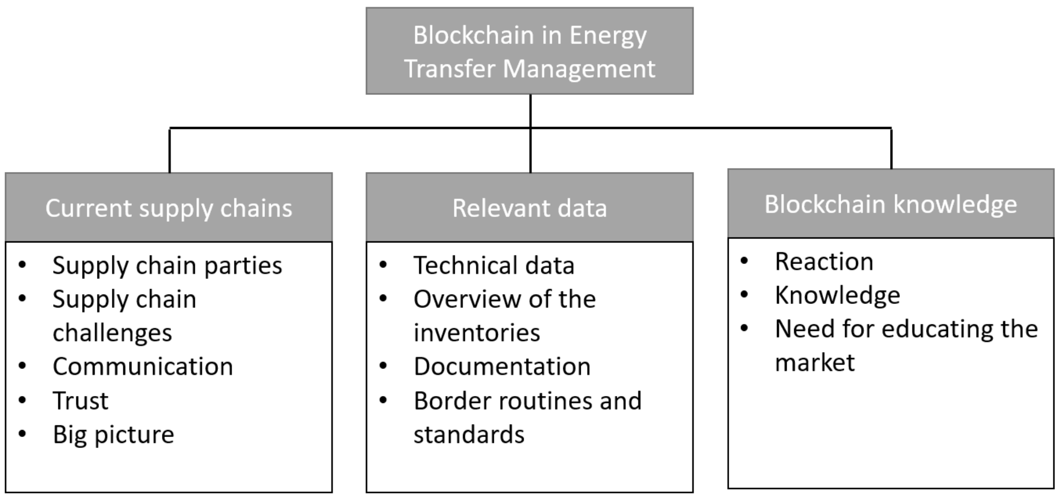


Figure 12 Overview of the results.

4.2 LNG supply chain networks currently

During the interviews the participants were asked to describe the current state of LNG supply chains and the practices and standards that are in use currently. As a result, the current LNG supply chains were discussed from several perspectives: issues originating from the nature of the transferred product, length and complexity of the supply chain, challenges of integration and interconnectivity between existing systems, current communication tools, relationships and trust in the network, and the big picture of the supply chain, to mention a few.

One of the biggest influencing factors in the LNG supply chain networks is the changing quality of LNG. The liquefied form provides an efficient way to transport the gas, but compression is a better way to store it. LNG is difficult to store for long periods of time, because it boils while not being used and the boiling of LNG leads to changes in its quality. This quality information is of utmost importance for the supply chain participants, because if the transported LNG doesn't meet their pre-defined specifications, they might not be able to use any of the gas. If an end-user has a chance to decline the transported LNG that doesn't fit their specifications, a trader who sold it for them needs to find a new user for the gas. Overall, if there are a lot of delays and the quality goes down, it means a lot of costs for the supply chain participants. Most of the time it is also difficult to determine who will take the responsibility in case of problems with the quality. This adds to the complexity of the network.

> *"And this is information or let's assume that the quality changes on the way, and the customer has his specifications. So, if the customer has a possibility to refuse, to take the LNG. So that information is of course very important. You know to... to have that information early as possible… Now that we have a quality problem, we need to check it with a customer if they accept it. If they don't accept it then we have to relocate load somewhere. Then we can take it to somebody who can use it." – Interviewee 8*

The interviewees were asked to describe the LNG supply chains in general and the players participating in it. In general, the supply chain participants according to the interviewees are:

- Producers
- Liquefaction plants
- Distributors

- Terminals
- Traders
- Transportation
- End users

Interviewee 7 described that the small scale LNG supply chain itself can be quite complex, for example starting from liquefaction plant to a ship, a terminal, another ship, a terminal, a truck, and then the end-user. Most participants are individual operators and there is no automated way to exchange information. The long supply chain coupled with the changing nature of LNG makes it extremely important for the users to have up-to-date information and be sure that once they receive the LNG, it matches their specifications. Currently, if an operator needs information about the quality before receiving it, they need to request it from the other players. At that point, it is up to the trust and relations between the players, if they can disclose information between each other. Therefore, most of the time the information about the volume and quality reaches the users at the same time as a new LNG load arrives to them.

> *"Also, the supply chain itself is quite long. There is liquefaction plant, ship, terminal, then there might be another ship, then again terminal, then a truck, then the end user. And that end user wants to see for example the quality of the shipped LNG. So how does he get the quality when he doesn't have the equipment to measure. So that equipment is usually at the terminal, and terminal sends this information..." – Interviewee 7*

It was surprising to hear in the interviews that the level of trust is considered to be quite high in the network and many contracts are made also based on trust. Interviewee 1 emphasized that the players in LNG networks are doing pioneering work in their field, and therefore the trust between participants must be high. Due to previously described situations, such as LNG quality going down and becoming unusable, sometimes the supply chain participants help each other with figuring out where to locate a load and who can storage or use it. This kind of collaboration however requires very good relations within the network participants and readiness to return favors if a partner that helped you out in turn runs into trouble. Due to the increasing competition in the field, the trust is also existing only between established partners, not throughout the whole network.

> *"In my opinion the level of trust is surprisingly high. They trust that some trade just continues. It is like, "I took care of this difficult situation, so you will help me out when I have a difficult situation." I was surprised that*

this kind of arrangements are done and there is a will to build business models upon collaboration like this." – Interviewee 1 (Translated from Finnish)

"For example, if you are in good relations with the supplier or terminal, then you can provide and get data instantly. But if your relations are more or less official, then you might struggle, and this is the matter." – Interviewee 5

The integration of systems was brought up in both internal and external interviews. Current systems are built in a way that they mostly only cover one company's data and share that data only within the company's borders. Any information to external participants is passed via traditional communication tools, such as phone or email. Many documents are handled in a paper form. Participants 1 and 7 explained that practically any tool can be used to pass information. Interviewee 2 mentioned specific communication systems that the companies use. To get information from another company or operator takes time, because one must search for the right person to give the relevant information.

"... So should we be somehow able to check what was a problem with the quality in a real time, it would be very helpful. But otherwise we spend like half a day calling, searching for a right person to talk to who accepted the cargo and telling what was wrong..." – Interviewee 7

The interviews created an impression that data and interconnectivity would be important in the strategic planning and effective co-operation in the supply chain, but on the other hand many participants are highly protective of their data and felt that disclosing information could possibly harm more than benefit them at the end of the day. Therefore, even though a system that provides interconnectivity is needed, it still must be quite closed and limited to protect each participant's own data, with an option to share pieces of information with trusted business partners. Too much openness is seen as intimidating.

"... Yeah but if I know what... who is, and when is and... what volumes are scanning to... I can analyze the data and see what's their capacity. And what the volume was sold... To whom sold and who provided that. It's technical data but it's very relevant for me." – Interviewee 5

One constraint when talking about new technologies in the process industry is that the companies can be quite conservative. The operators mostly are interested in doing their own part, their own core business. Most LNG supply chain participants may feel comfortable with the traditional ways of exchanging information, and don't necessarily see a reason to adopt new technologies. The interviewees brought up that if there already exists a way to communicate and exchange information, the new method must be justified well and bring obvious benefits for the users. In the case of blockchain, the network of companies must be quite large, so it would require engaging a large group of companies in adopting the system. Also, if a new technology requires more or the same amount of work and inputting information, it is unlikely that the adoption will happen.

When asked about the big picture of LNG, participants mentioned that there is no necessarily an overall LNG big picture. The field is quite fragmented and is considered to consist of individual parties. Depending on the supply chain party, some may be more interested in the whole chain's information whereas others may be interested only in their own part of the chain. Interviewees 1, 2 and 3 especially brought up that some supply chain parties have a stronger interest in data, and therefore have a bigger role in setting up the systems needed for it. Other parties may find it hard to be motivated to use the systems, because the benefits are not equally important to everyone. In LNG supply chain the party responsible for transportation was mentioned as the one that most commonly is interested in delivering a good from point A to point B, and information about where the good is headed after their part is not relevant for them. The information about the big picture more likely interests the players with most power, which also creates an imbalance in the network. In order to get the big picture, all participants should be engaged in the network.

> *"Then there are the different players, so how do we get them to work together. How can we engage a single party in operating in the chain."*
> *– Interviewee 3 (Translated from Finnish)*

4.3 Relevant information and benefit of sharing data

In the interviews, in addition to learning about LNG supply chains, the aim was also to recognize what kind of data is needed or already passed in the network. The values taken as an example in the use case, such as volume, quality and energy value, were seen as important, but also some new ideas were suggested by the interviewees. Most of the time, interviewees did not provide one single piece of information that would be more important than others.

One vision for blockchain was that it could be used in modeling the inventory space within several companies. The storage and how transfers are proceeding in the network could help in the creation of the big picture and the overall availability of LNG. This would however require the companies to become completely transparent about their energy transfers within a closed network.

> *”My vision is that this could be used in creating an overview of all the inventories owned by different companies. It would be the valuable information and as such would be an application that many would buy, as long as the beginning group is large enough. It would be the same that is going on already, that the storage space is communicated between companies. It is an issue that has needed a solution for a long time, but the problem is that the companies don't dare to become transparent because not many peer companies are transparent either. But here everybody is in the same situation, so it could be solved.” – Interviewee 1 (Translated from Finnish)*

Interviewee 8 mentioned that one of the most difficult tasks in his work include varying cross border routines between countries and documentation related to that. According to him, a more standardized approach would help the trader's work significantly. Crossing country borders with a load can take from one hour up to twenty-four hours and often times the reason for delays is the documentation. The delays at the border are harmful, as the quality of the transported product can go down.

> *“So if it [the documentation process] could be somehow digitalized, it would be a huge advantage. I mean when the ship is coming to a terminal there's a lot of paperwork… related to that. And also, when we are taking loads we are exporting or importing them, taking across the country borders is lots of hassle and bureaucracy on the border. So, first thing that comes to my mind is if that process could be somehow easier.” – Interviewee 8*

Some ideas on how to use blockchain were completely different compared to the approach introduced in the use case. A couple interviewees suggested that maybe blockchain could be used in verifying the manufacturing process and provenance of the product. As the suggestions go outside the scope of this study, they are not further discussed but noted for future investigation.

In general, the interviewees seemed to consider additional data always useful and that it helps in the strategic planning of the supply chain. However, many doubted whether the companies would be willing to disclose information between one another. As interviewee 1 explained, the companies don't dare to become transparent, because they are not used to disclosing information and not many others in the supply chain are transparent yet either. Therefore, a model based on blockchain, at this point, seems like a very theoretical solution to the supply chain's challenges.

The problem with blockchain's transparency is that the interviewee participants thought that it exposes too much. The interviewees were concerned that if the distributed ledger would provide information about the senders and receivers, timestamps, and some technical data, then it wouldn't put the sharing party in a good situation. At the same time this information would be very useful for the supply chain participants, but it would be harmful in the hands of the competitors. Many interviewees pointed out, even though the original use case included all kinds of network participants including companies that are each other's competitors, that the information sharing must be restricted to trusted partners only.

> *" Yeah but if I know what… who is, and when is and… what volumes are scanning to… I can analyze the data and see what's their capacity. And what the volume was sold... To whom sold. And who provided that. It's technical data but it's very relevant for me." – Interviewee 5*

Interviewee 8 suggested that the information shared on the ledger could be limited in a way that doesn't expose too confidential data. As many participants agreed that the quality information is important, it was suggested that only that piece of information could be shared instead of volumes and energy values. If a value that can be shared with the whole network can be agreed, it would be possible for the companies to become gradually more transparent. The challenge is, how to find the values and information that would be equally important for all participants.

> *"…But if there is some information that the parties could share that could be kind of a… like for example the quality. So that, that part of information could be shared. Not necessarily the volumes, or that kind of stuff. But part of the information that is like not that confidential. Then it could be." – Interviewee 8*

Even if companies could agree on data they can share, it would still be necessary to justify why they should share the data with others and why it would be beneficial to join a blockchain network. As the difference between traditional database and the benefits of using blockchain is debatable, it is still not completely clear why to choose blockchain over traditional database. The one major differentiator of blockchain, which is transparency, may seem intimidating. In blockchains, transparency, decentralization and security are all tied together. Therefore, if one feature is being limited or diminished, it also has an effect on the others.

> *"Of course, it must be justified how constructing a system like this would benefit the customer. Does it provide security? Though current systems are secure as well... Does it provide agility? Or what was it… you said… transparency? So, would that be it, why the customer or a network of customers, would start using this? – Interviewee 2 (Translated from Finnish)*

Interviewees pointed out that supply chain applications are sensitive to the flow of information breaking at a certain point – for example due to an error or unwillingness to input the data, because of which the rest of the participants in the chain won't get the benefits from using the application either. This brings forward the question about how the real-world values are measured and transferred into a digital system. Whenever information needs human input and interaction, there is a higher chance for delays and errors. Keeping up the flow of information could be eased with the use of automation.

4.4 Scarce knowledge on blockchains

An important theme that emerged in all interviews is that blockchain is a new concept for many. Most interviewees had heard about blockchains before, but the knowledge is still on a surface level. Some of the interviewees expressed that they are not very familiar with the technology and therefore feel somewhat uncomfortable discussing it and its potential. Blockchain was also seen as a very technical concept, that would not be visible for the end-users of a system or the business people. Overall, based on the expression received from the interviews, it will still take some time that the market gets educated and informed about the technology.

> *" … Let's say this whole matter is unclear to me, so I can't say whether that vision has that something so the shared information would be equally important for all the participating nodes." – Interviewee 3 (Translated from Finnish)*

> *"For example, for me as a client it doesn't matter, but for my IT system… head of IT systems. Yeah, it matters probably. Yeah that's why I don't feel very comfortable to discuss whether it's good or not." – Interviewee 6*

Even though there is a lot of talk on media about blockchains, many cases and real-world implementations are still somehow related to cryptocurrencies. This can turn out to be confusing for a company contemplating whether they should start using blockchains or not. Association with cryptocurrencies can also hinder the understanding of blockchain uses in different contexts, such as supply chains. Enterprise blockchains are not very well known yet in the process industry, and the companies are confused why to use blockchain-based systems to begin with if something similar can be achieved with traditional database technologies. The difference between blockchains and traditional systems interested many interviewees, and for many it was one of the first questions that they made. Even though the decentralization, immutability and security aspects were brought up in the interviews, they were not probably seen as much more valuable features than the ones that the current systems can provide.

> *"I could not understand yet that what the real difference between blockchain and the traditional thing is." – Interviewee 4 (Translated from Finnish)*

> *"What is the difference between blockchain technology and not blockchain technology?" – Interviewee 6*

Some interview participants were eager to hear answers to more technical questions, some of which are hard to define at this point of the technology's development and may vary depending on a platform. The questions regarded issues such as: How does Bitcoin mining work? How is validation accomplished in the network? Who is accepted in the network as a validator? If there is a need to change the information in the ledger, how does that happen? Etcetera. These questions were followed with several follow-up questions and in many cases, there didn't seem to be enough time to discuss all blockchain related issues. On the other hand, it points out that there is interest towards blockchains and need for simple enough ways to educate and present them.

When telling the interviewees about blockchains, different kind of reactions could be observed. People's reactions towards blockchains seem quite polarized: either very enthusiastic and embracing or cautious and denying. Interviewee 1 mentioned that the topic is very interesting for him and he tends to support blockchains, but therefore he also has a strong bias. The rest of the interviewees had a more neutral stance towards the topic or were more reserved. Towards the end of the interviews most participants, even the most cautious ones, seemed to think there might be potential in the technology after all, but there definitely are roadblocks that need to be managed before real-world implementations could take place.

The costs of blockchain based systems also interested many of the interviewees. Generally, blockchain was seen as another system similar to existing automation systems, which are big investments for the companies. It was also brought up that some smaller operators in the infrastructure probably can't afford to invest in blockchain based systems and would therefore be left out of the network.

> *"What are the costs of such system? Because if I have like five regas stations with small turnover, it's a big question do I have to invest in such a technology because we can do it manually…" – Interviewee 5*

> *"-- it is very seldom I see the opportunity for them to have integrated one system because it would mean that all of them would have to buy the same system and not for everybody this is affordable." – Interviewee 6*

In general, as the interviews proceeded and blockchains were discussed further, the interviewees seemed to open up for the idea, at least in some way. Even though blockchains were seen to have some potential, it was also recognized that the market needs to be educated and that there are still technical questions to be answered before real implementations can take place. It will still take time that the market, companies and individuals become comfortable with talking about blockchains.

> *"So, it's very useful but you need to educate the market in order to accept it..." – Interviewee 5*

5 DISCUSSION

This chapter binds together the key findings from the interviews and the existing literature. As the results from the interviews indicate, there are many similarities with the theory and practice in the intersection of LNG supply chains and the blockchain technology. Therefore, the interview results did not provide a lot of surprises.

The biggest difference between collected data and literature is in the perception of supply chains, which is due to the special nature of LNG supply chains. The research on supply chains seems to emphasize the production of consumer goods, which of course differs from that of LNG. Small scale LNG networks are quite new, and currently there are new players entering the industry and the competition is getting tougher. The big picture does not necessarily exist, and it could be difficult to convince all supply chain parties in creating one. The players in the supply chain would find collectively shared data useful but see the transparency as a threat that could be used against them. The creation of big picture is more likely in areas that only consists of few players that have mutual trust, such as in Finland. The interview results indicate that the main focus of the supply chain participants is to serve their customers in a best way possible, which is in line with Chopra and Meindl (2015).

Overall, the LNG supply chains reflect the virtual integration, where each participant focuses on their core competence and the markets are fast-paced. Based on the collected data, the five supply chain drivers: production, inventory, location, transportation, and information, introduced by Hugos (2018) can be observed from the point of LNG supply chains. Out of the five, especially the impact of inventory, location, transportation and information can be highlighted. The inventory driver, and the information about the state of the inventory is important due to the changing nature of the LNG. The geographical location of the supply chain also had an effect on the results from the interviews, because especially in Eastern Europe the competition between the traders is tough compared to Finland, where there is less competition in the market. The transportation driver is stricter compared to description by Hugos (2018) and there is not so much opportunity to choose between efficiency and responsiveness, because of the limited ways to transport the gas. The transportation requires special types of ships and trucks that can maintain the low temperature of the gas. In the location planning it is possible to be more responsive by bringing CNG and LNG stations closer to customer, on the off-grid locations where the gas is transported by trucks.

The information driver is the area where this study and Valmet Integrated Operations is mostly focused. According to Hugos (2018), the information driver is the basis for decision-making in the supply chain, in the coordination of daily activities and planning for the future. The use of blockchain would place in the interconnectivity of different players. Even though information wouldn't be automatically shared with everyone, the players could create channels within the network to share information with their trusted partners and help in each other in the decision making.

The bullwhip effect and the information distortion were touched upon only lightly. In the light of the results, it seems that the information distortion in LNG supply chains result to large extent from competition and that a party sees oneself separate from the rest of the supply chain. According to Lee et al. (1997) and Hugos (2018), the effectiveness of the entire supply chain is highly dependent on the collaboration of the participants and integrity of data. The more participants see themselves as a single unit and are not willing to share data between one another, the more ineffective the whole supply chain will be. This is in contradiction with serving the end customers as well as possible.

The data regarding the blockchains is very much what could have been expected. It was surprising to notice that in general, the interviewees' reaction towards the research topic was quite critical. This could partially be because there is not much information about enterprise blockchain yet available, and most knowledge is based on Bitcoin or cryptocurrency related applications. There is marketing material and lots of talk about blockchains, quite similar to discussion about artificial intelligence, but not yet many real uses cases and benefits to business available. On the other hand, the reaction can indicate the general attitude in the field towards the adoption of new technologies. Currently blockchain is seen as a theoretical solution, that does not have many concrete use cases backing it.

5.1 Why to use – or not to use blockchain

One of the main questions arising from the theory and data still remain, why should blockchain be used in a specific case instead of some of the readily available and mature technologies. Blockchain is nicknamed the trust layer of the internet, but where is such robustly built trust needed? Immutability and security are one of the most important features of blockchain, but the interviewees expressed that the current systems, as they are, are secured as well. Similar concerns are expressed in literature as well, and they are in line with the observations of Wüst and Gervais (2018) among others.

As Wüst and Gervais (2018) argue, similar applications are possible to be built with a centralized database. The traditional, centralized database has many advantages over current blockchains: they have a very high throughput, low latency, and can include a high number of readers and writers. All users are known. The centralized database is a familiar concept to many, both technical and business-oriented people. The centralized databases have less anonymity and don't feature a consensus mechanism. The database is always managed and owned by a central party, that acts as an administrator. The downfalls include that due to centralization, the database can be vulnerable to attacks and because of low redundancy there needs to be up-to-date backups available.

When discussing the features of blockchains, it is necessary to make a distinction between public blockchains and permissioned blockchains. Public blockchains with a large number of users currently have a low throughput and high latency. They are open for anyone to join, and therefore allow a high number of readers and writers that can be completely anonymous and untrusted. The ownership and management of public blockchains is truly decentralized.

Permissioned blockchains on the other hand, have a higher throughput, medium latency, high number of readers but a low number of writers. Permissioned blockchains require identification of the users, and therefore some level of trust needs to be reached for the participant to join the network. The ownership is not necessarily centralized under one owner, but also not decentralized in the same manner as public blockchains.

Even though blockchains can't compete in speed and efficiency with a centralized database, it could possibly unlock opportunities that are not possible to reach with current mainstream technologies. The decentralization of blockchain provides a characteristic that could definitely be interesting to businesses: It provides more fair distribution of ownership and responsibility and gives back the companies the right for their own data and how it is disclosed. Blockchain's immutability guarantees that the data is not tampered with, making sure that no one is replicating or changing the data values. If there is always validated data available, the whole network can plan actions and base their decision-making accordingly. The opportunity for transparency, which is often considered one of the main functionalities of blockchain, currently seems more of a threat for the companies participating in LNG supply chains. In different parts of the world competition is more tough, and therefore open sharing of technical data is not considered possible.

The flow chart (introduced in chapter 2.2.3.) by Wüst and Gervais (2018) is one reference to look at when considering whether a blockchain is usable for one's business use case. If followed, the following implications can be made:

- There is a need to store state
- There are multiple writers
- No online trusted third party available
- All writers are known
- All writers are not trusted
- No public verifiability needed
  - ➔ Private Permissioned Blockchain

The implications are based on the interview results, where there is a need to storage the state of finished energy transfers, there are multiple participants and no online trusted third party available for the interconnection of the participants, all participants need to be identifiable, all participants are not mutually trusting, and there is no need for public verifiability outside the network. Following these implications, the use of blockchain could be argued for.

The public blockchain's main features are decentralization, immutability, trust and transparency. In permissioned blockchain decentralization must be compromised because there will always be some party to authenticate new users and manage memberships. Due to timestamping and consensus algorithm immutability is not necessarily removed but could be weakened. Trust layer is one of the key characteristics of blockchain and will remain whether the used platform is public or private. Transparency naturally is the feature that must be limited the most when used in an enterprise context, due to privacy requirements the companies have.

Blockchains are in an early phase of their development. The companies that pick up the technology now will be the pioneers that are the first ones to benefit from it and on the other hand the first ones to bear the risk of failure. The risks are still quite high as there are no standards and established best practices available, as expressed by Mougayar (2016) and Andoni et al. (2019). But if the company is willing to be the frontrunner in the industry and explore the possibilities, it could be beneficial to start step by step familiarizing with the technology. The companies that pick up blockchains should always remember to justify the use from the point of business and the real-world problems being faced. Just because of the technology itself or as a new form of database won't provide the benefits that the technology is capable of.

5.2 Industry's readiness

One of the most apparent themes that occurred during the interviews was definitely the uncertainty about one's own knowledge about the blockchain technology and what it potentially provides for the users. The lack of understanding can lead to curiosity and urge to learn more but also to resistance to change and denial of the new technology. There was also confusion about how blockchain could be used especially in the context of energy transfers if no financial information is involved. These findings are in line with that of Mougayar (2016).

Even though blockchain as a concept has been around for a decade or so, it has just started attracting attention more widely during the past couple of years. Blockchains have been relevant for businesses and organizations for a relatively short period of time, and there are no established understanding or concrete skills related to blockchains in many organizations yet. Therefore, it will still take some time and gathering knowledge that companies will feel comfortable making strategic decisions regarding blockchains. What is challenging about understanding the concept is that it is fundamentally different from current technologies and requires adapting to a whole new mindset. In order to make blockchains more mainstream and increase understanding on it, companies will need to organize trainings and educate their employees. One way is also by recruiting people knowledgeable about the topic. Open source projects and hubs, such as Hyperledger, offer platforms and tools to experiment with the technology and a community to discuss the topic with. Open source, and collective effort also link with the decentralization principle of blockchains.

It can be difficult for the organizations to see how blockchains could be used in their own specific field. Even though there are industries that are already experimenting with blockchains, the financial industry at the forefront, some industries are more willing to experiment with new technologies than others. The financial industry also has more pressure to exploit blockchains because the disruption threat is bigger than in many other industries. Cryptocurrencies, where the blockchain derives from, also naturally link to the financial industry, making it more relevant for them.

Blockchain integration to supply chain management is represented widely in the literature, in the articles by Wüst and Gervais (2018), Korpela et al. (2017) and Li et al. (2018) among others. In supply chain management, while recording the transfers, blockchains are aimed at increasing the overall visibility and efficiency of the supply chains. Even though there are clear connections between blockchain and supply chain management, there are also open questions that need answers. According to Wüst and Gervais (2018), even though blockchains hide the identity of participants, the ledger data could still potentially leak business critical information, a same concern that was also expressed by some of the interviewees. According to the interviews, current processes and information related to the transfers are mostly paper based and require an employee to record the information in the systems. This poses another problem to blockchain: even though the information is immutable once entered into the system, if filed by a human, there is still a chance for errors and manipulation before entering the system. The interviewees also mentioned that if a supply chain party forgets or refuses to enter data into the system, it will harmfully impact the effectiveness of the entire system.

Because blockchains are essentially about networks, they are very powerful when adopted by a large user base. It is important that when new pilots are planned and launched, that the beginning group is large enough and the participants are committed to the system. This way its success to a big extent relies on how the different parties can be convinced about the technology's benefits and motivated to use the system. Blockchain really is about improving the overall performance of supply chains consisting of several parties, and there is a need to prove how this overall integrity can benefit everyone. A blockchain based system would require collaboration from participating members, but in the process improve the roles and relationships taking place in the network.

In literature, blockchains are seen to go hand in hand with the internet of things and artificial intelligence. According to Christidis and Devetsiokiotis (2016) in supply chains, IoT devices can help in asset tracking, taking measurements and automation of actions. The integration of sensors and automation have a potential in becoming a part of blockchains in the future as the technology matures and standardizes, but it will still take time that enterprise blockchains are developed to a point where they can be seamlessly integrated with sensors and real-world assets.

6 CONCLUSIONS

Through the past few years blockchains have attracted a lot of attention and become a popular topic regarding the enterprise use. The technology is currently heavily promoted, and businesses are looking for ways to implement it in their practices. Supply chain integration is one of the most promising uses for blockchain, and there are already some practical implementations and projects existing. All blockchain projects are however in a nascent phase, and there is very little evidence on the technology's benefits over more mature database technologies, especially in the enterprise context.

The key findings of this study are related to the special characteristics of LNG supply chains and the current state of blockchains. LNG supply chains are quite unique and in an early phase of their development. There is need for up-to-date information about the transfers taking place in the supply chain, one important piece of information being the quality of transported LNG. Wide integrity and access to data would improve the overall performance of the supply chain, but currently there is no automatic and secure way to record and share confidential data. Higher availability of quality information would make it easier to locate the points where problems have occurred and solve them faster.

Blockchain technology is still quite unknown to many business practitioners and the common language for exchanging ideas has not completely formed yet. Currently some terms are used interchangeably in the literature, such as blockchain and distributed ledger technology. The benefits and risks of using the technology are not completely clear. There is no standardized way to use blockchains, because the technology is also in such an early phase of its development. Not many practical and developed use cases exist at the moment to benchmark or compare to. On the bright side, there is a lot of interest and discussion in both academic and business world about blockchains, and they are being shaped all the time by new projects and attempts to implement the technology. The knowledge is being built up and spread gradually.

The research questions introduced in chapter 1 are following:

- How to utilize blockchain in supply chain management in a way that it solves the stated challenges faced by end-users and customers?
- What are the main challenges and obstacles in implementing blockchain in the product and how to overcome them?

The focus of this study has shifted during the research process. As in the beginning the purpose was to investigate how to implement blockchain into a single software product, it turned out that blockchain is probably not usable as such but could be used as a separate platform or application in increasing interconnectivity within LNG supply chain members and as a secure channel for passing information about the energy transfers. It seems more likely that enterprise blockchains are a collective effort, and not provided only by a single central entity. In an LNG supply chain context, this would require creating consortiums and networks that engage and contribute in the same enterprise blockchain. This answers to the first research question of this thesis. The second research question, regarding the challenges in implementing blockchain in enterprise use include the lack of knowledge and concrete skills and proving the technology's benefits over other existing and well-established technologies. These challenges can be overcome by increasing knowledge in the organizations by arranging training and education or by recruiting. The benefits are possible to further define through concrete use cases, by establishing projects, creating proof of concept based on a real business case and piloting with a committed group of users.

The theoretical implications of the study are following. The intersection of LNG supply chains and blockchain technology is underrepresented in academic research and this study has contributed in filling that gap. The key findings of this study support the findings made previously in research related to supply chain management and blockchains. Additionally, the results provide a richer understanding on the challenges and specific characteristics of LNG supply chains. As a practical contribution, this study has aimed to form a basis to build on to create a blockchain application that supports LNG infrastructure and its supply chain parties. The research has included mapping out the challenges, available enterprise blockchain platforms, and the real-world problems faced by the various supply chain parties. For organizations, this study provides more understanding about the blockchain technology and how it can be used in increasing interconnectivity and integrity of data in LNG supply chains and energy transfer management.

The limitations of this study include, that the interviewee participants are from Finland and Eastern Europe, so the generalizability of results apply only to LNG supply chains operating in those areas. All interviewees are also operating within small scale LNG supply chains, which differ from that of large scale. It should be noted, that the results may vary depending on the geographical location of the supply chain participants, their cultural background and the level of competition in the area. Characteristic to a qualitative study, there are also accordingly limitations regarding the validity. The future research areas regarding this topic would be creating a proof of concept for a blockchain application in LNG supply chains and implementing it in practice. This would open new opportunities to further explore the use of blockchain in practice and measure the user experience and performance. The ideas and implications suggested in this study are only the beginning, and a practical implementation would offer a whole new level to conduct research on. Additionally, opportunities in different kind of blockchain applications could be explored, such as provenance tracking and documentation handling.

REFERENCES

Androulaki, E., Barger, A., Bortnikov, V., Muralidharan, S., Cachin, C., Christidis, K., De Caro, A., Enyeart, D., Murthy, C., Ferris, C., Laventman, G., Manevich, Y., Nguyen, B., Sethi, M., Singh, G., Smith, K., Sorniotti, A., Stathakopoulou, C., Vukolić, M., Cocco, S.W. & Yellick, J. (2018) "Hyperledger Fabric: A Distributed Operating System for Permissioned Blockchains." *Proceedings of the 13th EuroSys Conference*, EuroSys 2018, 2018-January.

Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., Mccallum, P., Peacock, A. (2019). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renewable and Sustainable Energy Reviews*, 100, pp. 143-174.

Antonopoulos, A. M. (2017) *Mastering Bitcoin 2nd Edition - Programming the Open Blockchain*. O'Reilly Media.

Buterin, V. (2013) Ethereum white paper <https://github.com/ethereum/wiki/wiki/White-Paper>, retrieved 9.4.2019.

Buterin, V. (2015) "On Public and Private Blockchains" in *Ethereum blog.* < https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/>, retrieved 8.3.2019.

Carter, C. R., Rogers, D.S., & Choi, T.Y. (2015) "Toward the theory of the supply chain" Journal *of Supply Chain Management*, 51 (2), pp. 89-97.

Charmaz, K. & Belgrave, L. L. (2015). "Grounded Theory", in the *Blackwell Encyclopedia of Sociology*, G. Ritzer (Ed.).

Christidis, K. & Devetsikiotis, M. (2016) "Blockchains and Smart Contracts for the Internet of Things," in *IEEE Access*, vol. 4, pp. 2292-2303.

Chopra, S. & Meindl, P. (2001). *Supply chain management: Strategy, planning and operation*. Upper Saddle River, NJ: Prentice Hall.

Digieconomist (2019), <https://digiconomist.net/bitcoin-energy-consumption>, retrieved 13.2.2019.

Drake, M. (2012). *Global supply chain management*. [New York, N.Y.] (222 East 46th Street, New York, NY 10017): Business Expert Press.

Goldkuhl, G. (2012). Pragmatism vs interpretivism in qualitative information systems research. *European Journal of Information Systems*, 21(2), pp. 135-146.

Gunasekaran, A. & Ngai, E.W.T. (2004). Information systems in supply chain integration and management. *European Journal of Operational Research, 159(2),* pp. 269-295.

Haber, S. & Stornetta, W.S. (1991) “How to time-stamp a digital document”.

Hirsjärvi, S. & Hurme, H. (1980). *Teemahaastattelu*. Helsinki: Yliopistopaino.

Hirsjärvi, S., Sinivuori, E., Remes, P. & Sajavaara, P. (2004). *Tutki ja kirjoita* (10. osin uud. laitos.). Helsinki: Tammi.

Hugos, M. H. (2018). *Essentials of supply chain management* (Fourth edition.). Hoboken, New Jersey: John Wiley & Sons, Inc.

Kallio, H., Pietilä, A.M., Johnson, M. & Kangasniemi, M. (2016). Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *Journal of advanced nursing*, 72(12), pp. 2954-2965.

Li, J., Greenwood, D. & Kassem, M. (2019). “Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases.” *Automation in Construction*, 102, pp. 288-307.

Locke, K. (2001). *Grounded theory in management research*. London: SAGE.

Martin, P.Y. & Turner, B.A. (1986). “Grounded Theory and Organizational Research”, *The Journal of Applied Behavioral Science*, 22 (2), pp. 141-157.

Mougayar, W. (2016). *The business blockchain: Promise, practice, and application of the next Internet technology.* Hoboken, New Jersey: John Wiley & Sons, Inc.

Myers, M. D. A. & Avison, D. E. (2002). *Qualitative Research in Information Systems: A Reader*. London: SAGE Publications.

Nakamoto, S. (2008) "Bitcoin: A Peer-to-Peer Electronic Cash System".

Orcutt, M. (2019) "In 2019, blockchains will start to become boring*" MIT Technology Review*. <https://www.technologyreview.com/s/612687/in-2019-blockchains-will-start-to-become-boring/>, retrieved 26.2.2019.

Orlikowski, W. & Baroudi, J. (1991). Studying Information Technology in Organizations: Research Approaches and Assumptions. *Information Systems Research*, 2(1), pp. 1-28.

Prater, E. & Whitehead, K. (2013). *An introduction to supply chain management: A global supply chain support perspective*. [New York, N.Y.] (222 East 46th Street, New York, NY 10017): Business Expert Press.

Reyna, A., Martín, C., Chen, J., Soler, E. & Diaz, M. (2018). "On blockchain and its integration with IoT. Challenges and opportunities". *Future Generation Computer Systems*, 88, pp. 173-190.

Sakmar, S. L. (2013). *Energy for the 21st century: Opportunities and challenges for liquefied natural gas (LNG)*. Cheltenham: Edward Elgar Pub. Ltd.

Saunders, M., Lewis, P. & Thornhill, A. (2003). *Research methods for business students (3. ed.)*. Harlow: Prentice Hall.

Szabo, N. (1994) "Smart contracts" <http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.htht>, retrieved 8.4.2019.

Szabo, N. (1997). "Formalizing and Securing Relationships on Public Networks". *First Monday*, 2(9).

Teslya, N. & Ryabchikov, I. (2018), "Blockchain Platforms Overview for Industrial IoT Purposes," *22nd Conference of Open Innovations Association (FRUCT)*, Jyvaskyla, pp. 250-256.

Tschorsch, F. & Scheuermann, B. (2016) "Bitcoin and Beyond: A Technical Survey on Decentralized Digital Currencies," in *IEEE Communications Surveys & Tutorials*, vol. 18, no. 3, pp. 2084-2123, thirdquarter.

Valmet Oyj (2019) “Valmet: technologies, services and automation to pulp, energy and paper industries” <http://www.valmet.com>, retrieved 2.4.2019.

Wüst, K. & Gervais, A. (2018) "Do you Need a Blockchain*?" 2018 Crypto Valley Conference on Blockchain Technology (CVCBT)*, pp. 45-54.

Zheng, Z., Xie, S., Dai, H.N., Chen, X. & Wang, H. (2018), “Blockchain challenges and opportunities: A survey” *International Journal of Web and Grid Services*, 14 (4), pp. 352-375.

Zoican, S., Vochin, M., Zoican, R. & Galatchi, D. (2018) "Blockchain and Consensus Algorithms in Internet of Things," *International Symposium on Electronics and Telecommunications (ISETC)*, pp. 1-4.

APPENDICES

Appendix 1 Interview question guide

INTERVIEW THEMES

Supply chain related themes

- Supply chain
  - What is your supply chain like?
  - What are the biggest challenges in your LNG/material supply chains?
  - How would you improve your supply chain?
- Supply chain network participants and roles
  - Who are the different participants and what are their roles in your supply chains?
  - What kind of intermediaries or third parties are involved in the supply chain?
- Collaboration and trust
  - How does the collaboration with supply chain participants work?
  - What kind of trust relationship is there between different supply chain participants? Trust/no trust?
  - What kind of transactions or agreements are done within the network?
- Transaction data sharing and communications
  - What kind of information or documents are involved in LNG transfers?
  - How often do transactions take place?
  - What communication tools are used in the distribution of documents and information related to LNG supply chain?
  - What are the methods to share data between companies currently?
- Big picture
  - How is the big picture achieved?
  - To what extent is the big picture achieved?

Blockchain related themes

- User perspective
  - What do you think about the described application?
  - How this kind of application would change the ways of working in your company?
  - What is the most important feature this application would bring from your company’s perspective?
  - Could this kind of application be used in speeding up some processes regarding energy transfers?
- Opportunities and challenges
  - What kind of opportunities or challenges do you see in using a described application in your business?
- Security and privacy
  - Would your company be willing to share energy transfer data with peers?
  - Is there any security or privacy constraints in sharing the transaction data?
- Implementation perspective
  - What do you think about the described application?
  - How would this technology fit the product?
  - What opportunities or challenges do you see in using this technology?

- Decentralization
  - What intermediaries this kind of application could remove?
  - How do you see the decentralized approach could complement the current centralized approach?
  - What do you think about decentralized applications?
  - What benefits or obstacles do you see in implementing a decentralized application?
  - Would you prefer having data stored decentralized across several parties or rely on a central entity in storing and validating data?