Utilization of blockchain technologies for enhanced transparency and traceability in Supply chains

A use-case study in collaboration with SKF Group

Master thesis in the Master´s Programme Management and Economics of Innovation

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Gothenburg, Sweden 2019
Report No: E 2019: 046

MASTER´S THESIS E 2019: 046

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Gothenburg, Sweden 2019

Acknowledgements

This master thesis have been conducted as the final part of our Master within the master´s programme Management and Economics of Innovation at Chalmers University of Technology during the spring of 2019 in collaboration with the company SKF in the bearing manufacturing industry as well as several professionals from the same.

First of all, we would like to acknowledge and give our greatest thanks to SKF and all the professionals at SKF for collaborating with us during this master thesis. Without your engagement and each of your individual contribution of time, professional perspectives, valuable information and knowledgeable insights, the completion of this thesis project would not have been possible. We would also like to give our sincerest thanks to our supervisor Magnus Kuschel at SKF for your time, knowledgeable guidance and support during this research project.

Finally we would like to give a special thanks to our supervisor Gunnar Stefansson at Chalmers, who has supported and guided us through the academical process of this study by the contribution of valuable time for knowledgeable consultation and insightful feedback throughout the entire research study.

Chalmers University of Technology
Gothenburg 2019-06-14

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Abstract

Utilization of blockchain technology for enhanced transparency and traceability in supply chains is in focus for this research study. The globalization of markets and new information technologies have presented companies with both new opportunities and challenges. Where increased industry competition and continuously changing customer demands are pushing companies in manufacturing industry into becoming increasingly responsive and productive. In a rapidly shifting competitive landscape, outsourcing on one hand may enable higher productivity and responsiveness of a company's supply chain. On the other hand, it may result in a disintegrated supply chain, where transparency and traceability becomes inhibited. Inefficiencies such as information asymmetries, fragmentation of data, desynchronization between supply chain actors and activities lead to reduced supply chain performance.

The area of blockchain technologies have experienced increased attention the last few years as a potential solution for mitigating these inefficiencies. Where a blockchain can be described as a tamper evident and tamper resistant digital ledger, implemented in a distributed fashion. As blockchain solutions could potentially enable enhanced transparency and complete traceability, it becomes interesting for investigation. The purpose of the study has thus been to evaluate how the emerging blockchain technologies can ensure enhanced transparency and traceability in the supply chains of the manufacturing industry. Four use-case scenarios in a large global manufacturing firm have been studied, counterfeiting and piracy; remanufacturing; warranty; and export control and clearance of dual-use goods.

The characteristics of blockchains as a nascent technology have been examined. Furthermore, the characteristics of the generic supply chain in the manufacturing industry have also been mapped. Data have been gathered through literature searchers and interviews with industry experts, where empirical findings have been analysed using two different frameworks. Firstly, an evaluation tree has been used to establish whether there is an actual need for a blockchain solution. Secondly, an SFA (suitability, feasibility, acceptability) framework was used, where the business potential of each individual use-case scenario in relation to a blockchain solution have been analysed. The findings of this study contribute to previous research by indicating that blockchain technologies could provide substantial benefits primarily in two of the four investigated use-case scenarios. Utilization of blockchain technologies for enhanced transparency and traceability in supply chains will most likely be key for success, where collaboration between supply chain actors and organizations already addressing business potential of blockchains will most likely be a critical enabler for proficient use. As well as for overcoming the inherent technical limitations, such limited interoperability, speed and resource efficiency of current blockchain technologies.

Keywords: *Blockchain technologies, Supply chain, Transparency, Traceability, Manufacturing industry*

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1. Introduction

1.1 Background

The evolution of the technological landscape has enabled the globalization of markets (Chandra and Grabis, 2016). Where the globalization together with innovative information technologies have presented companies with both new opportunities and challenges in a transformed market landscape with increased competition. Continuously changing demands and requirements of various stakeholders such as regulators and customers are pushing companies into becoming increasingly more efficient and transparent. While at the same time companies must be able to show that a higher degree of sustainability has been incorporated and maintained (Lactose, 2016). In order to stay competitive, companies has to find new ways to cope with these demands, encompassing for example lowering costs, increasing responsiveness and quality levels. As a response to the changing competitive landscape, companies have become less vertically integrated, relying more heavily on outsourcing as a new alternative strategy to increase their level of agility and responsiveness (Chandra and Grabis, 2016). The globalization of firms has contributed to supply chains becoming increasingly elongated and disintegrated That in turn have led the emergence of significant complexity challenges related to management of activities, actor relationships and management of information and data of the same in the manufacturing industry (Pearsall, 2016). Furthermore, the increasing reliance of outsourcing of business activities has transformed the manufacturing supply chain into becoming increasingly fragmented with higher complexity due to the multitude of different actors and use of various information technologies in business operations (Wadhwa et al., 2010).

As complexity increases, companies face problems concerning their supply chain transparency and traceability. This in turn has resulted in various supply chain inefficiencies such as information asymmetries, fragmentation of data, desynchronization between supply chain actors and their individual business operations as well as overall reduced supply chain performance (Wadhwa et al., 2010 ; Füzesi, Lengyel and Felföldi, 2018). The introduction of the disruptive blockchain technology (Gupta, 2018) is suggested to provide a potential solution for mitigating these issues by enabling higher transparency and traceability. Where the negative outcomes of limited transparency and traceability are reduced levels of trust, in which stakeholders are inclined to mistrust the information provided by external actors. Leading to reduced cooperation as well as reduced efficiency and ability related to tracing of goods and sharing of information (Pearsall, 2016). Creating difficulties for companies in securing the origin of sourced material and products, as well as controlling quality levels related to the product itself and supply chain processes performed by various actors (Füzesi, Lengyel and Felföldi, 2018). The limited transparency, visibility and traceability thus creates increased incentives and opportunities for opportunistic behavior related to counterfeiting or tampering and falsifying of documentation. It also have a negative impact on delivery, administration and processing lead times, as well as supply chain responsiveness (Heutger, Kückelhaus, 2018).

Where the increased complexity and limited transparency, is affecting the efficiency in supply chain related operations and areas related to anti-counterfeiting, warranty processing, remanufacturing and export control and clearance (Heutger, Kückelhaus, 2018; Jin et al., 2017).

The aspects of transparency and traceability in business operations have thus gained a lot of interest and importance in the world of supply chain management as a way to ensure efficient collaboration and coordination through proper data and information management, as well as to verify sustainability claims and that ethical business practices have been maintained. Where BSR (2014, p.6) defines traceability as *"the ability to identify and trace the history, distribution, location and application of products, parts and materials".* Where the ability to gather, consolidating and sharing information regarding the origin of products and raw materials as well as trace the distribution and usage of the same have become of increasing importance in modern business and supply chain operations.

These growing complexities and the resulting issues have an especially large impact on global manufacturing companies where an efficient supply chain is vital. The continuous emergence of new information technologies have allowed for global digitalization, which have contributed to new business opportunities and sources of competitive advantage (Easterby-Smith, et al., 2015). However, the current systems and practices available are unable to handle the increasing complexity of global supply chains and decoupled markets. From which a need for new technological innovation have emerged to counteract the growing complexity and associated issues. The introduction of blockchain technologies and its features have been suggested to be a potential and prominent solution for dealing with inefficiencies related to transparency and traceability and trust, which are currently characterizing the manufacturing supply chain. As it enables enhanced transparency and visibility in business operations as well as enhanced traceability efficiency as it provides a complete historic trail of all transactions ever made by all entities on the blockchain. This leads to an increased level of trust in relationships as all transactions can be linked back to its original source (Gupta, 2018).

The blockchain technology works by using distributed and decentralized ledger technology fused together by cryptography to record and store transactional data in a verifiable, immutable and tamper evident fashion in blocks that are linked together forming the blockchain (Yaga et al., 2018). In contrast to a traditional network which rely on intermediaries and a where network actors have to trust in the integrity of a central authority for correctly managing and verifying transactions. The blockchain network is not governed by any central authority. Transactions are instead independently and collectively managed by the distributed peer-to-peer network in which all participants referred to as nodes acts as both publishers and receivers of transactions within that network. The distributed and decentralized architecture allow for a shared ledger, where multiple copies of the ledger exits at all times, rather than keeping information in one central point (Dhillon et al., 2017). As the technology is still in its infancy there is an interest in investigating what types of scenarios or business applications that could benefit from the use of blockchain. Previous research has covered the subject of blockchain technologies quite extensively in various industries and industrial settings, foremost in the banking industry, food industry, and medical industry which are the most prominent and widely researched (Dib et al., 2018). However, even though the field of research related to the topic of blockchain technologies, a gap exists in research field and literature related to intersection between blockchains and supply chain management and more specifically the issue of transparency and traceability in supply chains. Therefore, this research study aims at reducing this gap and further contributing to this field of knowledge.

The Swedish company SKF is a major bearing manufacturer with customers and distribution in 130 countries, with more than 90 manufacturing sites spread over 24 countries. A global distribution network of 17000 distributors worldwide, encompassing Europe, Brazil, Afrika and the US. With supply chain activities related to reliable rotation bearing products and applications across 40 different industries, including Industrial distribution, heavy duty industries, Marine, aerospace, Energy, Automotive et cetera. The supply chain incorporates a wide range of supply chain actors and activities, such as purchasing, procurement, manufacturing and distribution as well as logistics and transportation. Furthermore, the company have a complex global supply chain network of manufacturers, customers, suppliers and various other actors. In addition, SKF currently have 44428 employees (SKF, 2019), with net sales during 2018 of SEK 85,7 billion with an operating profit of SEK 11,0 Billion (SKF, 2018). This thesis have been conducted in collaboration with SKF as the company can serve as a case object for further investigation as a large manufacturer with a globalized supply chain within the manufacturing industry. SKF further has an interest in continuously exploring alternative technologies and ways of working to enhance transparency and traceability within areas of their supply chain.

1.2 Purpose

The purpose of the study is to evaluate how the emerging blockchain technologies can provide enhanced transparency and traceability throughout the supply chain of companies with focus towards the manufacturing industry. Thereby providing a deeper understanding of the opportunities and challenges that may come with using blockchain. Four use-case scenarios will be explored related to the supply chain of the large global manufacturing firm SKF, together with references in industry and literature. In order to achieve the stated research purpose, the characteristics and nature of blockchain technologies as a nascent but promising technology are examined in relation to the supply chain of firms. Where in addition, the inherent characteristics of the generic supply chain in the manufacturing industry have been mapped and investigated to provide the foundation for evaluation of blockchain technologies potential in relation to this specific setting.

1.3 Research questions

In order to achieve the purpose of the study and reach a more profound understanding of the research area, a number of guiding research questions have been suggested. Furthermore, delimitations are presented in the next chapter. As indicated by Dib et al., (2018) and Yaga et al., (2018) , blockchain technology have become a one of the most attractive and widely discussed topics. Where blockchain technology is thought of as something revolutionary that will completely transform and disrupt several industries and business practices of today. The technology is further suggested to have extensive areas of use, with far reaching implications and major positive impact on for example supply chain transparency, efficient traceability of materials and information as well as enabling trusted transactions between network actors without reliance on any central authority or intermediaries. Hence the first research question is aimed at establishing and understanding the scope of this technology´s potential:

- ***R1****: What is blockchain technology and how can it be utilized in business?*

The Global standards organization (2017) suggests that several industries, the manufacturing industry being no exception is characterized by various challenges which can be directly or indirectly attributed to a lack of transparency between supply chain actors and insufficient traceability related to the physical material flow and digital information and monetary flow. As stated, the purpose of this research study is to investigate how blockchain technologies can contribute to enhanced transparency and traceability in the supply chain of companies in the manufacturing industry. In order to achieve this purpose, the inherent challenges and inefficiencies related to limited supply chain transparency, and traceability that characterizes supply chains in the manufacturing industry had to be mapped and understood. Therefore the second research question is as following:

- ***R2:*** *What are the issues related to the traceability and transparency in the generic supply chain of the manufacturing industry?*

Supply chain transparency and traceability are two critical elements for overall supply chain performance in upstream and downstream activities (Bosona and Gebresenbet, 2013). Where Dib et al., (2018) suggest that the characteristics and features of blockchain technologies could potentiality act as an enabler for achieving enhanced transparency and traceability. Hence, the third research question focused on investigating how blockchain technology can be used to enhance transparency and traceability within the supply chain:

- ***R3:*** *How can blockchain technology provide enhanced transparency and traceability in the generic supply chain?*

In a globalized world with increasingly complex supply chains in which an array of network actors and activities are involved, have resulting in the emergence of various inefficiencies related to coordination, configuration and collaboration. Where frag mentation of data and information asymmetries and desynchronization of supply chain actors have led to a favorable landscape with reduced trust and increased incentive opportunistic behaviour. Where actors seek to in various ways take advantage of the existing information gaps steaming from poor transparency and traceability characterizing the global supply chains for their own gain.

Blockchain technology have been suggested as a potential and promising solution for mitigating issues related to the same, while creating enabling new business opportunities. Hence, the fourth research question focus on:

- *R4: How can blockchain technologies be used for mitigating issues related to transparency and traceability in supply chain related business applications?*

Prior to the development of the fourth research question, the initial research questions was studied and partially answered in order to be able to further contemplate on what specific areas related to the research topic could be framed, studied and used to anchor and exemplify the studied phenomena. During this initial phase of iteration and reflection, four promising use case scenarios were identified and developed in collaboration with the case company SKF. Where these use-case scenarios were evaluated to be of great interest for the company and a good for further research as the same were characterized by constraints related to limited traceability and transparency. And where blockchain technology was perceived to potentially add value. The relationships between the research questions are illustrated in figure 1.

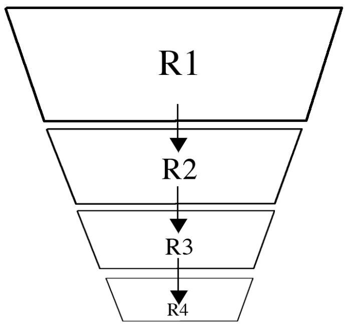

Figure 1 - Representation of the relationships between the research questions

1.4 Delimitations

This thesis focus on how blockchain technologies can contribute to enhancing transparency and traceability in the supply chain in the manufacturing industry. This research will specifically focus on how enhanced transparency and traceability can be ensured throughout the supply chain and related activities with the utilization of blockchains. Furthermore, due to the limited practical use and incorporation of blockchains technologies in the manufacturing industry, the study will not focus on the practical implementation, nor related practical requirements or resources needed for implementation of the findings. Hence the focus is rather on the general evaluation of how blockchain technology can aid in securing enhanced transparency and traceability as critical elements in the relation to the supply chain of the major incumbent manufacturer SKF from a hypothetical perspective. The specific focus for the research will be towards investigating on a general level four identified use-case scenarios of blockchain characterized by limited transparency and traceability. However, in order to understand the concept of blockchain technology as well as the impact it has on supply chain procurement activities, a foundation of basic and descriptive knowledge about the characteristics and functionality of blockchains is presented.

2. Relevant literature

In this chapter the relevant literature is presented which have been used as the foundation for reflection and analysis of the empirical results presented in chapter "Empirical results". Literature related to blockchain technology, supply chain configuration, transparency and traceability is presented. In addition, literature related to the four scenarios of counterfeiting, warranty, export control and remanufacturing are presented where the characteristics of the individual areas is outlined. The relevant literature used aims to provide the reader with the building blocks necessary to establish an understanding of the various aspects of the research area encompassed by this study.

2.1 Blockchain technology

2.1.1 Background

The blockchain concept was first published in a white paper by the pseudonym Satoshi Nakamoto in the year 2008 as a way to reduce the network actors dependence on the centralized banking system by solving the double spending problem without the reliance on a central authority (Thombs and Tillman, 2018). Double spending is the inherent problem of digital currencies, where the currency can be spent more than once. This problem have traditionally been mitigated through utilization of a trusted central authority, such as a financial institution or bank which have been tasked with the responsibility for verifying the validity of transactions. However, trust-based model comes with inherent flaws, vulnerabilities and inefficiencies such as a single point of failure (Dhillon et al., 2017).

The first practical application of the new blockchain technology came with the introduction of the now widely known cryptocurrency Bitcoin, utilizing a decentralized and distributed peer-to-peer network system for financial transactions in which the need for a trusted centralized party is removed (Yaga et al., 2018). Instead, the verification of transactions and ensuring that double spend problem is avoided is entrusted to the network itself. Hence, blockchain technology which is based on a consensus model can alleviate the inefficiencies and security gaps of the traditional system (Dhillon et al., 2017). Although the technology is still in its infancy, new potential application areas have emerged where the technology is suggested to disrupts several industries, including the manufacturing industry in the future and have captured the attention by scholars and practitioners (Dib, et al., 2018).

2.1.2 What is blockchain technology

The blockchain is fundamentally an open, decentralized and distributed digital ledger that can theoretically be programmed to record any type of transactions between network peers in a verifiable, immutable and permanent way. Yaga et al., (2018. p1) describes blockchains as *"tamper evident and tamper resistant digital ledgers implemented in a distributed fashion"*, where *"at their basic level, they enable a community of users to record transactions in a shared ledger within that community"*. The blockchain network is not governed by any central authority, transactions are instead independently and collectively managed by the distributed peer-to-peer network in which all participants (nodes) acts as both publishers and receivers of transactions within that network. However Yaga et al., (2018) describes that nodes should be distinguish between so called full-nodes and partial nodes in the network. Full nodes all haved full copy of the ledger and therefore a complete record of all transactions. They partake in the publishing of new blocks and the verification of transactions, ensuring their validity. In contrast a partial node only act as a distributor of already transmitted transactions on the network, hence they do not hold or maintain a complete copy of the ledger.

The fundamentally different approach of a decentralized and distributed architecture eliminate the need for trusted third-parties and centralized governance. Instead participants (nodes) engages in the verification and validations of transactions through consensus, in which the distributed network itself act as a trusted collective authority (Dhillon et al., 2017). Yaga et al., (2018) further suggests that the incorporated consensus based model within blockchains allows for distributed authority, where a transaction have to be agreed upon by all participants as valid to be granted. Hence, trust and security is created through specific attributes of blockchain technology. Which allow transparent and secure transactions in a fashion that are tamper resistant, in a network consisting of many different actors, without the need for a governing central authority (Dhillon et al., 2017). Firstly, the unique decentralized and distributed ledger technology in which a complete historic data trail related to any transactions is recorded and can be accessed by anyone in the network holding a copy of the blockchain ledger. Secondly, the consensus based model which allows for collective validation of each transaction. Lastly, the cryptographic protocols (cryptography mechanisms) which prevent third parties from viewing and altering data, ensuring that data within the ledger is secure and have not been tampered with (Yaga et al., 2018). See figure 2 for illustration on a general blockchain transaction. The components of blockchain based networks will be further explained in the following chapter.

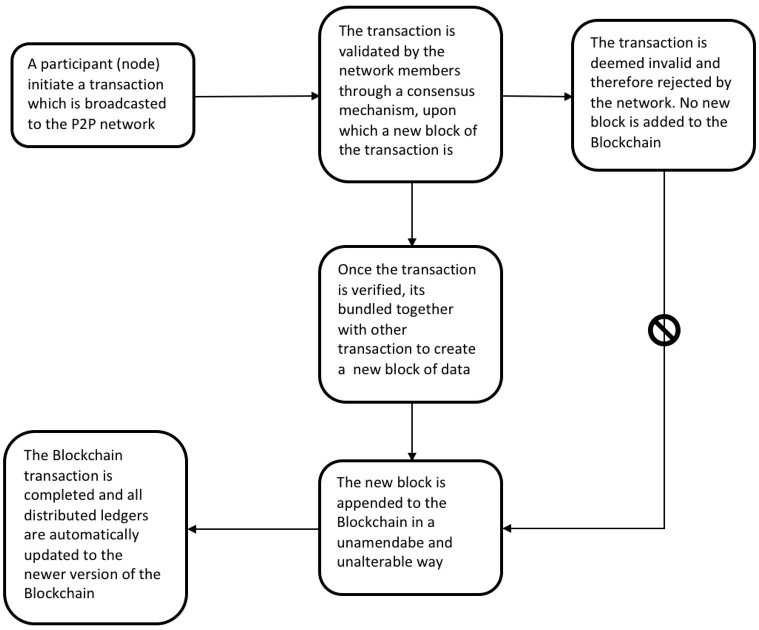

Figure 2: The blockchain transaction process, Adapted from Gupta (2018)

2.1.3 Components of blockchain technology

2.1.3.1 Cryptographic hashing

A blockchain consists of consecutive series of blocks in which bundled sets of time-stamped transactions records made on the blockchain are stored. Each block is connected to the previous blocks through a cryptographic links (i.e. hash) which is unique to each block and forms the chain over time (Gartner, 2019), where and illustration is provided in figure 3. According to Gupta (2018) anyone with access rights can trace any previous transaction and the involved parties. This leads to a high level of trust as all transactions can be linked back to its original source. The type of information included in each block is depending on the application of the blockchain as well as its purpose. And what determines the properties of the individual blockchain is stipulated in the blockchain protocol, i.e the code embedded in each block that determines what the blockchain is capable of.

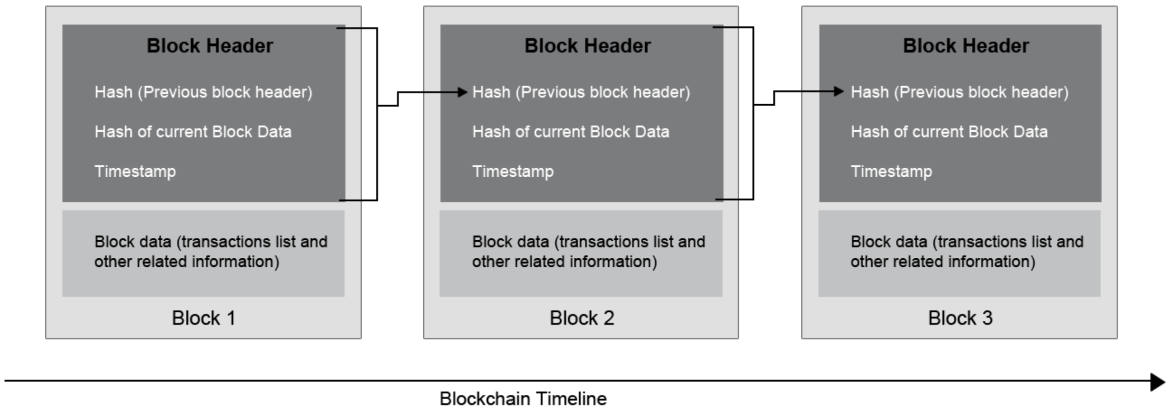

Figure 3 - Generic Chain of Blocks, adapted from Gupta (2018).

Cryptographic techniques are vital to the functionality of blockchains with the primary function of guaranteeing the immutability of the blockchain. The cryptographic mechanism blockchains utilizes is referred to as hashing, which is based on an advanced algorithm that takes the input data of each block and transforms it into a seemingly randomised sequence of letters and numbers of a predetermined length (Dhillon et al., 2017). A unique key characteristic of hashing in comparison to other cryptographic techniques is that the output hash can never be reversed. Hence, any changes made in the input data will result in a completely different output hash as shown in figure 4 by comparing the output texts after the addition of the word “world” in the output data. This means that it is impossible to predict the output based on the input data. Unlike other types of encryption techniques hashing can be described as a one way street, there is no way to be able to figure out the input data based on the output data, this enables the hash to be distributed without compromising privacy (Yaga et al., 2018).

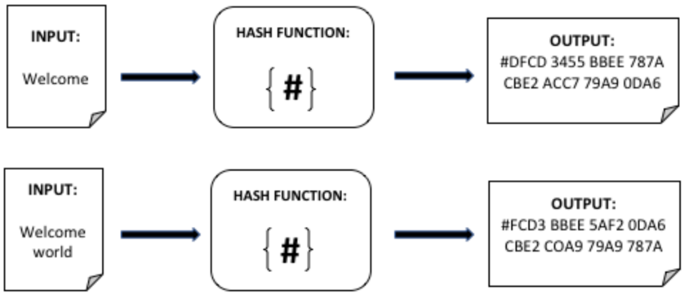

Figure 4: Blockchain hashing mechanism, adapted from Yaga et al., (2018)

Yaga et al., (2018) further suggests that the hash also acts as a unique fingerprint ID for a specific block and its content as output. Where each new consecutive block that is created is automatically chained together with the previous blocks through the same hashing mechanism, as the hash of the previous block is also stored in the new one. Hence, creating a consecutive trail through all blocks back to the first block referred to as the genesis block (Gupta, 2018).

2.1.3.2 Asymmetric-key Cryptography

Another security feature of blockchain based network is the use of asymmetric key cryptography. Which is a dual-key system where a participant hold one public and one private cryptographic key for publishing and verifying transactions. Making it impossible to decrypt, access or sign encrypted transactional data without possessing both key. This in turn ensures that only participants with proper authority can access the data and thus also establishes a trusted link between anonymous network users (Yaga et al., 2018).

2.1.3.3 Decentralized and distributed ledger governance

Blockchain based networks are based on a distributed and decentralized ledger architecture in which the ownership is shared between the network participants. Where Yaga et al., (2018) describes a ledger as a physical or digitally stored book containing recorded transactions and exchanges of merchandise. The decentralized structure enables both independent transactions across the entire network without the need any third-party acting as a central authority, verifying the validity of these transactions. In contrast to centralized based networks the decentralized and distributed architecture also removes the need for trusted intermediaries and central governance. Yaga et al., (2018) further suggests that networks based on a centralization comes with some inherent limitations that can be mitigated by blockchains.

Firstly, the centralized network governance impose limited transparency in the verification and validation of transactions. Where non-governing network participants have limited insight and must have complete trust in the governing authority and the integrity of the same to act in a righteous and ethical fashion, not tampering with transactions in any way. In addition, as the ledger is often stored in databases located in a single location (i.e centralized), further exposes the availability of recorded data if the system breaks down or comes under any form of attack. The decentralized and distributed architecture of blockchain based networks however, allow for several copies of the complete ledger to exists. Where each new network participants (nodes) holds and maintains a separate ledger copy where storage is not limited to any single geographical location. When a new block is created on the blockchain and validated by all nodes, all copies of the ledger are updated to the newer version, ensuring that all nodes have the same data set at all times. This increase the reliability of the network by preventing a single point of failure (Rijswijk, Hermsen and Arendsen, 2019). Another benefit of a blockchain architecture is the fact that all transactions transmitted in the network requires collective verification and validation by all nodes. Which is done through various consensus mechanism that will be explained in more detail in the next chapter. All nodes can be seen as interdependent, where authorization and governance power is distributed equally. Hence, the network itself acts as a collective governing authority, which removes the need for any third-parties or intermediaries (i.e institutions and banks), prevents that wrongful and harmful transactions are recorded on the blockchain (Yaga et al., 2018).

2.1.3.4 Consensus mechanism

A fundamental aspect of blockchains is that actors should be able to interact with each other without the need to first establish trust. According to Gupta (2018), the blockchain technology is based around the notion that the network should reach a network wide consensus for validation of transactions. Depending on the type of blockchain and its purposes, the consensus mechanisms can vary and the cost associated with them. Bitcoin for example uses a proof-of-work consensus, while Etherium adopts a proof-of-stake method (Feng, Zhang, Chen and Lou, 2018). The consensus mechanism plays a vital role in legitimizing the content and trust amongst the network participants. The various attributes and differences between three existing consensus models are presented in figure 5.

Name	Goals	Advantages	Disadvantages	Domains	Implementations
Proof of work (PoW)	To provide a barrier to publishing blocks in the form of a computationally difficult puzzle to solve to enable transactions between untrusted participants.	Difficult to perform denial of service by flooding network with bad blocks. Open to anyone with hardware to solve the puzzle.	Computationally intensive (by design), power consumption, hardware arms race. Potential for 51 % attack by obtaining enough computational power.	Permissionless cryptocurrencies	Bitcoin, Ethereum, many more
Proof of stake (PoS)	To enable a less computationally intensive barrier to publishing blocks, but still enable transactions between untrusted participants.	Less computationally intensive than PoW. Open to anyone who wishes to stake cryptocurrencies. Stakeholders control the system.	Stakeholders control the system. Nothing to prevent formation of a pool of stakeholders to create a centralized power. Potential for 51 % attack by obtaining enough financial power.	Permissionless cryptocurrencies	Ethereum Casper, Krypton
Delegated PoS	To enable a more efficient consensus model through a 'liquid democracy' where participants vote (using cryptographically signed messages) to elect and revoke the rights of delegates to validate and secure the blockchain.	Elected delegates are economically incentivized to remain honest More computationally efficient than PoW	Less node diversity than PoW or pure PoS consensus implementations Greater security risk for node compromise due to constrained set of operating nodes As all delegates are 'known' there may an incentive for block producers to collude and accept bribes, compromising the security of the system	Permissionless cryptocurrencies Permissioned Systems	Bitshares, Steem, Cardano, EOS

Figure 5: Consensus Comparison Matrix (Yaga et al., 2018, p.25)

2.1.3 Types of blockchains

Blockchain applications can be crated in a variety of ways to fill different functions as is described in the blockchain protocol. The literature describes four main variables that determines the characteristics of the blockchain, permissioned versus permissionless or private or public. Hence, four types of blockchains can be distinguished which will be further explained below, followed by a classification of each, see figure 6.

2.1.3.1 Permissionless blockchains

Permissionless blockchain networks are decentralized ledger platforms that allow anyone to publish and subscribe a transaction by including it in published blocks on the blockchain without it being processed and accepted by an central authority. These type of blockchains usually utilize some form of consensus mechanism, such as proof-of-work to prevent certain users from abusing the system, thus inducing a cost on publishing new blocks which can make them inefficient and expensive in a business setting. In permissionless blockchain, the user is pseudonymous in which the real identity is not disclosed to the network (Yaga et al., 2018).

2.1.3.2 Permissioned blockchains

According to Yaga et al., (2018) permissioned blockchains uses some form of centralized or decentralized authority for publishing new blocks, where the governing authority can impose restrictions on reading and writing of transaction. Feng, Zhang, Chen and Lou (2018) further suggests that permissioned blockchains accepts and verifies potential users through a validation process. This allows for the identification of the actors connected to the blockchain. Which in turn creates transparency as they are known to the network and have the permission of the other participants to be active in the network. For permissioned blockchains where restrictions are imposed, a higher trust for the governing authority is naturally required compared to permissionless blockchains. The users identity in permissioned blockchain networks, depending on the chosen characteristics of the blockchain (consensus model for example), can be either completely anonymous of pseudonymous (Yaga et al., 2018).

2.1.3.3 Private blockchains

Private blockchains can be viewed as a closed network, where the extent to which each participant may read, initiate and validate transactions on the blockchain is pre-determined by a selected central authority. Only those entities that have been granted permission initially by the network creator have the ability to participate. Hence, private blockchain can be used in such a manner that ensures that access to specific data on the blockchain is restricted to specific entities on a need-to-know basis keeping non-permissioned entities securely out. This makes private blockchains suitable for verification of intra-firm transactions as it takes advantage of the important and beneficial features of blockchain technology, while keeping a high degree of network control (Dib et al., 2018).

2.1.3.4 Consortium blockchains

Consortium blockchains are considered to be a hybrid of public and private blockchains with characteristics from both. Employing a semi-decentralized and semi-permissioned structure in the sense that, the consensus process for participation and validation of transactions rely on a group of pre-approved network nodes, determining which transactions are to be validated. Consortium blockchains are often closely associated as with business use between a group of companies striving to improve the efficiency of their business operations with the help of blockchain technology. This is because consortium blockchains possess the all built in security measures of a regular blockchain, but at the same time allow for greater control over the network (Dib et al., 2018).

2.1.3.5 Public blockchains

Public blockchain can be viewed as an open network in which anyone, anywhere in the world have the ability to join and become a participant without any imposed restrictions related to reading or writing of transaction data. Hence, everyone connected to the network have the ability to input and validate transactions on the public blockchain. Public blockchains are also fully decentralized and distributed, in the sense that every node have equal influence and control over the network. Where each transaction to be considered valid must be verified and authorized by all network nodes through a consensus process prior to the transaction being recorded and appended to the blockchain, hence no single actor can theoretically influence the network in their favor (Dib et al., 2018). The classification and characteristics of the various blockchains types are stated in figure 6.

Features	Public	Private	Permissioned	Permissionless	Consortium
Participation and ownership	Public ownership Open for anyone to read/write transactions	Private ownership Open for a pre-selected group of nodes	Private ownership Open for a group of pre-selected nodes that meets certain	Public ownership Open for anyone to read/write transactions	Semi- Private ownership Open for a pre-selected group of nodes
Management	Fully decentralized and distributed No central Management	Single organization manage the network	Single or multiple organizations manage the network	Fully decentralized and distributed No central Management	Multiple organizations manage the network
Security and consensus mechanism	Proof of Work	Pre-approved nodes (participants)	Pre-approved nodes (participants) Consensus through multi-party algorithm	Proof of Stake	Pre-approved nodes (participants) Consensus through multi-party algorithm
Identity	Anonymous user	Known identities	Known identities	Anonymous user	Known identities
Trust	Trust-free	Trusted	Trusted	Trust-free	Trusted
Speed	Slower	Faster	Faster	Slower	Faster
Scalability	Limited	High	High	Limited	High
Assets	Native assets	Any asset	Any asset	Native assets	Any asset

Figure 6: Classification of various blockchains, adapted from (Dib et al., 2018, p.53)

2.1.4 Business applications of blockchain technology

Blockchain technologies, depending on their characteristics have a wide array of different application areas and business potential. As already stated previously, blockchains can effectively and efficiently be utilized as a system for fully transparent and tamper resistant record-keeping of various transactions (Dhillon et al., 2017). From the birth of bitcoin, other application areas of blockchains have emerged, such as automated transactional agreements through smart contracts, record-keeping and use of blockchain for supply chain transparency and traceability (Dib, et al., 2018). The three areas will be presented in more detail in the next chapter.

2.1.4.1 Smart contracts

Contracts can be defined as agreements between different stakeholders conducting business. They can vary in scope and complexity and there are some elements that the contract needs to contain in order to be legally binding (Morabito, 2017). Thus some types of contractual agreements are be more suited for smart contracts than others. Generally a legal contract specifies the involved stakeholders, the rights and obligations as well as the consequences of a contract breach. This can encourage long-term relationships in environments where relationships thrive upon trust (Morabito, 2017). Thus ensuring that all parties are in agreement of what is expected of the involved stakeholders before business can be conducted. The contract therefore acts as a mechanism to enhance trust between the parties as it clearly dictates the consequences are if there is a contract breach, such as poor quality or delays. The consequences may vary depending on the severity of the contract breach. Contract breaches can be settled between the involved actors but ultimately contracts are only enforceable through a court of law.

Where according to Sklaroff (2017) traditional contracts are being criticized by scholars for being inefficient, due to the inconsistency in interpretation and unpredictability of contract law. And for industry actors it's considered to be money and time consuming due to the arbitrary complexity of current legislation systems, where smart contracts could potentially become a viable alternative in overcoming these inefficiencies. According to Morabito (2017) a smart contract is computer code stored on the blockchain applies a "if this then do that" logic to run on the blockchain while supported by a network of computers to ensure trust.

To set up a smart contract the first step is to formulate the contract terms. The contract terms should according to Morabito (2017) include the involved parties, their individual obligations, settlement instructions for the smart contract and conditions for execution. Morabito (2017) further explains the trigger of the smart contract as certain events such as received information or initiated transactions. Where in the advent of such event triggers the value transaction to the intended recipient based on the terms of the contract. If the value transfer concerns digital assets on the blockchain, the user accounts are updated automatically. If the assets are non-digital the changes will need to be registered in a ledger (Morabito, 2017). Since the smart contract is based entirely on logical operations rather than written language, conditions will either be evaluated as fulfilled or not fulfilled, eliminating any possible grey area. The terms and conditions can be programed into the smart contract so that it resembles a traditional contract with the benefit that it automatically executes any transactions written in the agreement. Thus removing the need for third parties to act as central authorities to provide trust as the execution and recordings of transactions are enabled by the characteristics of the blockchain infrastructure (Governatori et al. 2018). Smart contracts can act as a more efficient solution to carry out agreements between actors where the conditions are predetermined and visible by the involved parties. The smart contracts can be adapted to the need of the blockchain and the level of self-execution and enforcement can be varied depending on the need. As a component of blockchain the smart contract shares characteristics such as that transactions are traceable and not reversible. It needs to be mentioned that although the smart contract is a agreement between two parties it is not necessarily the same as a legal contract nor can it fully replace it in business settings.

2.1.4.2 Supply chain transparency and traceability

Supply chain transparency, traceability and visibility have become of increasing interest and importance throughout the years as essential elements in the development of sustainable, efficient business operations as well as maintaining good customer relationships by providing a transparent, trustworthy and auditable trail of information. An example where problems with an insufficient degree of transparency and traceability throughout the supply chain have led to serious consequences, where major manufacturers, suppliers and retailers have been accused and charged in various countries throughout the years with fraudulent behaviour encompassing label tampering, re-branding and alteration of content. These revealing's have in turn had serious implications for these industries such as highly fragmented trust between supply chain actors, especially between companies and customers. Companies have come to the realization that they need to increase supply chain transparency and efficiency in their traceability systems to ensure complete and reliable data related to their supply chain actors and operations. The increasing complexity steaming from the globalization of supply chains in conjunction with a higher degree of outsourcing of various activities, information gaps have been permitted in the supply chain due to limited insight and control in business operations external to the company. This is one of the main factors for inefficiencies, allowing exploitation and fraudulent behaviour, causing companies to become exposed to reputational risks, penalty costs and loss of competitiveness and loss of revenues (Sarpong, 2014).

Blockchain technology gives promises of providing a potent solution for fully transparent supply chains in which complete traceability and visibility is possible (Benton et al., 2018). (Benton et al., 2018) further suggests that a major benefit with blockchain technology is that it provides a way to in a tamper evident resilient and permanent way store transactional records over time with an attached timestamp and information about the specific origin for each transaction made, hence giving a complete historic trail. These characteristics of blockchains makes is highly suitable for supply chain applications where companies in an efficient and reliable way need to store, access and back trace information related to for example products specifications, procurement processes, suppliers, manufacturing operations or other supply chain related activities. According to Casado-Vara et al., (2018) this is critical in the identification of origin sources for potential errors or inefficiencies that might occur in a company's supply chain and mitigation of the same, to develop sustainable operations and enhance the overall performance of the supply chain.

Blockchain also have the ability to provide a trustless environment in which network actors can facilitate verified transactions between each other through the utilization of the embedded consensus mechanisms through which a “single truth” can be achieved. This component together with the tamper resistant and distributed ledger technology prevents the manipulation of information, while ensuring the authenticity of all transactions and thus providing a fully transparent system (Casado-Vara et al., 2018).

2.1.5 Limitation of blockchain technologies

From the introduction of cryptocurrencies, especially bitcoin in the financial sector, blockchain technologies have been precluded and painted as the magical formula that will disrupt every industry and reforming markets and business practices. This have led to an array of attempts to implement blockchains in various settings without proper evaluation of its actual use or the negative effects that might come from the same (Dhillon et al., 2017). Even though blockchain technologies theoretically have endless possibilities, its not without its limitations (Yaga et al., 2018), where some of the these will be further presented below.

2.1.5.1 Sustainability limitations

Adoption

The limited adoption and actual understanding of the technical and technological aspects of blockchains imposes both societal and economical limitations. The practical use in organizational or business settings per today are limited as well as the experience and knowledge about the benefits and risks involved. Where blockchains have not yet been mapped extensively, slowing the advancement of the technology. The limited knowledge in conjunction with the fact that blockchain technology is highly unexplored might create friction and resistance when its comes to trusting in the functionality and integrity of the same. Where potential risks and costs are currently seen as outweighing the potential benefits (Chang, Iakovou, Shi, 2018). Another critical limitation is the insufficient legal and regulatory framework for blockchain networks. As described by Chang, Iakovou, Shi, (2018), the distributed characteristics of a blockchain network imply a potential global geographic distribution of participants which makes regulatory and legal management problematic as no standardized framework exists across geographical borders. In addition, smart contracts are not currently seen as legally valid which makes the utilization and enforcement of the same problematic from a legal and regulatory perspective.

Resource demanding

Depending of the characteristics of the blockchain, the consensus algorithm and hashing methods used, see figures 5 and 6, an inherent economical limitation is the extensive consumption of electricity and computational power that is required to process and validate transactions on the blockchain network. Hence there are high costs attached to the utilization of blockchain based network for both costs of electricity and purchasing of hardware for setting-up and maintaining the network (Yaga et al., 2018). This is one of the major limitations of public blockchains using proof-of-work. As more participants join, the slower the network becomes due to increased consensus complexity, while requiring additional computer power to maintain the network.

2.1.5.2 Technological limitations and Security

Trade-off between speed, control, scalability and efficiency

As stated previously, depending on what type of blockchain is utilized, there is a trade-off between transaction processing speed and security of the network. Where (Chang, Iakovou, Shi, 2018) suggests that, while the decentralized and distributed architecture together with the consensus and cryptography mechanisms of blockchains enables a high level of security and a trust-less environment. Current blockchain applications are suffering from scalability constraints due to the slow processing capacity of transactions. (Chang, Iakovou and Shi, 2018), further state that current blockchains can only process a maximum of thirty transactions per second, while VISA electronic processing capacity is at least 2000 times that amount.

Interoperability and architecture challenges

Current blockchains only partly support exchange of transactional data between different blockchain network (Chang, Ikaovou and Shi, 2018). This poses a real challenge, as network participant currently have to collectively agree on the utilization of a common interface. Hence the architecture, functionality and features in developing a blockchain requires extensive consideration in regards to both present and future area of use and application. The immutability of the blockchain also restrict actors from changing the blockchain itself once implemented. Where transactions and information once stored on the blockchain are permanent and cannot be altered. This imposes a potential limitation as incorrect or malicious transactions cannot be changed. Which is especially important to consider in the utilization of Smart contract, where continuous changes to the predefined terms and conditions in agreements between parties initially programmed to be self-executed may be necessary.

Human and system errors

Yaga et al., (2018) stipulates that blockchains are prone to both human and digital systems errors as any other digital system. Where the blockchain may record falsified or incorrect data transactions published on the blockchain. Where the network assumes that the information is anchored to and reflects the reality. Hence, blockchains are reliant on external systems and humans for ensuring the authenticity of the data that data transactions transmitted on the network are accurate. Furthermore, even though blockchains are evaluated as a fully secure and trusted systems, these are still reliant on the capacity of its developers to eliminate bugs and loopholes (Chang, Iakovou, Shi, 2018). Where one of the major flaws with blockchain technology is the so called 51% rule. Allowing a collective of network participants to take control over the network, should they gain control more than 50 % nodes, where the same will have the ability to alter data or disrupting the distribution of the same (Yaga et al., 2018).

2.2 The Manufacturing Supply chain

A supply chain can be defined as operating system i aiming at in various ways and stages creating, and transforming products and services to satisfy a market or customer need. Encompassing various organizations (actors), their unique resources and related operations as well as information flows between these. A supply chain can be further considered a network of interdependent actors connected through interdependent relationships, information and material flows, where the same collectively utilizes their combined resources and technologies (Chandra, Grabis, 2007). The material flow refers to the physical flow of raw material, components and finished products. Consequently the information flow refers to the actual transactions of information between the different supply chain instances and commonly starts with some kind of order demand input initiated from the customer's end. An illustration of a generic Supply chain, and the material and information linkages between actors is provided in figure 7. Figure 8 illustrates a general Supply chain network.

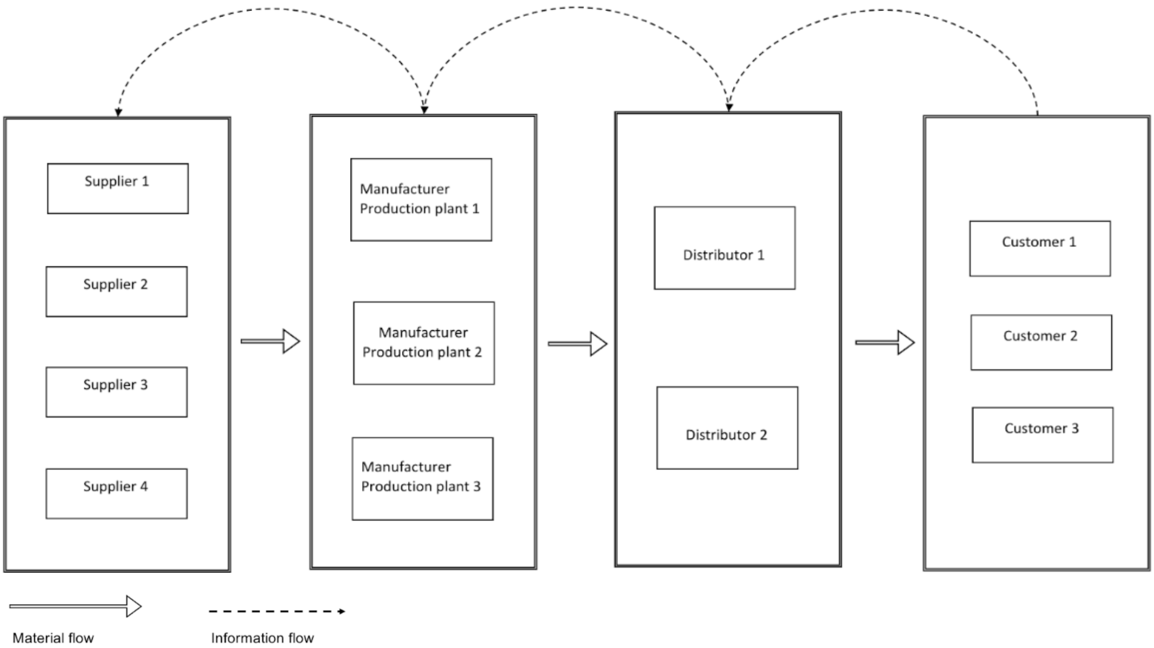

Figure 7 - Horizontal extent of a general supply chain, adopted from Chandra, Grabis (2007)

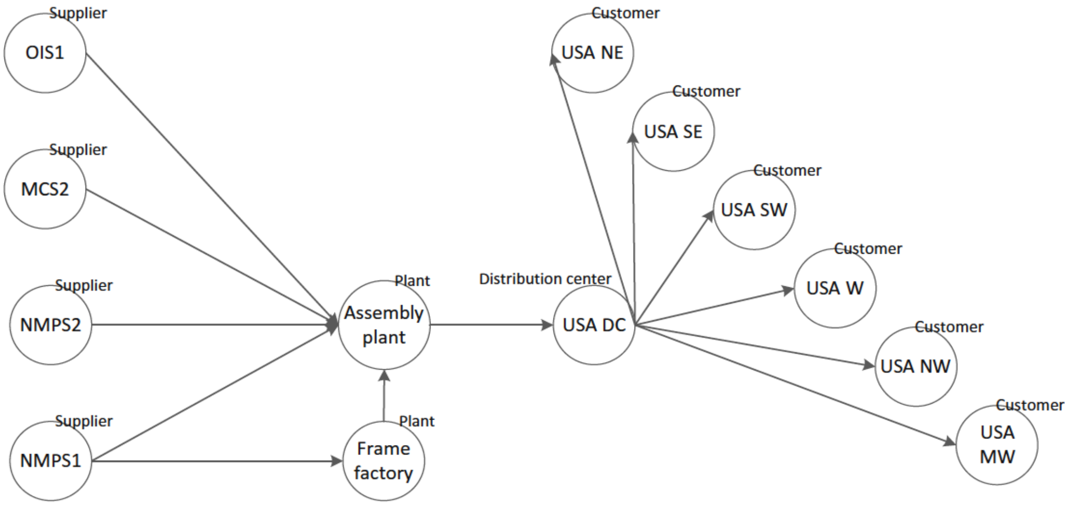

Figure 8 - Illustration of a general simplified Supply Chain Network (Chandra, Grabis, 2007, p19)

According to Chandra, Grabis (2007) the Supply chain network represents the structural pillars while the collaborative activities collectively performed by the actors in that network represent the dynamic linkages between the different actors which are part of the network. *Where "the supply chain inputs are materials and services provided by supply chain units outside the scope of the given supply chain, and outputs are products and services delivered to customers"* (Chandra, Grabis, 2007, p23)

The globalization of markets have resulted in the emergence of Supply chains which are characterized by increasingly complex actor networks and relationships, increased number of activities. With the necessity of incorporating and collaborating with additional supply actors and their activities to satisfy the need of decoupled global marketplaces. Where Pearsall (2016,p1) describes the development as, *"there has been an infrastructure change from a single integrated process performed within the boundaries of the traditional corporations to a fragmented and disintegrated process".* The same further states that globalization and transformation of modern supply chains have not only impacted the basic structure of the supply chain. New challenges and risks of large incumbents supply chains have emerged related to transparency and visibility and the consistency of the supply chain. The disintegration of supply chain activities and alternative sourcing strategies such as outsourcing have lead to increased flexibility but a the expense of transparency and visibility and in turn direct control over quality related to supply chain operations, as well as access of data and information input and output from the same.

Outsourcing have presented itself as an appropriate and viable option for coping with and overcoming efficiency limitations and constraint adherent a company's own internal capabilities and know-how as well as the rapid development and globalization of markets Pearsall (2016). Reason for outsourcing can be for example, high operating costs, focus on core activities, reduced development costs, get access to new technology and know-how currently not present in the company (Weely, 2010). Where outsourcing according to Weely (2010) can be described as a process where certain supply chain functions and activities once performed by the company have been transferred and are now being bought in from a third-party supplier. Where according to the same, outsourcing includes four important elements, 1) encompass as already stated, activities are transferred to an external third-party, 2) resources and knowledge are transferred to the external party, 3) the relationships is characterized by collaborative and trusted commitment over a longer period of time, 4) lastly new costs-risk profile emerges. Some of the major advantage and disadvantages with outsourcing are illustrated in the figure 9 below:

Advantages	Constraints
Resources can be directed and focused towards core business actvities	Increased dependence on suppliers
Optimized utilization of knowledge, resources and third-party expertise and experience	Necessary to continuously monitor and audit suppler relations
Increased operational flexibility and capacity	Risk for commnication and organizational management problems in the advent of outsourcing
Primary processes and operations becomes more easy to manage due to increased focus and resources available	Risk for unwanted access to sensitive or confidential information and data
Information from an independent third-party source reduce risk for acting on short-term and introvert solutions	Powerbalance and conflicting intrests, inability to deliver according to agreements and incentive for corrective measures
	Risk adherent to losing critical strategic knowledge

Figure 9 - Advantages and constraints with the utilization of outsourcing as strategic option, adapted from Weely (2010).

Pearsall (2016) further states that the increased complexity can also be attributed to the introducing of new emerging information and communication technologies (ICT) and the fundamental change in the supply chain structure. Where, traditionally the supply chain structure commonly encompassed a *"simple pyramid structure where one sub-tier level builds on another"* Pearsall (2016,p2). Modern supply chain now instead consists of several layers (tiers) of suppliers which in turn have their network of sub-supplier and on it goes, creating a highly complex web-like structure of actors, creating challenges and risk related to the management and coordination of supply chain activities, material flow and information flow.

The introduction of new information technologies such as have enabled a higher level of end-to-end interconnectedness and more efficient ways for communicating and consolidation of knowledge and expertise between supply chain actors. Organization's ability to efficiently capture, consolidate, store and share data from a multitude of information sources have heightened significantly during the last few decades due to this technologies advancement. However, due to faulty configuration and the lack visibility and transparency in supply chain actors business operations in conjunction with limited incentive to properly document and share data, the challenges of data traceability in which data can be tracked and traced back to the root cause in the advent that potential errors occur remains. Making is extremely difficult to establish who and what carries the responsibility in the investigation of for example warranty cases and how the same issue can be mitigated in the future (Pearsall, 2016), imposing unnecessary costs and use of resources related to the highly reactive approach.

Campos, Miguez (2009) further states that there are some inherent traceability challenges of modern supply chain directly related to the interoperability between the different company specific IT and business systems solutions and interface utilized by various parties in the supply chain. The same further describes that efficient and value adding traceability solutions should provide not only a sufficient historic track record of transactions and documentation, but it should provide the correct and necessary data in relation to a company's specific traceability requirements both downstreams and upstreams in the supply chain of firms. The overall development have put increasing pressure on proper Supply chain management operations which refers to the management practices, coordination, configuration and controlling of the supply chain and involved actors encompassing manufacturers, suppliers, distributors and customers as well as activities related to production and delivery, innovation and product development, procurement and purchasing of materials as well as the flow of goods and services. With the aim to deliver higher customer value through the achievement of a higher degree of efficiency and synchronization of the these activities (Hutt, and Speh, 2013). Cooper and Ellram (1993) provides a descriptive and contrasting overview (see figure 10) between the traditional and the modern perspective on supply chain management practices and shift of focus.

Element	Traditional management	Supply chain management
Inventory management approach	Independent efforts	Joint reduction of channel inventories
Total cost approach	Minimize firm costs	Channel-wide cost efficiencies
Time horizon	Short term	Long term
Amount of information sharing and monitoring	Limited to needs of current transaction	As required for planning and monitoring processes
Amount of coordination of multiple levels in the channel	Single contact for the transaction between channel pairs	Multiple contacts between levels in firms and levels of channel
Joint planning	Transaction-based	Ongoing
Compatibility of corporate philosophies	Not relevant	Compatibility at least for key relationships
Breadth of supplier base	Large to increase competition and spread risks	Small to increase coordination
Channel leadership	Not needed	Needed for coordination focus
Amount of sharing risks and rewards	Each on its own	Risks and rewards shared over the long term
Speed of operations, information and inventory levels	"Warehouse" orientation (storage, safety stock) interrupted by barriers to flows; localized to channel pairs	"Distribution center" orientation (inventory velocity) interconnecting flows; JIT, quick response across the channel

Figure 10 - Characteristics differences between traditional ways of managing the supply chain and (Cooper and Ellram, 1993)

2.2.1 Actor roles, relationships and trust in the Supply chain

A generic supply chain commonly encompass four distinct actors, supplier, manufacturer, distributor and customer which each have a unique role in the supply chain of firms. The role of the common supplier is related to the sourcing of raw material and in the provision and delivery of materials products or services to another entity upstreams in the Supply chain. The relationships characteristics between a company and its suppliers can be short-term transactional based as well as more long-term through for example strategic long-term contracts or collaborative partnerships (Chandra, Grabis, 2007).

The purpose of the manufacturer is to transform raw material and semi-finished goods into a finished assembled product which is then sold and sent upstream in the supply chain to a distributor for further distribution to the customer. In contrast the role of the distributor in the Supply chain is related to the distribution and delivery of finished goods to the end customer. Lastly, the customer's role is related to the purchasing and use of the delivered products or services from the distributor (Chandra, Grabis, 2007).

2.2.1.1 Actors relationships

As stated by Cooper and Ellram (1993) actor relationships have transitioned towards becoming more partner-like with a collaborative character and long-term perspective. Companies have realized that in order to stay competitive they are forced to achieve increased operational efficiency and increase the overall performance of their supply chain. In order to achieve this the same have been forced to enter into various kinds of strategic partnerships and collaborations and rely extensively on outsourcing.

Hutt, M and Speh, T, (2013), suggest that the characteristics of the relationships between the supply chain actors directly affect the efficiency and overall performance of any supply chain. Where close and collaborative relationships and coordination of the same have become an increasingly important source of competitive advantage as it promotes collective goal, to create higher value for the customer and researching higher efficiency through the capitalization of the collective skills and knowledge base. A prerequisite and challenge for successful collaboration and achieve high performance within the supply chain network is trust. Cooperation and collaboration is also necessary for reducing the emergence of conflict of interest and risks related to opportunistic and fraudulent behaviour.

2.2.2 Supply chain transparency and traceability defined

Supply chains can be complex structures with many different actors involved. With the current debate on sustainability it becomes increasingly important for companies to be able to map their products from the sourcing of the raw material up to the point where the customer uses it. In supply chain management three critical concepts in order to create an effective and sustainable accepted supply chain is transparency, traceability and visibility. The first is enabled and achieved through the enactment of the last two elements. Although the three concepts are interconnected they each represent different areas in supply chain management which should be carefully and thoroughly addressed (Morgan et al., 2018).

2.2.2.1 Supply chain transparency (SCT)

Supply chain transparency refers to the level of openness and disclosure of information as well as the extent that stakeholders, customers and end-users have access to information about the various actors in the supply chain, encompassing the companies, suppliers, their respective business operations and sourcing options used. Transparency can be further stated as the elimination of gaps in the information flow showing accountability, and ensuring that standards related to quality, safety, and ethics are met, in which traceability and visibility are considered key element (Morgan et al., 2018).

2.2.2.2 Supply chain traceability

The global standards organization (2017) defines traceability of a product or service as the ability to trace the origins of its parts and materials, as well as its processing history and after delivery, its distribution and location. Where Cheng, Simmons (1994, p. 4). defines traceability in a similar manner, as *"the ability of a system to indicate the current or historical state of activities" and implies that for an object to be fully traceable it needs to be mapped from the point of which its most basic elements are created and manufactured all the way up until it reaches its final customer"*. Traceability and the capability for tracing of specific information related to companies upstream and downstream supply chains activities and products have come to play a vital part as it allows supply chain members to keep track of the maintaining of performance levels and established standards related to the same. It also provides a faster way to establish a reference point for evaluation and monitoring of operations as well as improved accuracy in the identification of problem origins when they arise, allowing for quick problem solving and continuous improvements to be made (Bosona and Gebresenbet, 2013).

2.2.2.3 Supply chain visibility (SCV)

Supply chain visibility refers to business-to-business information and data transactions and sharing with the aim of making data readily available to the stakeholders in the supply chain. Visibility is thus related to information and data management to make the supply chain system operations more efficient through sufficient and effective information sharing and connectivity, in turn allowing the actors incorporated in a company's supply chain and their various functions to collaborate more effectively and help mitigate risks. Having a sufficient degree of visibility is critical as it allow for better decision making, enabling actor to take informed decisions regarding planning and their interdependent supply chain operations in relation to various factors of demand and supply. This will in turn lead to improved synchronization and an better overall performance as cooperation is promoted where actors can collectively, identify, respond to and solve problems more quickly (Morgan et al., 2018). A sufficient degree of visibility also increases trust between supply chain members further promoting increased performance and improvements. For example, in the case of a manufacturer who deals with contract outsourcing or packaged goods, the importance of visibility would encompass insight into and knowledge about interruptions and other risk factors such as inventory shortages along the chain that could potentially affect product delivery.

2.2.3 Information and communication technologies (ICTs) in supply chains

According to (Deitz et al., 2009; Kelepouris et al., 2007) the technological development is a prominent enabler in the development of global supply chain configurations and enhanced traceability. Through utilization of information and communication technologies such as the internet and integrated EDI (electronic data interchange) systems, companies are taking advantage of swift coordination and information sharing across supply chain actors and their respective operations in the modern age. Larger as well as smaller companies have become irreversibly relient on various IT system for managing internal and external business operations and for improving transparency and traceability of the same. Where companies have incorporated a unique IT ecosystem with features adapted for their specific businesses (Fransman, 2007). This have contributed to the complexity and difficulty of attaining supply chain transparency due to compatibility problems giving rise for latency issues and slow response, conflicting data and limited visibility leading to decreased trust and lower supply chain performance (Deitz et al., 2009; Kelepouris et al., 2007).

The introduction of new traceability systems such as the *RFID (Radio frequency identification system)* which uses electromagnetic fields for automatic tracking and tracing of objects. Where the same provides a product or component with a unique identification ID tag, that contains data about the specific item or object (Martein Meints, 2007). The technology is a two-way communication system, where the RFID tag transmit an encoded radio signal at a certain radio frequency to be captured and read by an RFID reader. Which scans and decodes the identification ID data and other item related data stored on the tag, such as the origin of the item, production operation data, dates, stock or batch number. The system provides each tag with a unique serial number, allowing for simultaneous scanning and identification of multiple items and data sets at one time without errors or interference, where batches can be read instantly (Martein Meints, 2007). This type of system can be effectively utilized in various supply chain applications such as tracking of goods, toll collection and contactless payments, tracking and billing systems as well as inventory systems. The advantages with the modern RFID systems can be attributed to foremost to the canceling out the need for manual data entry through its automatic identification. In addition, the miniature size of RFID tags allow for easy attachment and concealment in various items and object containers while the tags data remain readable (Weis, Stephen, 2007).

Technological advances have also lead to the introduction other identification track and trace systems such *barcodes*. In contrast to RFID systems which uses electromagnetic fields, barcodes uses visible parallel lines in which different data sets may systematically be encoded by altering the spacing between the lines. The disadvantages of using barcodes can be attributed to the functional limitations and need for manual reading and data entry as well as having the requirement of being visible in order to be scanned. Barcodes may also only be read one at the time in contrast to RFID tags, where multiple tags can be scanned and processes simultaneously (Palmer, 1995). The benefits of a barcodes system can be associated with the possibility of attaching a unique identification number to a specific item or product and easily link product-related information and data about the origin, quantity, item type, shipment order number, or destination to that ID number, which is stored and later accessed using a database (Burke, 1989).

2.2.4 Supply chain sustainability

An increasing number of companies connects various sustainability initiatives with long-term profitability and competitiveness (Closs et al., 2010). Where sustainability have been defined as "*a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations*" (World Commission on Environment and Development, 1987). Hence supply chain sustainability can be seen as the operational and process management practices encompassing efficiency initiatives trough cross-functional integration, development and incorporation of value-adding processes throughout the supply chain. The same further highlights that the level of sustainability is closely connected to level of transparency and traceability a firm maintains in its activities. (Closs et al., 2010) suggests that there are four different dimensions at the core of sustainability, environmental, economic, education and ethics. The four dimensions will be further explained below.

2.2.4.1 Environmental

(Closs et al., 2010) states that the environmental dimensions of sustainability is commonly associated with reactive rather than proactive actions considered to be without inherent value for the company, initiated only as a response to regulations imposed and enforced by the government with the purpose of minimizing the negative environmental impact of companies business operations. However, companies that pursue environmental effort beyond what is required by regulation may reap also additional competitive advantages through conservation of resources, reducing waste and reach higher supply chain efficiency through better business practices (Corbett, Kleindorfer, 2003).

*2.2.4.2 Economic*al

The economic dimension refers to the degree which a company's is able to develop and initiate value-adding activities while at the same time reducing overall costs of these activities. Where (Closs et al., 2010), suggest that this dimension encompasses two sub-categories, internal management and external management upon which a company may achieve economic value. The former considers internal operational practices and philosophies aimed at achieving higher internal efficiency and operational excellence, while keeping costs to a minimum through continuous improvements by utilization of various management philosophy such lean production. The latter considers how activities and business operation external to the firms should be managed to create higher economical value (Lintion, Klassen, Jayaraman, 2007).

*2.2.4.3 Education*al

The educational dimension encompasses continuous development, improvement of the internal key strategic resource, human capital. In a modern and globalized world in which industries are characterized by increasing competition and rapid innovation, firms have come to rely more on the development of the competencies and capabilities of their staff to continuously improve overall performance. Where its imperative for an organization's survival to develop and implement correct strategies, which is achieved through the training of competent managers and implementation of actionable management practices (Closs et al., 2010).

2.2.4.4 Ethical

Related to the trend change towards a more extensive sustainability perspective in business operations, (Closs et al., 2010) highlights the importance of incorporating ethical business practices and enforcing socially accepted policies aimed at creating circumstances with positive environmental and economic impact on society. Companies that does not consider, engage and incorporate transparent sustainability strategies into their daily business operations risk degradation of brand reputation and loss of market competitiveness (Tate et al., 2010).

2.2.4.5 Sustainability benefits

Incorporation of a broad sustainability perspective in long-term corporate and business strategies as well as all supply chain operations may lead to a number of advantages and benefits. Such as supply chain cost savings, increased efficiency and performance in supply chain operations and activities, including sourcing of raw materials to manufacturing of high quality goods and services to final delivery to customer (Lintion, Klassen, Jayaraman, 2007; Closs et al., 2010). Therefore companies should not only focus on their own sustainability initiatives as an isolated entity, rather the entire value chain needs to be taken into consideration (Lactose, 2015).

2.2.5 Four areas affected by limited transparency and traceability in supply chains

The globalization and increased complexity related to modern supply chains where an increasing number of processes and actors are involved have lead to the emergence of certain problem areas and inefficiencies. Some of these problem areas can be attributed to counterfeiting, warranty processes, export control and clearance and remanufacturing of goods. Where some of the adherent issues and constraints that have emerged in relation these are increased complexity and amount documentation, information asymmetries and complex actor relationships. These areas are further defined in coming chapters.

2.2.5.1 Counterfeiting

Counterfeiting is an intentional executed process which involves the imitation of something authentic with the intent to steal, destroy or otherwise take advantage the higher value of the real thing in illegal transactions (OECD, 2009). Where counterfeit products and goods are illegal replicas of the real product and is a form of theft ICC (2017). According to the same there are different types of counterfeiting and piracy of manufactured goods where the most common involves: 1) Straight up counterfeiters that basically produces something that looks almost identical to the original product in shape and size with the authentic manufacturer´s brand on it. 2) Cloners that basically make copies of the authentic product but sell it under a different brand. 3) Lastly we have copycats that break the product apart and figure the technology and functionality behind the product and how its manufactured in order to re-design the product according to their own specifications. Basically cannibalizing on the research and development conducting by the company manufacturing and selling the authentic products.

Counterfeiting have become a universal issue in several industry sectors as counterfeiters have gained substantial ground during the last decades, having a negative impact on the global economy (ICC, 2017). According to OECD (2009), counterfeiting leads to loss of revenues, degradation of reputation and company brands as replicas with lower quality is flooding the market and are being associated with the authentic goods. The poor quality of counterfeit goods may even expose users to serious health and safety risks, leading to permanent damages. Counterfeiting and piracy is stated to have a significant negative effect on innovation as company initiatives are hampered due to decreasing benefits and returns steaming from the same (OECD, 2009). Where estimates according to the ICC (2017) the worldwide scope of counterfeiting and piracy in domestic and international trade in 2022 will rise around 990 billion dollars with continued growth. With estimated overall costs for businesses and society in the range of approximately 1,54-1,87 trillion dollars. ICC (2015) further states that the globalization of markets in which supply chains networks have grown significantly in size and complexity imposes new challenges for companies in relation to counterfeiting. As the number of actors and activities have increased, it becomes more difficult to identify, investigate and mitigate the problem of counterfeiting, due to the limited level of transparency and visibility related to transactions between the same. The challenges adherent to complexity and transparency have opened up new opportunities for counterfeiter to exploit.

Anti-counterfeiting activities have come to gain substantial importance in the business world and have gained ground as a legitimate issue from a government perspective. Where OECD (2009) further states that there are two broad challenges directly associated with battling counterfeiting and piracy of goods. The first challenge encompass issues related to current legislation and regulatory framework where new development of new policies and legislation needs to be considered, aimed at improving current anti-counterfeiting measures to further support and enhance enforcement of anti-piracy and counterfeiting laws. The second challenge is related to the limited awareness of counterfeiting and piracy issues, as well as insight into the negative effects these issues implicate on businesses. Where this can be mainly attributed to the limited transparency between industry and government actors as well as between the various companies themselves, creating the existence of information asymmetries and limited trust. Which in turn leads to limited information sharing and the creation of blind spots that counterfeiters can take advantage of. Trust and perceived mutual benefits are crucial lubricants for enabling more extensive collaboration and sharing of information between the various stakeholders. From which development better strategies and policies in the battle against counterfeiting can emerge and where issues of desynchronization between actors can be mitigated, improving responsiveness (OECD, 2009).

2.2.5.2 Warranty

A warranty in commercial transactions can be defined as *"a contractual obligation incurred by a manufacturer, vender or seller in connection with the sale of a product (...) where the* *purpose of warranty is to establish liability in the event of a premature failure of an item or the inability of the item to perform its intended function"* Wu (2012). Where a warranty agreement often specifies the type of item it covers, agreed period of coverage from the date of purchase, what the warranty covers and liability scope as well as actions to be initiated when a valid warranty claim is made. It further acts as a guarantee and assurance from one party to another, that a specific promise is uphold with reference to the consistency of a product and services sold in accordance with the predefined terms and conditions related to the quality, functionality or product life time levels. Warranty documentation encompass both claims data which refers to the specific data collected and consolidated in the processing of warranty claims. As well as other data which is valuable for proper management of claims analysis of the same. Examples of the former encompass data related to quality issues such as product failure and errors as well as performance issues. Where examples of the latter refers to data and information related to manufacturing, marketing or any other product specific operations and activities external to the claim or warranty process itself. Wu (2012) further provides 4 broad categories of warranty claims types and causes behind the same, shown in figure 11:

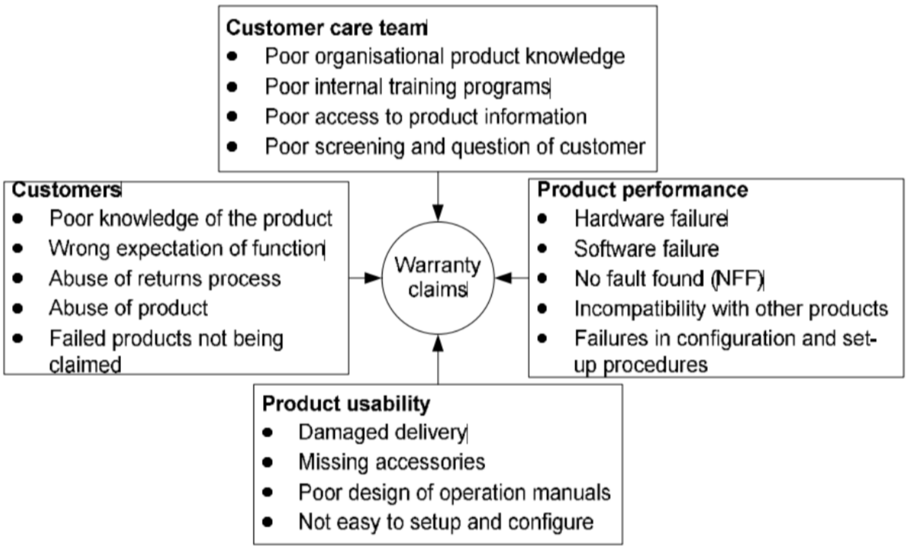

Figure 11 - Examples of causes of warranty claims (Wu, 2012)

Wu (2012) also states that its highly important for companies to incorporate measures to efficiently gather and consolidate information that enables detecting issues related to the reliability or quality of a product early on. As reliable warranty data is not only important for the management and analysis of claims. It can also be utilized in creating opportunities for learning and development of improved product designs as well as more efficient techniques for both proactively and reactively handle specific warranty related issues. And thus prolong product life time, reduce costs associated with product or process maintenance as well as reduced costs and lead time related to the management of the warranty claim process, resulting in increased value achieved both at the customer's end and the organization´s. However, transparent communication and collective sharing of data and information between actors are seen as highly important as it enables higher efficiency in analysis of warranty issues and the root causes.

2.2.5.3 Export control and clearance of military and dual-use goods

Export control and clearance of military and dual use goods refers to the controlling and prohibiting of export of certain goods and items in physical and digital forms. Export control regulations are thus laws and legislation that imposes restrictions on export of certain products and items or even information classified as having dual-use properties. Where dual-use goods refers to standard goods and components which properties and characteristics allow utilization in civil applications as well as military applications or in the creation of weapons of mass destruction (Utrikesdepartementet, 2017). Countries today have implemented regulations designed with the purpose to protect its interest, related to both commerce and military. Where Utrikesdepartementet (2017) states that for strategic export control of military and dual use items states that control of exports of dual use equipment is required in order to ensure that there is no conflicts with national and foreign policy objectives and obligations in term of national and foreign security and in disarming of the enablement of manufacturing of weapons of mass destruction.

Companies seeking to do business with foreign countries through export of goods need to acquire a valid export license commonly commissioned by the national export control authority. The license defines weather the product is classified as a pure military application or if it is dual use. These can be seen as two different levels of severity where a pure military application has the highest level of severity. The necessary information usually required to apply for an export application is primarily adherent to: the specific product, quantity, total value, military or dual-use, description of end-use, depending on end customer some type of certificate (end user certificate or end user undertaking) which depends on if customer is public or private (Utrikesdepartementet, 2017). The activity related to the actual classifying of dual-use goods is commonly performed by the exporting companies.

According to the (Utrikesdepartementet, 2017), the ISP instance (Inspektionen för strategiska produkter) requires companies engaged in export of dual-use goods to continuously provide information and updates about the same, including market development marketing and delivery of duals. Where the information is used as a foundation for reviews of future license inquiries. Manufacturing or sales of dual-use products within the borders of the EU does not as rule of thumb require any specific license. Nextlabs (2019) further suggests that current legal and regulatory compliance solutions are putting pressure on companies due to existing issues related to control and consolidation of export data. Where the use of various business systems and applications, involvement of multiple actor and globalization of markets and multiple geographical export destinations have added significantly to the complexity. The development have lead to reduced transparency and visibility, resulting in companies being forced to take considerable risks and costs for export compliance in terms of fines. According to the same companies due to the current regulatory compliance policies must be able to maintain a consistent flow of information in a secure fashion with multiple supply chain actors distributed across the world. While at the same time mitigating the risk for unauthorized access to the data. Where the security and capacity of existing export control solutions and means of communication such as the use of firewalls and email are limited, imposing increased risk on companies related to unwilling information sharing of a sensitive nature.

The relationships between the companies and the governing authority are according to Nextlabs (2019) utilizes a trust-based model that opens up opportunities for fraudulent behaviour in the advent of a conflict of interest. There is also an apparent traceability and compatibility issue where solutions for storing, consolidating and tracing necessary documentation is considered highly inefficient due to the millions of documents and several data formats and types of inputted and outputted from the various systems in use, resulting in long administrative lead times and excessive use of resources.

2.2.5.4 Remanufacturing

Remanufacturing can be defined as a process of rebuilding or restoring a product or item in accordance with the specifications of the original manufactured product through the use of repaired, recycled or new parts, replacing parts or components which are degraded. Hence, the remanufacturing process differs from the manufacturing process of a new item in the sense that degraded or outworn parts are replaced in order to restore and ensure original and "like new" performance of that product (Johnson, McCarthy, 2013).

Where the inherent benefits directly related to the remanufacturing of goods are for example, lower costs and extended product life cycle as replacing bad parts are often cheaper than purchasing an entirely new product. Remanufacturing also provides a more sustainable option, where purchasing of a remanufactured product can greatly reduce the negative impact on the environment due to conversion of materials through reuse of resources, reduced energy consumption during manufacturing processes and reduced waste (Johnson, McCarthy, 2013). The typical remanufacturing process of products or part encompasses several consecutive steps: 1) *Product collection* where the product is dismounted and gathered*, 2) Identification and inspection* in which an initial analysis of the product is performed, 3) *Disassembly,* where the product is taken apart to access the components with damages*,* 4) *Reconditioning and replacement of parts,* where the deteriorated components are replaced and the product is restored to its original state*, 5) Reassembly, in which the product is remounted in the application, and lastly 5) Quality inspection and testing,* where final quality control and testing of performance and functionality is conducted.

2.3 Scenario planning and analysis

Scenario planning can be in a simple way be described as an predictive approach or method for long-term strategizing for the future under circumstances characterized by uncertainty. Scenario planning is further based on identification of specific uncertainties and making predictive assumptions about potential transformation and changes that might occur in the business environment a company is operating within and how these changes might implicate a company in different ways. Hence scenario planning enhances the ability to take better and increasingly informed decisions and develop flexible and robust strategies for various future outcomes that might come to pass. Where the result if done effectively and efficiently allow for mitigation of risks, as well as increased changes to act on potential opportunities what might arise (Grant, 2015; Johnson and Scholes, 1993).

Scenario planning is often a vital tool in the development and evaluation of corporate strategic options. Where strategic options together with possible future scenarios needs to be properly and thoroughly analysed and evaluation based on their impact and their individual contribution of added value in terms of sustainable competitive advantage and advancement for the organization. Where Johnson and Scholes (1993) highlight three critical criteria for strategic evaluation and analysis, suitability, acceptability and feasibility also referred to as the SFA tripod matrix, see figure 12. Each category within the SFA (sustainability, feasibility, acceptability) matrix is commonly broken down into specific and relevant factors to each strategic option, upon which each factor is assigned a weighted value or rating to indicate the level of importance or impact on the organization. Where the average score of each criteria are then compared to each other, upon the option with highest score is selected.

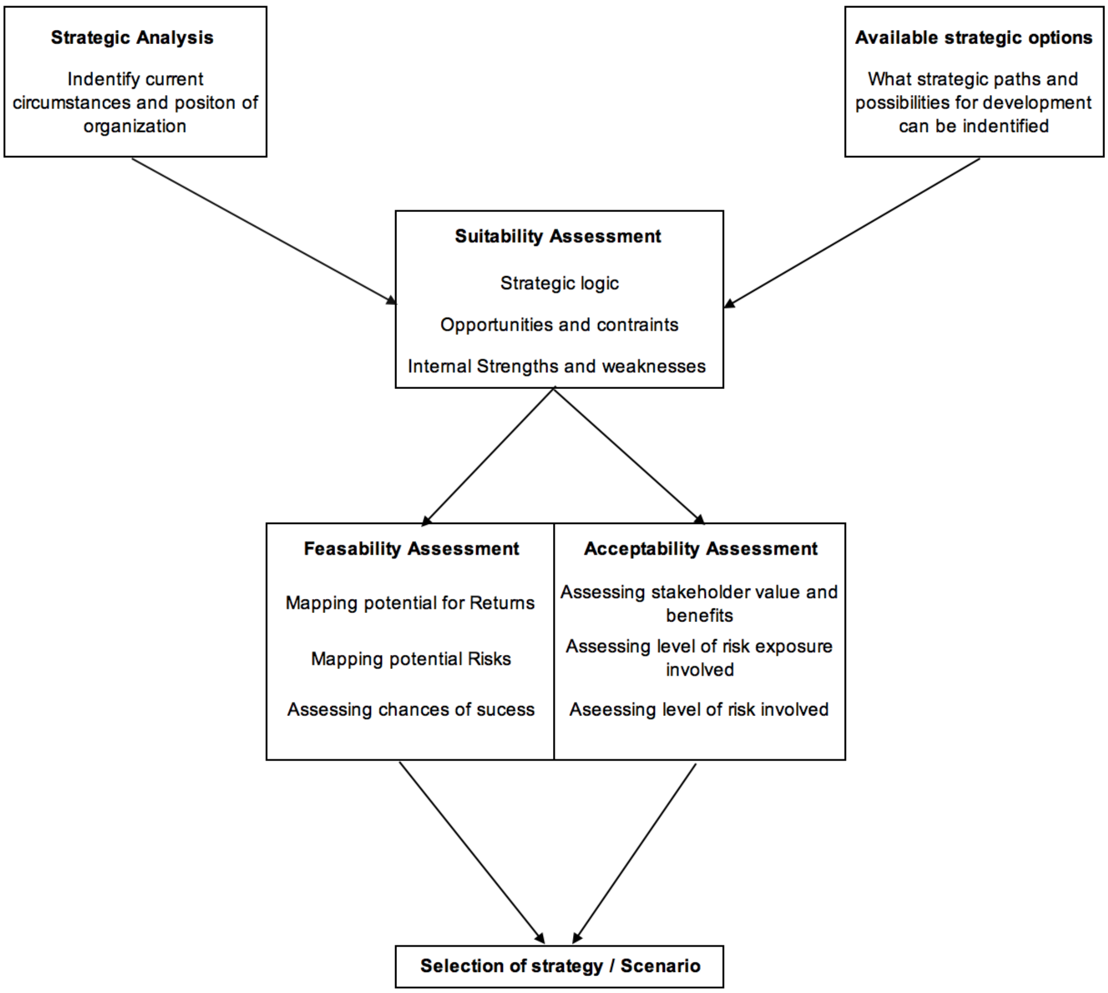

Figure 12 - Illustration of a general SFA model for strategic evaluation, adapted from Johnson and Scholes (1993)

2.3.1 Suitability

The suitability perspective relates to the opportunities and constraints the organization faces adherent to a specific strategic option of business venture and to what degree the company have the ability to capitalize on its internal strength and capabilities to take advantage of emerging opportunities while overcoming or to a great extent mitigate the organization's specific weaknesses (Johnson et al., 2008). The same suggests that this criterion further considers to what extent a strategic option contribute to the enforcing of a company's competitive provenance. This for for example encompass an analysis carried out for investigating if investments into a specific product or business solution is suitable for a company or not, where categories and criteria for assessment should be based on the specific need and wants the company wishes to achieve (Fred and Forest, 2015).

2.3.2 Feasibility

The feasibility perspective is commonly associated with process of objectively and rationally uncover the strengths and weaknesses of an existing business and proposed future business venture through the evaluation of the opportunities and threats present in the natural environment as well as evaluation of the resources requirements in terms of associated costs to carry through the strategic option with success. Which can be defined by the level of additional value created. Common factors used in determining the level of feasibility are for example, internal and external resources, knowledge and competence as well as legal barriers that exists. Where the chances that the organization can overcomes these are analysed. Hence feasibility evaluate whether or not a strategic option could work and be delivered successfully in practice (Johnson et al., 2008).

2.3.3 Acceptability

The acceptability perspective refers to the expectations and level of acceptance among the stakeholders involved in the implementation of a specific strategic option of business venture and how the same are affected a certain course of action. Acceptability further address questions related to the level of risk exposure and potential return accepted by the organization related to specific strategic decision implementation and investments, as well as if it is economically justifiable investment and in line with business strategy. (Johnson et al., 2008). Important criteria for analysing and assessing acceptability in terms of potential return encompass the overall benefits that stakeholders can expect and is measures both qualitative and quantitative through for example profitability levels, cost-to-benefits ratios, impact on shareholder value. Risk specifically relates to the probability and consequences that an organization faces in the advent of strategy implementation, concerning both financial risk but also risks related to the brand and reputation as well as missed opportunities (Fred and Forest, 2015).

3. Method

This chapter cover how the research study was approached and conducted, where the chosen research design will be presented. In conjunction with the presented research purpose and aim of the study, the research strategy and methodology that will be used have been selected and designed so that the stated research questions can be answered. The overall research approach is of a iterative nature and is illustrated in figure 13.

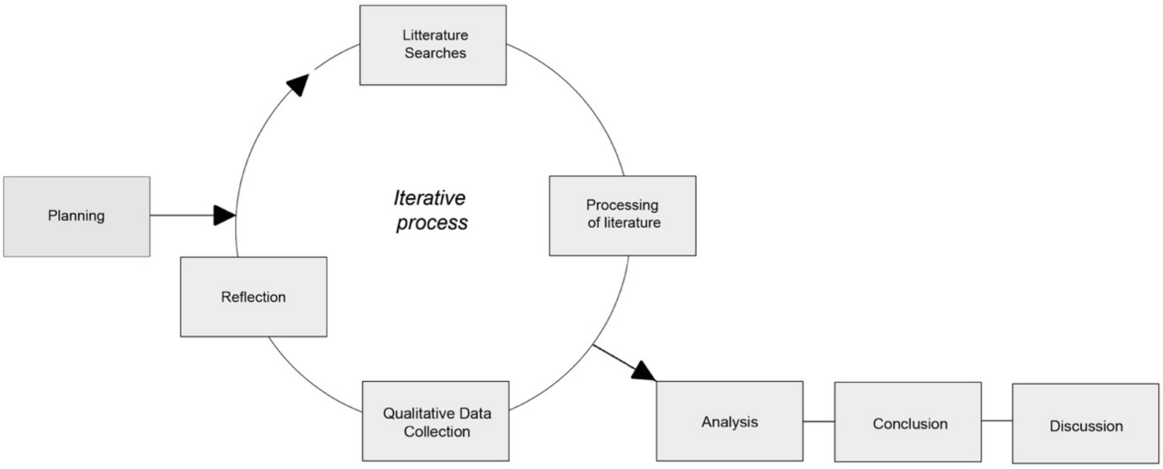

Figure 13 - Methodological approach: A continuous & iterative research process

3.1 Research Strategy

Research strategy can be defined as the "*general plan of how the researcher will go about answering the research questions*" (Saunders *et al*. 2009; p. 90). Its further stated that the research questions and preexisting knowledge and resources available should guide the researcher in the selection of research approach, therefore its further emphasized by (Saunders *et al*, 2009) that the researcher choice of adopted strategy should be grounded in the research questions and objectives of the study. According to Bryman and Bell (2015) there are two broad and commonly used research strategies, qualitative and quantitative. The former can be described as focusing on studying specific phenomena in their natural setting in which the researcher attempt to achieve a certain level of sensemaking by interpreting data as well as the meanings held by people related to the same. The qualitative research is thus exploratory by its nature in which the researcher seeks to understand a problem rather than the identifying and measure causality and relationships between variables as in quantitative research.

The purpose of the study is to evaluate how blockchain technology can provide enhanced transparency and traceability in the supply chain in the manufacturing industry. Therefore the study is of exploratory nature in which a qualitative research strategy have been chosen. The embedded experimental characteristics of the research phenomena, in which various scenarios will be developed and evaluated using specific key performance indicators in order to identify and assess multiple possible outcomes calls for the reflective characteristics of action research in the approach. Action research according to Easterby-smith et al., (2015) is research initiated, from the research perspective that the studied phenomena is constantly changing and evolving rather than being static. Action research further assumes an interactive and reflective inquiry process in which the researcher enters into a collaborative context, actively engaging in the research context in order to understand the underpinnings and causes of potential future outcomes through an experimental and data-driven analytical approach (Reason, Bradbury, 2007).

3.2 Research design and method

3.2.1 Literature

In conjunction with any research study, Easterby-smith et al., (2015) emphasizes that performing a literature review is considered as highly important as this will provide a starting point for the researches as well as a initial understanding and own perspective of the research field. In addition it allows the researcher to establish an awareness of how the research area have evolved and outline research gaps that exists in relation to prior knowledge and research. A literature review should thus indicate firstly, in what way the study is contributing to existing knowledge about the research area, secondly it should be defined why the research is undertaken and that the study is considered relevant to the broader research field.

In this study two individual literature searches have been conducted, where the initial literature search was aimed at capturing four broad research topics, manufacturing industry, supply chain, traceability and blockchain technologies. The literature search was performed in a structured manner using two different search engines and databases, Chalmers library and SCOPUS where different search strings and sequences of specific keyword related to the research area were used in order to generate as much relevant literature as possible. The generated literature from each search was later reviewed in a general manner as to establish whether or not the selection of literature justified further evaluation. The literature identified as having significant relevance was saved and processed in a more thoroughly manner and literature evaluated as redundant was ignored. This is also in line with Easterby-smith et al., (2015), which states that a through and critical evaluation and processing of literature should always be conducted in conjunction with the initial literature review. A critical evaluation provides a starting point for the researches for identifying and framing weaknesses and research gaps in current literature.

The initial literature review thus allowed the identification of a research topic in which previous research was lacking, and a gap existed. It also allowed for the provision of the research context. The second literature review in contrast was aimed towards providing a foundation for the theoretical framework necessary to conduct the research and analyse the empirical data gathered throughout the study. As stated by Easterby-smith et al., (2015) , due to the emergence of new and unexpected empirical findings and new context, the literature review and searches have to be revised to encompass these findings. Due to the nature of the study, where the second literature review and composition of the theoretical framework was conducted in conjunction with gathering of empirical data, this literature review can thus be described as an ongoing an iterative process throughout this research study. Both literature reviews was done with the research purpose in mind as well as the established research questions the study aimed at answering.

3.2.2 Interviews

There are different method for data collection which can be categorized into two broad groups, qualitative or quantitative methods, where qualitative methods seek to gather textual data in contrast to quantitative methods which aims at gathering numeric data. Data collection for this thesis have been made using qualitative method in form of interviews, where according to Easterby-smith et al., (2015) qualitative interviews are commonly used when the researcher seek to gain insights and understanding about the participants worldview and perspectives about the research topic through the understanding of their underlying constructs and beliefs. In addition to the gathering of data through qualitative interviews, data related to the blockchain technology and its business potential in the supply chain of firms have been collected through several literature searches encompassing various sources in form of peer-reviewed articles and academic books deemed to have high relevance to the research area. As well as publications from various established and renowned consulting and researching firms related to the research area. In accordance with Easterby-smith et al., (2015), these two types of sources for secondary data is considered to have high reliability and data quality as these have been revised by experts related to the academic field and is therefore highly appropriate and important for any research study to use.

3.2.3 Interview approach

There are three approaches to qualitative interviews, namely *structured*, *unstructured* and *semi-structured* interviews. Each of these differ in the degree of structure and freedom in terms of how the interview is conducted as well as the level of deviation from the interview guide and research topic that is deemed acceptable. Structured interviews follows a specific set of predefined survey-like questions stated in a predefined order, where the alternatives for answer are limited. Each interview is conducted in exactly the same manner and context. A limitation of highly structured interviews is that they does not allow for in-depth information to be captured about the research topic. In contrast, unstructured interviews open up for a general discussion about a certain topics the researcher wishes to investigate. This approach allow for the possibility to shift focus from one topic to another where the interviewer leads the interview and where questions are developed by the researcher during the process. However, one particular downfall related to this approach of interviewing is that it will likely lead to poor data with low relevance. Semi-structured interviews is the most common approach to interviewing in qualitative research. As in highly structured interview, a set of predefined questions are developed when a semi-structured interview approach is used often referred to as a interview guide. This approach allow more flexibility than structured interviews in terms of follow-up questions and deviation but less than unstructured interviews. Here the interview guide acts as a roadmap while the researcher have the opportunity to further study a certain topic of interest during the process and therefore also allow for a more in-depth gathering of data.

As the aim with the interviews was to capture a broad data set encompassing in-depth insights and knowledge about the research topic, a semi-structured interviews have been used in this study. As the nature of the research is exploratory, it further support the chosen approach. Throughout the study several semi-structured interviews were conducted at different stages with various experienced professionals, with knowledge and experience about the topics of supply chains, the manufacturing industry, procurement and purchasing. During the initial interviews and discussions together with representatives from the case company SKF, four company specific use-case scenarios related to the research area were identified and evaluated as relevant and interesting for deeper investigation. The four scenarios were identified as counterfeiting and piracy of goods, export control and clearance of military and dual goods, remanufacturing and lastly warranty processes. And were selected due to the need for enhanced transparency and traceability in the same. Furthermore, the objective of SKF with evaluation of the selected use-case scenario was to establish firstly how, what and if the added value blockchain technology could contribute. Secondly, the objective was to establish an understanding of what use-case held the most promising potential for further investigation in terms of a potential use-case pilot study in which a practical blockchain solution is developed and tested.

In order to obtain a high degree of trustworthiness the participants included in the study was carefully selected. Where each interviewee and their professional role in the respective fields was evaluated to ensure that the qualification of relevance was met and a broad and relevant base of information would be obtained. This thesis focus on how blockchain technologies can contribute to ensuring enhanced transparency and traceability in the supply chain in the manufacturing industry. Therefore different perspectives and insights on the topics had to be obtained, where interviews have been held with qualified individuals having knowledge and experience in each respective field.

3.2.4 Interview preparation

Prior to the interviews an interview schedule was developed with a set of predefined questions related to the research topic. According to Easterby-smith et al., (2015), having a predefined script with questions can act as an aid for guiding the researcher through the interview process in such way that the same do not deviate from the area which is investigated. In addition, Easterby-smith et al., (2015) states that the interview questions should be developed in such a manner which is easy to understand, minimizing potential misinterpretations and promoting openness for rich answers. Both the points made by Easterby-smith et al., (2015) and the purpose of the research have been taken into consideration in the development of the interview guide that have been used in all interviews of the study with the aim to answer the research questions. The guide was at several occasions adapted depending on what data that was sought to be captured in relation to the the four identified use-case scenarios.

3.2.5 Interviewee sampling

Selection of interviewees was performed using snowball sampling, also referred to as chain sampling or referral sampling where initial contact with a set of relevant participants was established, which in turn allowed for introduction to additional industry experts related to the research area. Snowball or referral sampling approach is assumed to be particularly useful in situation where access to information sources is either scarce, difficult to locate or in other ways limited in access to the researcher (Easterby-smith et al., 2015). By using the participants pre-existing professional network, it allowed for fast and efficient access to industry experts within the respective relevant fields and thus allowed for further data collection deemed relevant for the study. In figure 14 the various participants, their professional responsibilities are presented. A reference for each have also been given, which will be used when specific participants are addressed throughout this study.

Company:	Function:	Professional Title:	Responsibilities:	Reference:
SKF	Export Control of Dual-use Goods	Export Control Officer	Export control and clearance management and documentation	ECO
SKF	Supply chain Management	Supply chain manager	Supply chain operations	SCM
SKF	Group Quality Controller	Director Quality Control	Warranty and quality control operations	DQC
SKF	Business Development Wind O&M - Remanufacturing	Business Development Manager	Global business development operations of remanufacturing services within Wind O&M	BDM
SKF	Factory & Production	Industrial Factory Engineer	Operational Management, inbound and outbound material and information flow in production & Marking and authentication of finished goods	IFE
SKF	Quality Manager, Environmental Health & Safety Manager	Quality Manager, Environmental Health & Safety Manager	Warranty and product health and safety operations	QM
SKF	Business Consultant	Business Consultant	Professional management consulting services and project development	BC
SKF	E-Communication	Logistics and transport Manager	Coordination and management of Logistics and transport operations	L&T

Figure 14: Overview of the interviewed participants in this study and their professional characteristics

3.3 Analysis of empirical data

According to Easterby-Smith, et al., (2015) there are various approaches for analysing qualitative data that have been gathered, where the two most commonly used methods are content analysis and grounded theory. The former aims at *"drawing systematic inferences from qualitative data that have been structured by a set of ideas or concepts"* (Easterby-Smith, et al., 2015, p.540). Meaning that this method is of interpretive nature where the researcher are deducing meaning from the gathered data using pre-existing theory, and or the research questions which the study aims to answer. This approach allows for testing of both hypothesis and for building theories. Grounded analysis and analysis aims at *"derive structure (i.e. theory) from data in a process of comparing different data fragments with one another"*(Easterby-Smith, et al., 2015, p.546). Thus in contrast to content analysis which build on pre-existing theories, in grounded analysis, theories are developed and meaning emerged from the categorization of the data itself. In addition, grounded analysis as an analytical approach is deemed highly complex as a method for deducing data, in which Easterby-smith et al., (2015) emphasis that a high level of experience on the part of the researcher conducting the study in order to achieve efficient use of this approach. Content analysis have been evaluated and selected as an appropriate approach for analysis for this research as the study as it aims at investigating an emerging research area, that of blockchain technology in which inferences will be made between relevant emerging factors deduced from pre-existing theories as well as from the analysis of the data gathered itself. Therefore, this thesis will requires an interpretative approach which further strengthen the argument for content analysis as approach.

This research study aims at evaluating how a nascent and emerging information technology, that of blockchains can enhance transparency and traceability in the supply chain of a large incumbent manufacturing firm. Where it specifically attempts to evaluate how blockchain technologies can potentially be utilized to mitigate inefficiencies related to transparency and traceability in four distinct individual use-cases scenarios where the technology have never been used in a practical settings, but where its perceived to provide strategic and operational add value. In order to allow for an initial evaluation of actual suitability in terms of need and business potential of a blockchain solution, an evaluation tree was developed and used encompassing several sequenced yes or no questions, see chapter 5 Analysis, *figure 16.* An adapted version of the SFA. (suitability, feasibility and acceptability) framework was used for a more in-depth analysis of each individual blockchain use-case scenario´s business potential in order to provide an indication of the strategic choice SKF should pursue further. The SFA framework was selected as a framework for analysis due to its flexibility and ease of use. The SFA framework allowed for a more qualitative strategic evaluation of the different use-case scenarios. In addition, the SFA framework allows for evaluation of strategic options through incorporating company and context specific metrics. In collaboration with the case company several general and broad strategic sub-metrics for each of the categories, suitability, feasibility and acceptability that was deemed relevant and useful in the evaluation of each use-case scenario were developed. Broad sub-metrics was also used to account for distinct characteristic differences of the individual use-case scenarios, while simultaneously allow for a direct comparison between the same in terms of risks versus potential and benefits.

3.4 Research Quality

In accordance with Bryman and Bell (2015), in order to ensure the quality of and trustworthiness of any qualitative research study, the researcher have to consider several aspects such as the *credibility, transferability, dependability* and *confirmability* of the conducted research. These terms will be explained an elaborated in more detail in following chapters.

3.4.1 Credibility

Credibility of research is commonly seen as the most important factor in any research in order to establish trustworthiness. Credibility refers to the extent which the research can be deemed believable and appropriate in terms of how the research have been conducted, where its critical to engage in a transparent presentation of how the research was conducted and how the data was gathered (Easterby-smith et al., 2015). Credibility also refers to the aspect of whether an understanding and correct interpretation of the gathered data and research findings have been made by the researches in relation to a specific worldview or lens through which reality is interpreted (Bryman and Bell, 2015). In order to ensure a high degree of credibility of this research study, the interviews were conducted with a selection of relevant and professional individuals having extensive knowledge related to the research topic which allowed access to relevant data. To the extent possible, notes and recordings of interviews were cross-checked and reviewed at several occasions throughout the entire study. In order to ensure the credibility of the research study, a high level of transparency throughout the entire research process was sought. One aspect which could possibly be considered to have impacted the credibility is the fact that all interviews were conducted in Swedish which at a later stage were translated into english.

3.4.2 Transferability

Transferability refers to the aspect of the research generalizability, which in turn refers to the degree of which the research shows that the findings are applicable in other or similar situations and contexts. Providing a detailed and robust description of the research context, such as the cultural or social context, progression of events and the experiences of the researcher during the data collection process is highly important. It provide researchers external to the study to with a deeper understanding and to make a judgement whether the findings are transferable (Bryman and Bell, 2015).

3.4.3 Dependability

Dependability refers to the reliability of the research findings which can be determined by the degree of consistency and accuracy the study is considered to have. Dependability is achieved by ensuring that the data collected is consistent with the findings and are sufficient enough to give support for the same (Bryman and Bell, 2015).

3.4.4 Confirmability

Confirmability refers to verification of the level of objectivity of the research or the degree of which the findings are shaped or affected by the researcher held biases rather than being based on the participants narratives (Bryman and Bell, 2015). This research have been conducted for academic purposes only, where no form of economic compensation or other forms of compensation from have been received by any of the involved parties. A factor that might be considered to influence the direction of the research or led to alteration of research findings. In addition, is to be stated that the research has been conducted related to the specific research area and topic willingly and independently. From this viewpoint, the confirmability of this study have been ensured.

3.5 Ethics

According to Easterby-smith et al., (2015), studies related to social science and where the data is gathered through qualitative interviews with individuals, there are a number of ethical dilemmas that needs to be addressed. Participants included in the study should not be harmed. Secondly, informed consent should be ensured by the researcher. Confidentiality of research data and protecting the anonymity of individuals should also be ensured. A clear declaration of affiliations and the nature or aim of the research should be stated to avoid deception. Honesty and transparency in communicating of the research and avoidance of misleading or false reporting of research findings should also be ensured (Easterby-smith et al., 2015). The thesis encompass several interviews with several participants from the investigated case organization. Where it has been ensured that no harm came to the participants in form of physical of physiological incumbrance related to participation, by clearly stating that participation and the provision of answers to questions is voluntary. Informed consent was ensured by making all the necessary information available to all participants about the study in order secure that an informed decision could be made about the willingness to participate. The interviewees have also been kept anonymous throughout the research study and the confidentiality of data have been uphold as no sensitive data related to the companies businesses have been included or shared in this study without a formal consent.

4. Empirical results

The chapter presents the empirical results consisting of two parts. Firstly, in chapter 4.1 "blockchain technology", results and findings from conducted literature searchers on secondary data sources related specifically to the areas of blockchains, supply chain transparency and traceability are presented. Secondly, in chapter 4.2 and 4.3, the empirical results from interviews conducted at the case company with industry professionals are further presented.

4.1 Blockchain technology

The results and findings from the literature searches in this subchapter highlights various aspects of the blockchain technology and smart contracts in relation to supply chain transparency and traceability. Furthermore, the empirical results have been gathered through literature searches and consolidation of data from industry reports on blockchain technologies from several professional consulting firms exploring blockchain technologies. Common blockchain misconceptions, market contexts where a need for blockchains exits as well as potential application areas of blockchains are also presented. Furthermore, various approaches to blockchain setups will be presented together with several use cases from different organizations and business settings in which the practical use of blockchain technology have been evaluated through pilot projects. Lastly, common barriers and limitations of blockchain technology are presented.

4.1.1 The need for blockchain technologies

Ey (2017) states that there has been two major shift in how global supply chains functions during the last 30 years. The first being that the supply chain has gone from traditional constellations of manufacturers and suppliers into complex ecosystems with a lot of different actors involved while simultaneously attempting to coordinate their actions. The second change being that the dynamics of supply chains has increased. This is all happening at the same time as supply chains themselves are becoming a more important part in developing competitive advantage. As highlighted by EY (2017) the technology to support this shift in supply chain operations has not been able to keep up with the transformation creating what EY describes as "islands of insight", however the same further states that blockchain technology has the potential to create a more consolidated view.

Deloitte (2017) describes certain inefficiencies across supply chains that could be potentially be mitigated by blockchain technology. The first problem being that companies lack product related traceability in terms of ability to oversee events and related metadata. This inefficiency could possibly be dealt with through full auditability, where blockchain allows an eternal track record of the data flow in the supply chain (Deloitte, 2017). The second inefficiency is the current and complicated management related to compliance as companies needs to implement standards and controls in order to be able to provide evidence that they meet regulatory conditions. Where blockchain manages this by being tamper proof and immutable (Deloitte, 2017). Lastly, there is a lack of flexibility, where supply chains needs to quickly respond to external changes while keeping down costs. Here Smart contracts could be used to facilitate real time tracking of data (Deloitte, 2017).

Accenture (2018) highlights the complex problem of communication within the supply chains where each actor has its own version of documentation without having an efficient mean to synchronize transactional data across the involved parties, which easily leads to errors and duplications. Accenture (2018) further estimates conservatively that 10 percent of all freights have some form of issue with them. These errors and miscommunications could to a large extent be reduced with blockchain technology by creating a trustworthy single point of truth for the actors involved in a transaction.

IBM (2018) highlights that some of the most imminent challenges for global supply chains in various industries can be attributed firstly to limited visibility and data consolidation, where fragmented record keeping and information exchange at various supply chain points causes, system inefficiencies and inconsistencies due to information asymmetries as well as incomplete and unreliable data related to for example product certifications as a result. Another adherent challenge of modern supply chains can be further attributed to the general poor level of transparency, traceability and trust where companies lack the ability to efficiently identify root causes of product failures and more importantly establish where in the supply chain the problem originated. IBM further states that blockchain based record keeping have the potential to mitigate these problems by making all necessary information available and accessible simultaneously to all supply chain actors in a secure fashion. Blockchain based supply chains also have the potential to enhance transparency, traceability and visibility by allowing companies to create a complete trail of all transactional data related to a specific product´s physical flow, and processing activities.

4.1.2 Business potential of blockchain technologies

According to WTO (2018) blockchains *"could be to transactions what the internet was to communication. By breaking the various silos that currently exist between the many parties involved in cross-border trade transactions, blockchain could bring trade globalization to another level. (...) However, blockchain is not suited to all situations, nor is it a panacea for all problems. The technology works best in circumstances where multiple parties are involved in transactions that require trust and transparency."*

PwC (2018) states that blockchain technology have become a buzzword on everyone's lips. Where the emerging technology through its distributed, immutable and tamper proof nature, have the potential to offer very much needed increased level of transparency and traceability which in turn will increase efficiency and reduce the overall costs by removing existing friction in supply chain operations. Blockchain's transparency further provide a complete trail of documentation related to a product's journey from its point of origin to the end customer. This increases the trust among the various parties in the supply chain as all transactional records and data are visible for everyone with access to see.

EY (2017) also state that blockchain has many advantages to offer supply chains through mitigating of current issues related to the limited degree of transparency and traceability in information sharing in large networks characterized by many actors. Where according to the same, blockchain can potentially offer numerous improvements and opportunities for development of new business models in a variety of business areas. EY (2017) have identified several such application areas, one being the procurement process where blockchain is suggested to derive high volume purchase benefits by tracking purchases across subsidiaries and related parties within the company's supply chain network. Another application area is the ability to create more reliable data analytics, better forecasts and lower inventory levels or instance, due to the lower uncertainties, such as real time data and visibility, provided with the blockchain technology. EY (2017, p4) *specifically states that "while that inventory is often cheaper than a lost sale, it's far from free (...) it is often estimated that keeping $1 of inventory costs 20 cents to 40 cents per year, when you account for both the cost of capital and the rapid depreciation of technology products".*

Accenture (2018) further state that blockchain based systems can help mitigate a serious problem characterizing today's supply chains related to what the same refers to as *"the hall of mirrors´ effect".* Or more specifically the problem related to copies and duplication of records and documents imposing, huge additional costs and inefficiencies due to extensive paperwork trail, errors and desynchronization of records and information between different supply chain points. According to the same, supply chain operations generates a output of several billions of copies of documents continuously. Creating an information and data management problem between supply chain parties. Where simple individual changes in invoices or quotas, or other changes related to certain business activities requires synchronization and reconciliation of changes made through all supply chain channels. Which is today solved through establishing and sending new copies of documents encompassing the alterations made. In turn leads to errors, miscommunication and loss of the overall supply chain performance in terms of responsiveness and flexibility as tracking and tracing all data and information related to all supply chain operations becomes a highly difficult task.

Accenture (2018), further highlight that it's not uncommon for a company to pay around 10 dollars in average per invoice to manage billings which leads to high extreme unnecessary costs due to the high amount of copies. In this case, blockchain have the potential to mitigate this complexity and cost issue by providing a shared ledger system in which all transactions between all parties are recorded, stored and automatically synchronized and updated when a new transaction takes place. In addition, as all information about inventory levels, shipping receipts, invoices necessary to complete trades between parties can easily and collectively be accessed from one point regardless of actors geographical location, the blockchain. This eliminates the need for back and forth reconciliation. Blockchain immutability can also ensure that all the records in the chain are honest and not corrupted. And the high level of security from the cryptographic measures can eliminate the need for unnecessary audits, saving companies both time and money. WTO (2018) states that the transportation cost attributed to the shipping of a container of avocados from Mombasa to Rotterdam is somewhere around US$ 2,000, of which US$ 300 can be attributed to paperwork and documentation.

WTO (2018) further states that blockchain technologies have a positive future outlook within the area of supply chain management, enabling enhanced supply chain transparency and traceability. Which in turn can provide more robust processes to effectively track a product´s path through the supply chain while creating a complete trail of documentation related to the certificate of origin, quality standards and other product, actors or operational specific data. Having a mitigating impact on fraudulent activities and a positive effect on ethical and sustainable supply chain operations. Other positive effects of blockchains can be attributed to more cost efficient trade processes, where according to WTO (2018, p6) *"cost reduction estimates in the financial sector and the shipping industry range from 15 to 30 per cent of total costs"*.

WTO (2018), highlight that the blockchain technology in conjunction with the development of smart contract have great potential within the area of cross-border-trade and business-to-government trade through the digitalisation and automation of various trade processes. Where a specific area in which the characteristics of blockchains are well suited and have much potential is in the facilitation of efficient and transparent border and customs administration processes such as certification and licensing, expediting import and export licenses and release and customs clearance more efficiently. "*Storing an import or export license on the blockchain would save the importer or exporter the trouble of having to keep the permit in a safe place to avoid losing it and would allow customs authorities to easily check the authenticity and validity of the permit" (WTO,2018, p32).* And when it comes to release and customs clearance of goods blockchain could expedite company requests while also providing full transparency and swift sharing of information regarding individual rulings to involved parties as all data is stored on the blockchain in real-time. In turn enabling more efficient transport and logistical operations for companies engaged in cross-border trade while exposing fraudulent behaviour and use of fake permits as well as generating considerable time and cost savings, with benefits for all actors involved.

WTO (2018) also suggests that the blockchain technology have high potential for enhancing transparency and efficiency in the governing of IP (intellectual property) rights, having a positive effect on issues related to counterfeiting. Where *"Blockchain for registered and unregistered rights could arguably be used to provide proof of creation, existence, ownership and/or first use, to register IP rights, to facilitate the administration and management of IP rights on a global scale, thereby potentially contributing to the emergence of "global IP chains", and to enforce IP rights and fight counterfeits in a more efficient way"* WTO (2018, p4). Where the use of individual and product specific hash-based QR tags linked through cryptography to a blockchain can be used for physical products to verify their certificate of origin while more easily detect fakes. The enhanced transparency and traceability that blockchain provides can also have a positive impact on building and maintaining customer trust. Where the customer could potentially access all product specific historical supply chain information just by scanning a simple QR-tag attached on the product with their smartphone.

4.1.3 Smart contracts

Accenture (2018) states that blockchain based Smart contract have the advantage of enabling self-executing transactions when a set of predefined conditions are met, avoiding errors and misunderstandings pertaining transactions between parties. In addition, the automated mechanism of smart contracts allow further mitigation related to the issue and complexity document duplication and desynchronization of information between supply chain parties. It also enable automatic and impartial enforcement of contractual terms and conditions, in which alleviate potential breach of contract.

(EY, 2017) further suggests that smart contracts could be used to enhance efficiency and cut costs related to the payment transaction process of goods by eliminating the invoice time that occurs between the moment that a customer receives the goods until the supplier is paid by having the smart contract automatically trigger a monetary transaction when the blockchain has confirmed the delivery of goods. Such a measure has the potential to simplify financial operations and massively reduce the need for working capital as payments would happen instantly. Smart contract also have the potential to significantly reduce cost related to transactions as the need for physical and manual documentation of for example invoices or quotation is eliminated. Where *"the average U.S. Fortune 100 company has more than 60 days of sales outstanding (...) where all these companies are interacting with each other in contracts that specify payment upon receipt or, at most, within 30 days"* (EY, 2017, p5).

4.1.4 Blockchain setups and models

PwC (2018) states that in deciding what types of blockchain setup to develop, use and implement, participant need first come to an agreement about the design and operating standards of the blockchain system specific to the unique use case. Which encompass deciding whether the blockchain should be based on premises of being pemissioned or permissionless and decide what rules for management and access, reading and writing transactions on the blockchain should be established.

PwC (2018) further state that although the permissionless blockchain mode provides a higher degree of transparency and trust compared to the permissioned blockchain model, it's not deemed suitable for business applications in which sensitive information is transmitted on the network as everyone have the ability to access the data. In this case permissioned blockchains are a better fit as it allow a higher degree of control through incorporation of access restrictions in which only authorized actors have access to view certain transactional data and information. An alternative to mitigate the trade-off between transparency and control a better and more flexibility solution can be achieved by using a hybrid-model building the two extremes, where non-sensitive information is broadcasted on a permissionless while transaction of a more sensitive nature is transmitted on a separate permissioned blockchain. Notwithstanding the model evaluated as the best fit, EY (2017, p7) states that *"the blockchain essentially functions as a layer supplementing your existing enterprise resource planning (ERP) software (...) you can still see your existing user interface and business process. But now, when you look at* *inventory, you see everyone else's alongside your own. And instead of a placeholder of a price, the actual price based on the consumption of your supply chain network is available".*

4.1.5 Blockchain Use cases

With the constant development of the blockchain technology companies active in a variety of industries are pursuing opportunities provided by the blockchain technology. The following subchapter aims at providing some real-life examples of such use- cases of current blockchain endeavors.

4.1.5.1 Maersk and IBM blockchain use cases

The world leading shipping company Maersk in collaboration with IBM initiated a blockchain proof-of-concept project in 2018 referred to as TradeLens to develop a blockchain based shipping solution for the global shipping industry. With the objective to use blockchain technology to enhance collaboration and trade efficiency, transparency and security of transactions between the various actors involved in ecosystem of international trade. Maersk further states that TradeLens initiative future development will encompass involvement of more than a total of 90 different organization and customs authorities, where the blockchain solution will *"empowering multiple trading partners to collaborate by establishing a single shared view of a transaction without compromising details, privacy or confidentiality (...) shippers, shipping lines, freight forwarders, port and terminal operators, inland transportation and customs authorities can interact more efficiently through real-time access to shipping data ad shipping documents (...) to create an industry standard for the secure digitization and transmission of supply chain documents around the world,"* (Maersk, 2018). Lastly, Maersk states that TradeLens have the potential to significantly reduce the transit time of shipments while at the same time enhancing visibility, information sharing and auditing related to tracking and tracing of goods leading to huge cost savings for supply chain actors.

4.1.5.2 Walmart and IBM blockchain use cases

IBM a leading technology development company together with Walmart, a global retail giant have through a collaborative partnership initiated a blockchain two pilot proof-of-concept project to increase food safety by using blockchain as a means to enhance traceability and visibility across the value chain. Allowing tracing of the origin of food products coming from their suppliers network and as a way to more efficiently and effectively battle the hurdles of food safety issues. Where blockchain is stated to provide several benefits, such as enhanced tracking and tracing resulting and elimination of manual processes, enabling shorter response time to product recalls. Heightened ability for regulatory compliance among the various stakeholders while lowering costs related to the same as well as "have end to end visibility across your supply chain allowing you to meet your customers' demands for accuracy, transparency and agility" by enabling a complete and integration solution desynchronization steaming from the current fragmented silo-based data storage mode (IBM, 2017).

4.1.5.3 Daimler AG and Icertis blockchain use cases

Daimler AG, a leading pioneer in automotive engineering, as well as financial services and management have in collaboration with its division Mercedes-Benz Cars and the leading enterprise contract management platform provider Icertis has initiated a blockchain pilot project where the parties counts on blockchain technology for delivering enhanced transparency in complex supply chains. The blockchain prototype is stated to allow a fully transparent mapping and consistent documentation contract transmissions across the entire supply chain. Daimler AG further states that *"it requires its direct suppliers to vigorously pass on and control standards and contractual obligations with regard to working conditions, human rights, environmental protection, safety, business ethics and compliance within the supply chain (...) the Blockchain prototype allows a transparent mapping and understanding of this transmission across the entire supply chain (...) should one of the sub-suppliers deviate from the contractual obligations, this becomes visible in the blockchain, similar to a secure accounting system.* The blockchain prototype creates trust in the integrity of the supply chain by disclosing sustainability-related information, without revealing competition relevant information (Daimler, 2019).

4.1.5.4 Daimler AG and LBBW blockchain use cases

Daimler AG states in a press release that the company during 2017 entered into a successful collaborative partnership with LBBW for launching a blockchain pilot project encompassing a budget of 100 million euros for capital market transactions and financial processes, aiming at making financial processes simpler while increasing efficiency of the same and open up new market opportunities through innovative business models. Daimler AG and LBBW also state that *"Blockchain can affect nearly the entire value chain (..) that's why we, as a leading automaker, want to play an active role in the global blockchain community and help shape the cross-sector blockchain standards (...) where other possible applications of blockchain technology in the financial sector include payment transactions, the securities trade, and the cross-border shipment of goods".* Where the blockchain technology is perceived to completely transform the role of banking institutions as third-party intermediaries for managing capital market transactions and financial processes as blockchain makes it possible to in a direct and secure fashion process transactions across the world (Daimler, 2017).

4.1.6 Barriers and limitations for adoption of blockchain technologies

IBM (2018) state that blockchain technologies are still considered to be in the exploration and experimental phase where knowledge and experience related to the practical implementation and use in business settings are limited and it therefore have considerable levels of uncertainty and risk attached which must be overcome.

4.1.6.1 Lack of standardization and interoperability barriers

Deloitte (2018) states that there is an apparent need to enhance standards of the various blockchain platform systems that exists today, where standardization is critical for enabling integration and interoperability between existing blockchain platforms as well as actors networks and digital IT systems solutions currently implemented in the countless industry and business settings. In order for blockchain to achieve a solid foothold, the barrier of standardization have to be overcome, allowing actor and system networks to interact and communicate with each other, something that is currently not possible due to the limited level of interconnectivity. PwC (2018) also highlight interoperability and lack of standardization as one of the main concerns in the success of blockchain solutions. Where a higher degree of standardization is a fundamental requirement in enabling consolidation and governance of the large number of transactional records and data outputted from the various actor and IT system networks. It requires integration of several different ERP systems, databases and actors. Jabbari and Kaminsky (2018) also highlight the hurdle of how a specific blockchain network can become linked to other external markets and industries. Jabbari and Kaminsky (2018) further states that if there were only a single blockchain based market in which everyone was engaged, all transactions made in that market could be traced and verified. In reality, this is obviously not the case, where a supply chain or product is often linked to several overlapping markets in which different actors interact, making traceability and verification of origin more difficult.

4.1.6.2 Scalability and performance barriers

Blockchain systems stills struggle with accommodating large scale users at the same time. Deloitte (2018) highlight that blockchain based systems faces a major challenge in solving the existing scalability issue. Where compared to conventional databases, blockchains are slow with time consuming transactions and operations speeds due to the inherent limitations pertaining the existing consensus models and is therefore not considered as suitable for large-scale operations. Deloitte (2018) further highlights the issue through comparison, where traditional systems for processing transactions can reach a processing level of several thousand transactions per second, while public blockchain platforms such as Bitcoin or Ethereum are only able to process transactions in the very low two-digit span per second. PwC (2018), explicitly states that blockchain based supply chains tracking and tracing operations and resolving issues relating to scalability is a multi-actor endeavor, relying on network wide collaboration for success.

4.1.6.3 Complexity and cost barriers

Deloitte (2018) also states a concern related to low cost efficiency, where blockchain based systems requires vast amounts of energy and computing power to keep the network and transaction processing operations running imposing huge costs for network actors. However, this issue might mitigated with new and emerging cloud offerings coming to the market. Jabbari and Kaminsky (2018) further highlight, a concern related to how sufficient storage space can be allocated in order to store the large amount of transactional records made on the blockchain. Jabbari and Kaminsky (2018) further states that the transactional data emitted from the general supply chain is very extensive and complex. Transactional records from the supply chain that need to be stored and managed on the blockchain encompass not only data about the transaction itself, but also data related to for example production operations parameters and product requirements and structure. Resulting in huge amounts of data that needs to be consolidated, stored, verified and shared between network actors. In order to keep the trust that the decentralized nature of blockchain enables, each actor will thus be required to invest quite heavily in data storage utilities and solutions.

According to Jabbari and Kaminsky (2018) a supply chain specific barrier can be attributed to, how the physical material flow can be properly linked to the digital blockchain ledger. In contrast to blockchain based digital currencies in which no transactions of physical goods need to be considered, supply chains encompass various physical flows (transactions) of products and materials not directly linked to the digital blockchain ledger. Where established technologies such as regular barcodes or RFID-tags that are used to create a digital footprint linked to the physical flow in supply chains comes with inherent problems related to duplicability, making these susceptible to fraudulent behaviour. Where for example a fraudulent actor can simply duplicate the original barcode or RFID signal and attach the same to counterfeited products.

Another issue stated by Jabbari and Kaminsky (2018) is directly related to how the complex structure and unique requirement of each individual chain can be accounted for in the utilization of blockchain. Most supply chains often encompass several main as well as sub- operations, creating a complex web of activities that are performed by different actors and company specific functions within the supply chain. How data and information related to these activity and actor linkages is to be captured, consolidated and sorted is a major barrier in the utilization of current blockchains.

4.1.6.4 Regulatory and legal barriers

Regulatory and legal uncertainty have been highlighted by PCW (2018) as one of the main industry related barriers that needs to be overcome for a widespread adoption of blockchain technologies. Establishing support from governments legal institutions, where a new, broader regulatory framework encompassing cross-border trade and favoring the development of blockchain, token and smart contract technologies is deemed necessary. PCW (2018) further state that companies should aim for collaborating with various authorities to circumvent the obstacle of compliance and collectively, through increased transparency, create a deeper understanding of how industries evolve, to efficiently take advantage of emerging opportunities and enhance regulatory compliance. Where "the wide-scale deployment of blockchain requires a conducive regulatory framework that recognizes the legal validity of blockchain transactions, clarifies applicable law and liabilities, and regulates the way data can be accessed and used" (WTO, 2018, p5).

4.2 Supply chain of SKF

Logistics and supply chain operations
As stated in chapter 1 "*introduction*", SKF's supply chain spans the entire globe, with customers and distribution in 130 countries. With 90 manufacturing sites spread over 24 countries and a global distribution network of 17000 distributors worldwide.

SKFs supply chain is further described by the SCM to have a functional organization and with a large number of manufacturing units, with a high degree of decentralization, where functions can act independently in several aspects. Activities and routines are more or less standardized in each, giving the benefit of knowing what to do and how to do it. At the same time independent ways of working can contribute to the disadvantage of experience “silo mentality”. For example, in functions of logistics and transport and supply chain management it is highlighted by both the L&T and the SCM that the “silo like” mentality creates issues such as limited insight and visibility between functions and their operations. Each function have a specified level and scope of access to information in databases, where no single function have full access to all information.

For efficient distribution of goods around the world, SKF have a global and well established logistical network. Furthermore, SKF mainly depends on third party logistics and transport providers for all shipments. SKF also have independent logistics and transport units within the logistics function. These are geographically distributed and each entity have different geographical areas (set of countries) which they manage and have control over. Collaboration between different entities exist, for example between logistics and transport operations in Europe, but to various degrees. Collaboration is further described to be suitable where the logistics networks operations and processes are perceived as having a high degree of standardization. The main concern and goal according to the SCM and the L&T is to keep logistics and transport costs down as much as possible while being sufficiently efficient.

Outsourcing

SKF is, depending on the specific country, having certain activities related the transport and logistics outsourced through various partnerships and collaborations with third-parties. Efficiency is one of the primary factors considered when deciding if functions are to be outsourced or not. The SCM further states that there might also be strategic reasons to keep functions in-house, such as to retain knowledge. In conjunction to utilization of established partner networks, SKF also rely on various short-term contracts with third-parties in the U.S, where logistics and transport services are bought for specific shipments. When it comes to transport and logistics joint-ventures and partnerships, the main operations of warehouse management and transports in the U.S are outsourced. However within Europe and Asia, warehouse management is done internally. Coordination and management of the global logistics and transport activities are done from a centralized transport unit. This unit coordinate with several logistics units and executives based around the world, where each have responsibility for managing operations in a specific geographical segment.

Actors and relationships

Relationships are commonly based on long-term contracts, where contractual terms and conditions are renegotiated on a regular bases. Transactions-based, or single service contracts are also utilized to some extent. Trust is seen as a critical component by both the SCM and the L&T in all long-term relationships. SKF have to trust that their partners keep performance levels high related to for example delivery reliability. If transport reliability is lost, and several scheduled deliveries are late, this can cause friction in the supply chain and negatively delivery lead times, supply chain performance and even cause SKF to be unable to deliver on customer promises made. In order to proactively and reactively avoid these kinds of issues and serious ramifications steaming from the same, SKF have enforced policies, including specific requirements that each partner have to achieve and maintain in order to work with SKF. Insight and visibility into other supply chain actors business operations are currently limited due to fear of exposing sensitive information or other intellectual property right issues.

Consolidation of information and data sharing

SKF is mainly utilizing EDI systems (electronic data interchange) for transactions of data and information between supply chain logistics parties for coordination and management of logistics and transport. Furthermore, according to the SCM all inbound and outbound transports and goods are scanned and registered via EDI to keep track on specific deliveries, times and dates. Having efficient ways of communicating this information is necessary to allow the receiving party to re-plan and reschedule following operations after goods are received. EDI is also used to collect data and information about performance aspects. However, related to tracing of goods, no real time data is currently collected during the specific route between checkpoints. The main focus is instead on total delivery lead time and reliability and that each shipment is delivered within a specified timeframe.

The SCM and the L&T describes that all activities conducted today are highly reliant on the IT infrastructure and systems in order to keep operations running. Traceability and tracking of goods and shipments are important aspects of the logistics and transport operations. The use of EDI systems enables efficient gathering, consolidation and sharing of updated information. Data relate to the location of a specific shipment, estimated delivery date and time. This further contributes to reducing friction between supply chain checkpoints and a higher end customer satisfaction, as the same can more easily plan ahead.

The company utilizes several computer based support systems for supply chain operations, several of them are developed in-house. Access to tracking data is open access, where any party (customer or internal shipping unit) can read data about shipment specifications, once the shipment is outbound and they have an order or shipping number. Information and data related to supply chain activities and bearing products are gathered, consolidated and stored in various data warehouses. Each individual data warehouse is currently used with restricted access to specific functions within the organization in a “silo like” fashion. Certain information is to some degree decentralized through the use of separate databases which specific sub-systems utilize. However, databases commonly only store fragments of the full data set, necessary to maintain a particular system, function and related operations. This fragmentation of data according to the SCM in turn sometimes create an inefficient environment as desynchronization and information asymmetries arises. For example, logistical and transport units may have to acquire various data from different databases via manual extraction to get essential data and information necessary to conclude analysis and execution of operations. The SCM further states that there exists a high demand for access, but that there is a real issue for management to evaluate whether or not to allow access to the internal or external applicant.

Having an efficient IT infrastructure with frictionless systems working together is described as highly important by both the SCM and the L&T when it comes to documentation and storage of data. Additionally, it's important for tracking of inbound and outbound transports between supply chain checkpoints and for checking if delivery was done according to schedule as well as for register potential errors that might have occurred and where in the chain. For example to access data related to customer order specification (size, volume, product type) and transport, to establish what order is to be shipped and when as well as destination of shipment. The SCM describes that, in the advent of a long-term system failure leads to serious desynchronization issues, where critical data is not accessible can lead to a poor decision making and lack of ability to perform proper analysis due to a limited information base. This in turn can cause strains on transport capacity and time planning, leading to longer lead and delivery times and problems in requesting quotations as well as more complicated manual planning of other logistical activities. In turn this can lead to situations where additional transport resources (mostly trucks or boats) have to be brought in to higher prices in order to be able to meet demand. Resulting in increased overall costs of transport and shipping for SKF.

Supply chain transparency and traceability

Transparency is according to the SCM and L&T of increasing importance as both customers and other supply chain actors is putting more emphasis on a company's ability to provide transparent information and data related to supply chain activities. However, the same states that there is an apparent trade-off between the level of transparency and control that need to be considered - *"How much does each supply chain actor need to know really and to what cost can we satisfy these needs?".* There are also according to the SCM technical constraints that need to be considered in order to achieve increased transparency and more efficient information sharing, for example, it would require extensive integration of various systems used by different supply chain actors which might be very resource demanding to pursue.

Future state of supply chain

On one hand are statements regarding the future state of the supply chain configuration indicating that the level of outsourcing increases if the efficiency of the value chain can be increased. On the other hand, it's considered to be highly important that control and management still remains within the company of SKF in order to not lose competence and quality. The SCM further believes that in the future SKF will become more of an entrepreneurial company that will look more at opportunities related to outsourcing.

The SCM describes that, having a high level of transparency and efficient traceability is perceived as becoming of increasing importance in the future, if not even a standard requirement in the transport industry. Where companies will have to be able to provide extensive information related to the how goods are transported, the location of trucks and shipments, transportation routes and costs and emission levels in real-time. Advanced IT systems is perceived to play an important role in the enabling of this future development. Driving forces will most likely be attributed to environmental and political aspects, where there will be increased pressure on being able to show that a sufficient level of sustainability is incorporated in all activities. As well as pressure from customers related to increased efficiency and performance in terms of lowered costs and improved responsiveness.

The SCM highlights that improved quality of data and improved traceability are potential areas where its believed that blockchain can create an advantage in the overall supply chain, as the responsiveness, accuracy and performance could be improved. However, the L&T's perception is that blockchain technologies and the potential within the area of supply chain transport and logistics is still somewhat limited. Blockchain is not perceived to provide extensive value to current logistics and transport operations as the issues are more related to other aspects. Such as finding and combining solutions for marking bearing products in a more efficient way, where individual bearing related documentation and data can be traced and combined more efficiently.

4.3 Scenarios

4.3.1 SKF and Counterfeiting

In an attempt to reduce counterfeiting, SKF have implemented various validation processes in order to establish the authenticity of goods. Procedures often include a thorough check and verification of the design and shape of the package, barcode labels as well as laser engraved labels on the actual product itself (designation and serial number). The utilization of unique barcode labels in conjunction with categorization of their different product series and types to more easily make a distinction and trace the origin of their products. To validate authenticity SKF further check for deviations of the original design, serial numbers or tracking numbers, dates and timestamps. Visual analysis of the appearance of a product is commonly also used, to see how the product deviate in appearance compared to an authentic product after processing. The aim behind marking and tagging of products and packages is firstly to provide a trail of documentation to more easily identify where potentially errors have occurred. Another factor is also being able to provide the customer with more information. Where lastly, the company aims to making it harder for counterfeiters to conduct business successfully at the expense of the company and other actors.

All information related to above mentioned is stored in central databases, which are used to check data related to inbound and outbound products. Furthermore, the SCM, states that in mitigation of counterfeiting and piracy goods in the supply chain, SKF can use the information on the product or package in order to verify if a bearing or its package have been manufactured and shipped by SKF. The information is checked against their digital systems and databases to ensure the authenticity of a product upon request of the customer. However, this option can be time consuming as some information must be compiled and extracted manually from different databases. Other issues of current marking and tracing methods as barcodes according to the SCM and IFE is that counterfeiters could easily circumvent the anti-counterfeiting mechanism by putting a counterfeit product into an original packaging box.

Actor roles and relationships
The IFE perception is that the issue of counterfeiting and piracy goods within the bearing industry is growing, either due to actual growth or because SKF have become increasingly efficient in detecting piracy goods that was not identified previously. In addition, SKF is working closely with various authorities such as the police and customs to gather evidence against counterfeiters and other useful information to collectively work against counterfeiting and piracy. Collaboration between customers and SKF is limited in the area of counterfeiting, where the as stated previously, products in customer applications are only checked upon at specific request. Furthermore, the IFE states that customers have limited access to data that is not directly related to their specific order, product specifications or documentation about certificate of origin. In some cases information about measurements and quality controls are also disclosed and shared with the customer, but no information is shared about production operations as these are classified as company secrets and intellectual property and only shared on a need to know basis.

Consolidation of information and data sharing
The IFE states that product efficient documentation and traceability through the supply chain is important for daily operations. Documentation about production date and time, certificate of origin, material certificate and product specifications as well as correct marking and labeling is critical, not only in regard to issues of counterfeiting but in general for efficient manufacturing and delivery operations. IT systems such as ERP systems are therefore critical for running and maintaining supply chain operations such as manufacturing today due to the high degree of automatization in various applications.

The IFE further highlights that failures in the IT infrastructure and systems could lead to a critical shut down of manufacturing operations and that a long-term failure would inevitably lead to limited access of critical data. Resulting in increased difficulty to process customer manufacturing orders as well as increased rejection rates at the customers end due to incomplete documentation of certificates leading to loss of sales. The IFE further states that the fragmented access to databases between functions impose major constraints for an independent function as information asymmetries arises. Hindering the same from working efficiently with counterfeiting cases where information from different databases is needed. An example where this inefficiency is evident, is in regards to the cross-functional consolidation of data related to for example classifications and material certificates of specific products and other relevant information for establishing the authenticity. Where an access request to a specific databases needs to be applied for, which is considered very inefficient as it often takes time to get approved.

In the case of counterfeiting, SKF is as previously stated checking various markings and labels as an initial way to determine a product authenticity and origin. Where each packaging label contains information about, when a bearing have been manufactured, country of origin, what package code, serial number and product type. This label can be scanned and the information can be checked against the central database to ensure that everything is correct. In addition the company have implemented a standardized protocol for labeling, where depending on the bearing type, will be marked with a unique label reserved for that specific product type.

The IFM describes that in the advent that a customer makes a request for authentication, the company can share information regarding the design of the label that have been used until a certain date as well as check in the company's internal system if that particular bearing with these specifications was produced during that time frame and in what volumes. A common factor behind an authentication request is that a customer experience some kind of quality or functional issue with a particular product.

The consolidation and tracing of information in authentication process of a product commonly starts with the customer turning to its supplier (the distributor of SKF). Where the distributor in the next step turns to SKF. Where lastly the company turns to the respective manufacturing unit or factory to determine if the bearing is a counterfeit, usually by checking deviations in steel quality for example. The distributors commonly have processes, tools and protocols in place for determining directly if a bearing product is counterfeited or not, without having to consult the company. Hence, it's only when they cannot determine the authenticity of a product themselves, they consult SKF for a more extensive analytical process.

The IFM and the SCM both state that this process can be time consuming as data i highly fragmented and have to be consolidated from several actors and their databases, where direct access is very limited. This issue is further enlarged due to the limited insight into customers and suppliers operations. Where data is only shared to the extent necessary for manufacturing bearing products according to specific requirement and applications. As well as data on material certificates required to ensure that quality standards have been met. Internally, a potential inefficiency is described by both the SCM and IFE to be a high level of manual documentation in physical formats. Which sometimes leads to slow synchronization between company functions and sources of information. Another highlighted internal inefficiency is the utilization of various sub-systems developed and use for certain areas, that have not yet been integrated fully, which can cause some friction due to different input and output formats.

Counterfeiting transparency and traceability

The IFE states that counterfeiters and piracy manufactures are becoming increasingly resourceful in the ways they counterfeit goods through various methods of markings and production techniques, where replicates very similar or even identical to the real thing have emerged. Where this poses a real challenge for detecting counterfeited products. For example, if a counterfeiter makes a package with a label identical to the real thing (with the correct date and time stamps, serial numbers et cetera), with a well-made counterfeit product inside having the specifications of the original product, it can be very difficult to detect. Where according to the IFE one major problems related to traceability aspects can be attributed to difficulties in backtracking information in the supply chain due to fragmented data and limited transparency between supply chain actors.

The IFE further describe that in the case of counterfeiting, it's a rather complex process due to the involvement and use of several actors, functions, systems and databases from which data needs to be extracted. Where actors and internal functions usually have to coordinate collectively to resolve issues related to the same. And due to a high degree of desynchronization, information asymmetries and fragmentation of data is present it leads to longer processing and administration lead times as information is not readily available to provide the full picture needed for all actors involved. Where the major risks for SKF in related to counterfeiting and piracy, is that use of counterfeited goods can lead to degradation of the company's reputation and incurred warranty or remedy costs if fake products are mistaken for the real thing. The use of the counterfeited product in an industrial application can potentially also inflict serious damage to both customer´s equipment and workforce, resulting in lawsuits.

Future state of counterfeiting and piracy

Future consolidation of information and data sharing

The issue with counterfeiting and piracy goods is expected to grow, while simultaneously, anti-piracy initiatives from various actors such as the government, police and customs together with companies is perceived to become more proficient and advanced making it much harder for counterfeiters. There will also most likely be a higher level of collaboration between all above mentioned actors to collectively mitigate this problem. The development regarding the use of IT-systems in the future will most likely go towards a more digitized organization and a higher degree of automatization of manufacturing operations through the industry 4.0. Furthermore, documentation and transactions will most likely take place in various cloud-based solutions.

The case company is also a partner and participant in a new an ongoing global initiative between several large incumbent manufactures aimed at combating the growing problem of counterfeiting and piracy goods within the industry. Where the incumbent will collectively consolidate and share individual product registries together with other relevant information in a shared database with open access to the data needed to authenticate a product. The major benefit is stated to be a broader set of accumulated data which can be used to more easily identify counterfeit products. As the initiative becomes more developed, the aim is to also include customer´s, where the customer will have the ability to scan a product and check it against the shared database to authenticate the product.

Future challenges related to traceability, transparency and trust

Customers are continuously expecting a higher quality level in products and services and are willing to pay a higher price for this due to the longer product life time, where SKF differentiate itself from other competitors by delivering a high quality level in products and services . Trust between the company and other supply chain actors will therefore continue to be a critical element in the future for maintaining solid long-term customer and supplier relationships. Where trust in future relationships will most likely be based on the company's ability to deliver high quality and reliable services such as maintenance and real-time analytics. Trust is also evaluated be of importance for future collaborations between the company and its suppliers for continuous improvements and efficiency initiatives and enhanced supply chain performance level.

Perceived potential and impact of blockchain technologies

The perceived advantages of blockchain technology is that it can potentially provide a way to increase visibility and insight into operations according to the IFE. A perceived limitation is how the various access levels for all the involved parties within the supply chain is to be solved. It's a trade-off between having control, protecting company secrets and being transparent and potentially more efficient through better information sharing.

4.3.2 SKF and Warranty

According to the QM, when a warranty issue related to any of SKFs bearing products emerges or is observed in the form of for example failing product quality. Or where the product life cycle time is shorter than what have been promised by the company, SKF immediately creates a task force to determine the root cause of the problem. The force is usually led by a quality manager from manufacturing. Activates and management in the warranty function fully integrated and are performed in-house. Additional external actors that sometimes are involved in the process are insurance partners, however these only gets involve when it's an insurance matter. The DQC states that compared to others bearing manufactures SKF have relatively small carrying costs adherent to warranty cases since it is a very small part of the total amount of products that are subject for warranty and reclamations.

In terms of the actual warranty process SKF have rules and protocols in place for how to handle warranty requests and claims, which are standardized and the same for all SKF departments globally. The QM states that SKF there are guidelines dictating the general warranty agreement between SKF and the customer. However, it is adapted and thus has a large variation depending on the specific context and the individual customer involved. In addition, the purchasing contract includes the specific terms and conditions for compensation.

Both the QM and the DQC states that the types of investigations and analysis may vary depending on the type of error and the type of bearing. There are mainly two categories of errors, "zero-hour" error which are error and issues encompassing a product that have not yet been in use (manufacturing error) or errors that have emerged during its use in the field. The QM states that there is also an important difference between a warranty case and a reclamation case, where both have different processes. The reclamation process, which is referred to as a "pre-warranty process" are often related to "zero-hour" errors. For "zero hour" issues the responsible party is often obvious. Depending on the type of error that have been identified, the entry channels to the warranty or reclamation process differs. The usual procedure in these cases goes through various steps of data and information gathering, as well as mapping of the incident and analysis encompassing, what, how and where the incident happened. As well as establishing how in the short term SKF can help mitigate the potential systematic or technical error related to the incident and the damages steaming form a faulty product. A root cause analysis is also performed to identify the source of the error. SKF always also performs a severity analysis in order to be able to classify how serious the error is and to prioritize the claims. All of this leads to a relatively long lead time for the process, since it may require a lot of data to be gathered and consolidated from separate systems and other meticulous work.

Each case is classified in relation to how critical it is in order to determine its priority. This is conducted with the aid of a diagnostic and decision diagram. Where severity is evaluated through consideration of where the product is used, which type of industry application and how critical it is for the customer's business. Where the application evaluated to be the most critical in terms of being highly reliant on SKF product is given priority and is processed first. As stated, the priority can also be influenced depending on what industry the warranty process is adherent to, where for instance in the high volume industries of automotive and aerospace, it is very important with quick response time and communication response time.

The evaluation of criticality is further based on the severity related to negative impacts a warranty case may have on SKF, such as potential loss of reputation or high costs related to contractual and judicial processes. Yet another element determining the priority of any case is how long the throughput time is on a specific warranty or reclamation claim. In order uphold customer satisfaction SKF seeks to limit the throughput time of warranty cases to what the customer reasonably expects. Although the time it takes is also influenced greatly depending on what type of product it is and the impact of the issue. In the end SKF exchange information related to the product error and analysis, as well as sharing of data related to the warranty process and what decision SKF have come to in case of granting or denying the warranty claim in the form of a writing report. Where in the end SKF and the customer formally signs an agreement stating the accepted terms and conditions related to the performed warranty process and operations to remedy errors.

Actor roles and relationships

The exchange of documentation and transactional interactions between the SKF and the customer is commonly very limited, where most of the transactions are performed between internal departments at SKF during the process. However, the QM states that in some cases where the process is for some reason extended communication with the customer can be more extensive. The actual process is well implemented and standardized throughout the company. Naturally in warrant cases there is a conflict of interest that lowers the trust between the different stakeholders.

The relationships are considered to be transaction based, where terms and conditions of each warranty contract characterize each unique relationship. Where the same contract creates some sense of trust between the customer and SKF through the acceptance of obligations stated in these. The QM further states that the customers and their unique position in relation to the company have limited direct influence on the warranty process itself as well as on which warranty claim gets prioritization. SKF commonly implement unique warranty conditions for each customer according to applications specifics, where different terms and conditions are specified and enforced for different industries.

Consolidation of information and data sharing
All reclamations and warranty claims are processed through a central system which is a core resource for the administrative process, where all input information and data related to the warranty claims are stored in a central database. In addition to the utilization of central system there are other support systems that handles functions such electronics and software errors analytics. The functions and departments that are notified and deemed necessary for processing of a specific warranty claim is determined by how it is logged in the system by the individual whom entered the claim information into the system.

The DQC further states that data today are stored case-wise in the system, without any effective option for compiling and storing a products historic transactional record and documentation, where currently the data is to a large extent saved locally and is thus not easily accessible. This results in difficulty of finding relevant and necessary information in some cases. The same also emphasizes that its highly dependent on how case managers tag the claims in the system. Currently the personnel have to manually search the system to find information which is time consuming as a lot of time is spent on manually handling this process.

All input, consolidation and sharing of information and data is mainly performed through the central system described earlier. Where according to the QM an efficient level of traceability can be achieved as records pertaining data related to each case is kept separate in the system and can be accessed easily when needed. Communication both internally between departments and externally with the customer are commonly performed through the use of email and the central system. However, when data is shared with the customer's through SKF own system it requires SKF to manually input the data that the company want the customer to have access to. In the cases where sensitive data such as intellectual property is shared NDAs are used to mitigate risk and enforce trust between the parties.

As mentioned earlier SKF use a structured root cause analysis procedure to tracking and identifying the root cause. Furthermore, SKF have to collect information and data from several sources in order to perform the analysis and to be able to identify the potential root cause. This process can be time consuming and resource intensive as the data have to be consolidated from various internal functions involved in the warranty process, where a request for accessing data of other functions is usually required. In addition, SKF does not have immediate access to the supplier's data and quality standards for purchased materials so they have to ask for it. The DQC elaborates that when buying material or components from suppliers, SKF usually get some kind of certificate, guaranteeing that certain specifications are met. Being able to trust the other party that they deliver the promised quality is here considered a very critical element.

Warranty traceability and transparency
According to both the QM and the DQC , It is very important to be transparent and have open communication towards the customer who provides the claim as well as having transparent sharing of relevant information related to the process itself as a way to create trust and confidence. The DQC further states that it is of high importance to have a sufficient level of transparency internally between functions and departments such as, sales unit, manufacturer

and in some cases the laboratory that examines the failed product. Where collaboration and visibility in others operations as well as having efficient information sharing is necessary as several functions are to some degree involved in each warranty case. Where the reason behind this is that information should be easily traced and identified and not hidden or due to other reason not accessible between the departments. When various issues are detected internally in the organization they need to be mapped and analyzed, furthermore this knowledge needs to be effectively communicated internally so that the same problems can be avoided by other departments. This is a concept referred to as "lessons learned". By communicating new gained knowledge through core documentation they have a way of enhancing internal transparency and responsiveness. However, the DQC also believes a higher level of transparency could allow for more sharing of "lessons learned" internally.

In relation to above mentioned, transparency and visibility is also highlighted as important according to both the QM and DQC for creating an environment for collective learning and development of improved solutions the to help mitigate errors, both internally and in conjunction with customers. Where more transparent communication and sharing of data could enhance the overall responsiveness and performance of the warranty process, where the throughput time and lead time for each case could potentially be reduced significantly. However, the DQC states that it's very important to be careful when aiming towards increasing the speed of a warranty or reclamation process so that the quality of the outcome is maintained.

If the situation is in somewhat of a grey area then SKF usually try to find some sort of settlement with a willingness to take on a relatively small costs that aren't necessarily theirs to take in order to maintain a good business relationship. The investigation process is in most cases quite resource demanding and therefore its usually cheaper to just go to a settlement directly. The DQC further state that SKF could potentially save money if all documentation needed to more rapidly evaluate each case fundamentally, were more easily available. Where for example if SKF could access information directly that suppliers processes have been performed according to quality standard specifications. It would simplify the investigation work a lot if this kind of information was readily available, as it would allow SKF to more easily rule out the manufacturing and supplier processes as the source of the problem.

Future state of warranty

Future consolidation of information and data sharing

According to the perception of the DQC, SKF will most likely not outsource any additional activities related to warranty and reclamation processes in the future. However, the same do believe that they will change the current system support. Where the system used today meet the current demands, but in the near future it will not be enough as processes and data input and consolidation are becoming more complex with additional functions involved.

Today actors that want to read and access part of any information related a reclamation or warranty case needs to be manually added in the system as an authorized individual to get access to the shared data which is can be time consuming. Where a solution for this kind of issue for the future would be beneficial. Where for example access granting to case related information for a specific customer could somehow become more autonomous.

Future challenges related to traceability, transparency and trust

The same states that there will probably emerge a need for a simpler and more easy to use system interface than the current system. Another area of potential improvement according to the DQC and the QM can be attributed to the concept "lessons learned". Specifically, how SKF ensure that all relevant and necessary information and data is distributed to and actually reaches all the factories as well as that critical core documents gets updated. The DQC conclusion is that they need systems that are perceived as easier to use and that the knowledge sharing can be performed easier that today.

In addition, the company is today generally working very hard to become more process oriented and to move away from the previous functional approach and the "silo thinking" where functions are seen as isolated and separate entities. The benefits perceived with this transition is that it would be possible to gain quality benefits from focusing on the entire value flow contra functional silos. The function and SKF as a company is also perceived by the QM to become more reliant on IT systems for business operations, but where the number of systems will become significantly reduced and integrated towards some kind of common one-size fits all solutions.

Perceived potential and impact of blockchain technologies

In relation to blockchain technology, the DQC states that, theoretically the potential benefits of blockchain lies in the possibility for providing a way to simplify things and reduce the amount of administration currently needed, for example in checking of quality standards and certificates. However, in order to get transparency and traceability a certificate must be incorporated at each step in the value flow to guarantee quality, where the certificate could be connected to the blockchain for easy quality assurance and follow up on quality standards being met. For example, some form of certificate from supplier, another one from production, another certificate concerning that the logistics process was performed correct, another that the customer assembled the product correctly and finally that the product runs as it should.

The same further states that the use of public blockchain is not desired as SKF the information is often of sensitive nature and should not be be transmitted in a way for the whole world to see. However, this is considered a minor obstacle if there is a way to be able to connect with and share specific information to specific and authorized customers. A perceived challenge by both the DQC and the QM in relation to the use of blockchains is attributed to the potential difficulties in convincing the many other supply chain actors to become engaged and see the benefits with the technology. Without getting the approval and involvement of other actors, the blockchain might not reach its full potential or achieve any form of increased benefits or value for the overall supply chain.

4.3.3 SKF and Remanufacturing

The remanufacturing process and service of SKF is explained by the BC as being organized as a step-by-step process, sometimes uniquely tailored to the customer needs and requirements. Where a remanufactured product is defined by the BDM as a product that is commonly a functioning product, that due to wear and tear from field use have undergone some kind of processing or restoration, to restore the original condition and performance of that product in order to extend the product life time. The BDM further states that the remanufacturing business development function of SKF is currently fully integrated with all activities performed in house. Where the global strategic remanufacturing business development function work closely with SKFs local business and sales unit networks around the world for active coordination and development of the local customer markets.

Starting with processing of a customer request to inspection and analysis of damages and needed remanufacturing work to be done. The first step in the remanufacturing process start with a customer request, upon the bearing is collected from the customer by SKF in order to perform an initial inspection and analysis of damages. SKF decides in conjunction with the customer when the removal of the product should be performed. The parties also establish who carry the responsibility to complete this step, where SKF commonly assist the customer with the removal of the bearing product. When the removal of the bearing is completed, the product is shipped to a manufacturing facility, where the actual remanufacturing process is initiated and upon completion, the bearing is sent back to the same customer which will perform the remounting of the product. The BC states that most, if not all remanufactured bearings goes back to the same customer that requested the remanufacturing and that the process is highly customer and case oriented.

Types of remanufacturing service levels

According to the BC and BDM, SKF provides four different technical service levels within the remanufacturing which a specific bearing product can be subjected to. The service levels represents firstly the severity of the wear and tear and the remanufacturing operations that need to be performed. With level one being the simplest, covering standard operations for fixing damages with low severity and level four encompassing more extensive remanufacturing operations, covering remanufacturing of products with more severe wear and tear. The different service levels also act as predefined standards established and offered to the customers by SKF. Where a fixed price is set and agreed upon for a specific bearing type. Each level involved several operations depending on the service level chosen by the customer, where operations commonly included are bearing washing, polishing and grinding.

There are no extensive initial back and forth interactions and transactions of documentation and sharing of information related to for example calculation of costs, inquiries or quotations, for the necessary work that have to be done in each individual case. However, in some cases where a received bearing have more extensive damage that anticipated or covered by a service level. And where additional operations may be necessary to fully restore the bearing, an in-depth analysis is conducted and a price calculation for additional services is performed, upon where the customer is consulted. The customer can then decide to either proceed with the remanufacturing process or purchase a new product. The BC further highlight that the customer can also decide to either use the bearing in a specific application up until the specifications of a certain service level (level of wear and tear) is reached and then send a request to SKF for remanufacturing.

Importance of remanufacturing as a business service segment for SKF strategic direction
According to the BC, remanufacturing has a key role in enabling SKF's strategy to move away from simply manufacturing bearings and providing the physical product, towards incorporating a more service oriented business. Encompassing both the physical product, remanufacturing services and additional add-on services including analytics and maintenance. Remanufacturing is a key function to achieve a more circular economy and sustainable business, where the customer doesn't just buy a bearing and then throw it away when weared out, but instead re-use it.

The drivers behind this change in direction and aim of SKF remanufacturing processes is to provide additional benefit and value for the customer. Where the main goal and benefit with remanufactured bearing products from a customer's perspective according to the BDM is that it allows an extension of the product life time while keeping costs down. Where it's usually a lot cheaper to restore a bearing in comparison to purchasing a new one. Another critical benefit is also the shorter lead time of 2 weeks that remanufacturing of bearings provide, where the manufacturing and delivery lead time for a new bearing is quite long, approximately 8 weeks. Both the BDM and BC further states that a potential unexpected stop in an application or process at the customer's end can thus become very expensive and impose high costs for the customer if its a critical process. And where the customer have to wait to get a new bearing replacement from SKF production plant. The BDM and BC further states that it's also here the new service orientation and remanufacturing operations of SKF have the ability to provide additional customer value. By enabling customers to reduce costs and expenses related to downtime and purchasing of process components while increasing the product life cycle time without compromising quality.

The growing environmental concern and sustainability pressure is also an important element. Where SKF is contributing to a positive environmental impact with remanufacturing services as parts and products are re-used again. And where both customer and SKF have the ability to incorporate a higher level of sustainability into their businesses. The BDM and BC also emphasize that the remanufacturing of existing bearing products also provides advantageous benefits for the organization of SKF, in terms of overall reduced manufacturing costs and improved customer satisfaction.

Actor roles and relationships
According to the BDM and BC, SKF is not at the moment utilizing retainer service contracts for continuous remanufacturing operations. Remanufacturing services are currently case-by-case based, where the relationships with the customers are more transactional in nature. Trust is considered as a critical element and in most business relationships there is some type of

established trust. Where SKF and the customer is normally using NDAs (non-disclosure agreements) when it comes to disclosing sensitive information and data. The incentive for sharing information is limited, where the current norm is that only specific information in order to complete a remanufacturing process is disclosed and shared by the customers. If SKF ask for additional data, this brings certain expectations to provide feedback from the customer's perspective. Hence there is a trade-off between sharing or not sharing information versus the value or benefit SKF can bring to the customer if access to additional data is granted. The BDM further states that there is limited transparency in the relationships between SKF and its customers, especially related to information and data sharing. In turn restricting the efficiency and effectiveness of the remanufacturing process, resulting in longer process lead time and delivery lead time.

Consolidation of information and data sharing

SKF uses digital solutions for creating so called "dashboards" in the factories, where information related to the product specifications and remanufacturing operations is consolidated, stating for example, exactly how many bearing SKF have stamped or refurbished, what the failure mode is and activity level of specific products. The customer is given open access these.

Between internal departments and functions involved in the remanufacturing, consolidation and sharing of data is done through old fashioned excel-files and central databases. However, the BDM and the BC states there are issues related to accessing information and data necessary for performing certain remanufacturing business operations. Where the main reason for this is because the remanufacturing function only have partial access to SKFs databases. There is also an issue of information being kept locally in "silos" within specific functions which creates information asymmetries and difficulty in tracing relevant data. However, the BDM further states that, often if you know to whom you need to talk to, the issue can be resolved, but it can be very time consuming.

The BC states that results from a previously conducted efficiency study in the remanufacturing process, showed that the main bottleneck could be contributed to long administrative lead times. Where some of the main issues contributing to this was the lack of knowledge and expertise of bearing products within different functions as well as limited data sharing and cross-functional collaboration. To acquire the necessary information needed to be able to provide information to the customer about the benefit-to-cost ratio and if remanufacturing is a viable option or not, the sales and administrative units had to consult extensively with service technicians. There are also certain issues related to consolidation and sharing of data due to limited data format standardisation, where different customers commonly provide data in different formats.

Issues related to traceability and transparency

Traceability is perceived as a critical factor, where SKF employ a special registration data process where each unique asset or product is marked with a unique barcode through which the same may be tracked throughout the various points in the supply chain. These unique codes are used as a reference point in the information system for establishing product specifications and processing steps in the remanufacturing process. However, the BC states that the fragmented storage of information in conjunction with utilization of several independent IT system, where some of the older systems lack compatibility, results in information asymmetries and desynchronization between supply chain actors and internal functions. Transparency and traceability in supply chain operations related to remanufacturing and customer applications is therefore a key aspect and critical enabler for making data and information available in a more efficient manner.

For example, the internal transparency in the actual remanufacturing service process performed by the SKF factory is very low. Where information sharing between the manufacturing function and other functions is limited related to what specific remanufacturing operations that have been performed and how the price for the same have been calculated. Resulting in that identification of potential improvement opportunities for lowering costs and providing added customer value might be missed. The BC and BDM further states that enabling a more efficient gathering and consolidation of such type of information could have a positive impact on trust in customer relationships. A higher level of transparency in relation to information sharing is also perceived to have a positive impact on the understanding of how remanufacturing services can be tailored to better satisfy a specific customer. It's also stated by the BC that it's not unusual that individuals keep information and data locally stored on their laptops, without sharing it through company channels to other individuals of functions within the organization. Further adding to to the problem of transparency, traceability and information asymmetries.

Another example highlighted by the BDM, showing the importance of having a sufficient level of internal transparency can be attributed to various functions of SKF located in different part of the world, continuously *"reinventing the wheel"*. Which mean that several solutions to a common problem is developed by different function as information is not shared between the same. Resulting in waste of resources and issues with inefficiency as each department usually starts from scratch to find and implement their own solution, unknowing that a successful solution already exists.

Externally, transparency is emphasized by both the BDM and BC to be of high importance for enabling proper scheduling and timing in the removal of the bearing product from the customer's application and the remanufacturing process itself. Information and data related to for example the number of operational hours a products have endured, which application it have been installed in, what the location or environment the bearings have been used in, et cetera is also necessary. As it enable precise assessment of when a bearing will reach a critical point and is in need for remanufacturing to restore its performance, and where consideration of planned stop in production at the customer's end can be made. Where additional cost related to unnecessary downtime can be avoided. Furthermore, if the customer waits to long, the cost for remanufacturing the product is risking to become too high due to the more extensive damage and wear and tear. Where the cost to benefit ratio is stated by the BC to be similar to an exponential curve, once it reaches a certain point the cost to remanufacture the bearing quickly becomes so high that it's more cost effective to purchase a new one instead.

However, both the BC and BDM states this is not the case today, where data exchange is restricted due to secrecy issues and challenges related to trust. Where it's often really hard to get access to this kind of information from the customer, as the incentive is limited. The BDM further emphasizes that enhancing transparency and access related to this type of information from the start would be highly beneficial for several reasons. Firstly, an improved understanding and knowledge about how SKF products are used and behave in the field could be achieved, resulting in the development of better, more efficient processes. It would also enable a higher level of learning from previously collected data and gained knowledge about aspects concerning customer needs.

Future state of SKF remanufacturing

The BC states that the remanufacturing function and service will play a much larger role as a prominent business segment in the future. And that remanufacturing as such have a great potential for growth as a end-to-end product life cycle solution, encompassing both the manufacturing and delivery of physical as well as product life cycle maintenance. Remanufacturing will also be of importance for achieving a higher degree of sustainability which is perceived as an important factor for competitiveness. The new business model of SKF remanufacturing would then transition from a transaction based model of individual physical products and individual services towards a subscription based model, where the customer pays a fixed fee for SKF to deliver a complete solution that ensures a specific operational and product cycle life time.

Where the future vision of remanufacturing as a emerging prospect is aimed at providing a completely circular economy of all bearing products for all industry customers. Where the BC describe that, SKF would then identify, purchase and remanufacture old bearing product from current SKF customers, non-customer and alternative brands. Where the collected and remanufactured bearings would then potentially be stored in a warehouse for remanufactured goods to be distributed later to any customer with a suitable application. Remanufacturing is thus perceived to potentially become an industry wide complementary solution for all customers dependent on bearing products in their business applications, as a cost-efficient alternative to newly produced bearings.

According to the BDM the markets and industry of SKF is developing rapidly, where companies have to incorporate flexibility and efficiency in everything they do. Outsourcing is therefore perceived to be of increasing value in the future. Where SKF is perceived to become more reliant on outsourcing of certain remanufacturing operations in order to become more flexible and efficient. Where SKF will most likely collaborate with local market third-party actors to perform some remanufacturing operations for SKF faster and cheaper and with closer proximity to potential customers. However, the same states that this might create a trade-off between efficiency and control, where its very important that SKFs quality standards are maintained in outsourced operations.

Future consolidation of information and data sharing

The BC describe that consolidation of information related to new remanufacturing solutions would presumably be more complex as additional actors, systems and information flows needs to be integrated. Where a solution for enhanced traceability must be developed, that allow tracking of a specific product through separate actors value chains in real time. And where the transfer of data in general need to become much faster in the future in order to increase the overall speed and capacity for gathering, consolidation and sharing of information. IT-systems and digital solutions is stated by both the BDM and BC to play an important part for this development. Where a concept under consideration is the use of sensors to diagnose the bearing in real time that could provide a more automated data gathering process. SKF could hypothetically read and analyse the state of any bearing product to determine when and if its a viable subject of remanufacturing. However, this would require a very high level of mutual trust between SKF and its customer.

Future challenges related to traceability, transparency and trust

The BC highlights that some inherent challenges that SKF needs to overcomes for the achieving the new vision of a fully circular economy. Trust and transparency will according to the BDM be core element in all relationships with supply chain actors both internally and externally for making information readily available. Enhanced traceability will also be of utmost importance, where consolidation of documentation and data is critical related to what operations been performed in what stages and by whom, as well as easy auditing of quality standards will be critical. Having open books and no “hidden agenda” and being able to show what is happening in the remanufacturing process in terms of activities performed that incur cost.

An additional challenge of the current limited traceability capacity is that the ingoing and outgoing material flow for the future remanufacturing process will most likely not be organized in a linear fashion as it is is now. where a product travel between SKF and a specific customer point in a closed loop. Incoming bearing after remanufacturing might have several alternative outgoing destinations further adding to the complexity.

The BC states that it becomes similar to trading where you have to buy the bearings reversed from the user. The added complexity necessitates firstly that SKF develop a more extensive knowledge base as well as more efficient information and data flow regarding the whereabouts and availability of bearings from individual market customers, which in this case are becoming suppliers to SKF. Where information about to the when and where a bearing is available, what applications its suitable for as well as data about the condition of a specific bearing product must be assimilated from a multitude of data sources and made available prior to purchasing.

Internal transparency and traceability according to the BDM is considered to be of increasing importance in the future for the overall learning process in SKF as it would enhance information and knowledge sharing between functions and departments, mitigating the problem of "inventing the wheel" over and over again as well as being able to in a more flexible and efficient manner identify improvement opportunities and take advantage of the same. Overall, having a high level of transparency and traceability will be critical elements in order to stay competitive in the future and mitigating issues related to information asymmetries and desynchronization between value chain points.

Perceived potential and impact of blockchain technologies
Blockchain technologies could according to the BC potentially be utilized as an interface for real-time consolidation and storing of information.Where authorized parties would have the ability to easily access information related to where their products are, in what kind of condition, when it needs maintenance or have reached the conditions for a certain remanufacturing service level. Or add information about where a product have been, how long and what has been done to it. Here blockchain could potentially create a higher level of trust between SKF and the customer as a full historic trail related to each unique bearing exists. And where customers are continuously and in real time updated with accessible information through a shared and collectively accessible data ledger.

The BC further states that the properties of blockchain would be especially beneficial in critical applications, such as tracking and tracing as well as automatically adding and sharing of new critical pieces of information. Which could also potentially help SKF and their customers to better plan their production and maintenance stops and thus create additional customer value by reducing downtime at the customer's end as well as shortening delivery lead time at SKFs end. Blockchains might also help a lot internally at SKF, specifically with administration processes and lead times. Where the BC and BDM states that if SKF could base their analysis on real time data they could potentially enhance their capability of building analytical models. Allowing SKF to more quickly understand and evaluate what kinds of remanufacturing operations should be performed in a particular case. And in turn improving response time and initiation of manufacturing and maintenance operations. One of the challenges perceived by the BC with adopting blockchain technologies can be attributed to compatibility and integration of the various IT systems at SKFs and the customer end. Where the blockchain solution need to be compatible with some of the very old DOS systems SKF uses. Another concern stated is the cultural challenge in adopting such a new technology, personnel at SKF could become an obstacle for implementation, where the same need to understand what kind of advantages it brings and why they should use.

4.3.4 SKF and Export control of military and dual use goods

The case company has operations related to the export of dual use goods all over the world in contrast to SKFs standard products, all military and dual use goods are directly sold between the company and the customer without use of intermediaries. Although it is an important part in their business it is a relatively small segment. The management of the military and dual use of goods is based on a general process that is adapted for the specific requirements of each region or country the product is manufactured in. The specific documentation and clearance process can vary depending on many factors such as the specific classification on the product, the country of origin and the final destination of the product. These things are decided by policy makers and can therefore vary over time and some countries has been “blacklisted” meaning that they are not allowed be traded with.

Each country has an independent government institution responsible for managing export control and clearance. Where the government institution and office for export control and clearance in Sweden is the ISP (Inspektionen för strategiska produkter). Generally, the export control office function of SKF acts as an intermediary between the government agency and the company, where the same is responsible for communication and managing of export certificate and license appliance operations.

The export process is initiated by the business development and sales function at the company when they have a potential customer. SKF then apply for a preliminary ruling from ISP, which is not final but gives an indication if a specific customer or country is a viable subject for receiving exported goods. The inquiry process for the license of a dual-use product starts with a tender notification sent to the ISP. If ISP approves the request, SKF will send a notification quotation to the customer, communicating that everything is in order. Upon which the customer will place an order to the company to be processed. The average administration lead of a export license inquiry at the ISP is usually around four weeks, which primarily depends on destination and the end-use of the product.

After the initial confirmation form the IPS, the company will send a complete inquiry for a export license, stating the receiving country and company, type of product and volume. Upon approval, the order is manufactured by SKF and shipped to the customer through various logistics channels. However each order shipment must be cleared with the customs office which perform a routine check of the shipment while controlling that the proper documentation related to the export is in place.

Actor roles and relationships

The export control function is performed in-house and is thus not outsourced. The export control function at SKF is solely responsible for managing everything related to the export control and clearance process, such as ensuring that export license application documentation and other relevant paperwork is in place, as well as handling communications with the ISP regarding status of current and new licenses.

Except for the involvement of the Export control function, the ISP customs and border control, other actors commonly involved to some extent in the export process are the company’s sales functions, the application-engineers, manufacturing as well as logistics. Where the sales department is in charge of establishing and maintaining contact with customers as well as consolidating information required for the export control function to file for a license inquiry to the export control office, which in turn has no interaction with the customer. Customer relationships are also commonly characterized by medium to long-term relationships and contracts.

The logistics department, which handles all logistic related activities, such as booking shipments and customs communication is fully integrated in the company, but relies on external third-parties to perform the actual transports. All dual- use products have to be processed and cleared in customs in order to be allowed for export. If the product is marked as a military product the customs must be consulted 24 hours prior to shipment. Thus, the logistics department needs be aware of all customer contracts and orders in order to be able to inform customs within the specified timeframe.

At the receiving end, the customer usually have a company export agent in place that receives the delivery and make sure that all the required import documentation is in place to finalize the transaction. Sometimes, the company will install their own agents at the customer end, which then act as transactional mediaries. However, according to the ECO it's highly beneficial for both entities that the customer act as the managing party as they commonly have a deeper understanding of their country's import procedures and required documentation.

Consolidation of information and data sharing
All of the company's communication and information sharing related to export control takes place through their internal IT and mail systems. The SCM further states that SKF have several information and management systems and protocols in place for management of Export control and clearance. Where according to the ECO the application process for the export control scenario is heavily reliant on precise information and having the necessary information available when needed. A company applying for an export license is required by the ISP to provide specific information and documentation related, technical specification and type of product to be exported, export volume, customer specific information and time period for export. The sales department also needs to have in their systems which products are classified as military or dual-use since they are not allowed to be sold in the same fashion as regular products.

The specific documentation and paperwork required is gathered and filled out by the specific export and shipping entity in charge of a specific country or goods. Where all the export control and clearance information, documents and certificates are consolidated and shared with the import/export agents upon the transaction is lastly processed and finalized at the customer's end. The ECO describe that the customer have the ability to place order, but commonly its customer service and sales department that receive an inquiry from the customer. However, the customer restricted insight into SKFs export processes or related operations. Where the ECO further states that customers and other parties engaged in the export of dual use goods has to sign a non-disclosure agreement for security reasons.

Most export license enquiry and requests are approved by the ISP, however the ECO describe that in the advent an application is not approved, the ISP have no obligation to inform the applicant of the reasons the application was denied. The above mentioned is perceived as constraint as SKF is required to manually control the status the application. Due to security reasons the communication and data exchange with ISP is performed through standardized channels dictated by the ISP and is thus very difficult for the case company to affect in any way. Where most communication related to the export control scenario is performed through email or telephone. When email is used it is obviously easier to document the process than when the communication is performed through telephone. All data concerning military classification of products has to be stored on local servers in Sweden, to which the export control office has full access rights to. In case the data would be stored abroad it requires a license from the ISP in order to do so, otherwise it would be considered a criminal offence.

Export control transparency and traceability

The ECO describe that there are still some areas where work is based on manual documentation, which at times can be time consuming and lead to longer administration lead time for example. Manual documentation is perceived by the ECO to potentially negatively impact transparency and traceability, as it becomes increasingly difficult to make the information readily available to all involved actors. Where issues related to information asymmetries and desynchronization arises due to fragmented data storage and sharing. Where the same state that transparency and visibility in the different instances of export control and between the involved actors is highly important to maintain an efficient process and. This is especially important when it comes to consolidation and sharing of data between SKF, logistics, ISP the customers and customs.

SKF also have limited insight into the actual end-use of the product. One of the primary determinants in the approval of a license is the intended end-use. Where the ramifications for SKF as a seller can be quite severe if the delivered product is used in other applications than stated in the export license. In order for SKF to protect itself, contracts are signed with the customer, clearly stating what scope or application the product is allowed to be used in. The contract terms and conditions also state that the company has the right to perform audits. Where audits are impartial and can be performed randomly at the customer. The purpose of conducting audits is to make sure that the contractual terms are enforced and that customers follow policies and guidelines stated by SKF.

Future state of export control and clearance of dual-use goods

Future consolidation of information and data sharing

The export control process is highly dependent on the political trends in the world since military and dual-use goods export is to a large degree determined by international relations and regulations. The ECO describe that the situation of export control will most likely become even more complex due to increasing demands and requirements from policy makers related to the process itself and the level of documentation required. The ECO further states that there will be an increased need for the export control function to keep track on the political aspects and relations to different countries, export approved countries, sanctions and documentation requirements keep changing.

Future challenges related to traceability and transparency

Transparency and traceability is likely to be of increasing importance in the future both for internal efficiency related to consolidation of data and lead times of administration processes. Increased transparency and traceability is also stated to be of importance for making relevant information more accessible to various actors in export control and clearance process, which in turn could have a positive affect the level of uncertainty related to for example what documentation is required in specific export or license approval case. As well as allowing SKF to stay informed about recent changes related blacklisted countries or new country specific export requirements, resulting in simplified assessment of customers and avoidance of sanctions and penalties related to malpractice.

Perceived potential and impact of blockchain technologies

Although military and dual use is a smaller business segment, yet with god margins, there are still long administrative lead times due to manual documentation and slow consolidation of data. A blockchain solution could according to the ECO potentially provide a better system for tracking, gathering and sharing different types of data and information in a more accessible fashion. Where data sharing processes related to export licenses inquiries, establishing and validation of certificate of origin as well as validation of export licenses in customs and clearance could also potentially become more transparent and efficient through the use of blockchains as all parties would have their dataset instantly updated whenever a new piece of information is added. However, a challenge is to establish what kind of information that should be stored and what actors should be granted access to the same. The BC also states that constraints are the high degree of process standardization and the several systems and subsystems that needs to be integrated. Another challenges is also related to acceptance of a blockchain based solutions within ISP and customs, where incentive is most likely limited and would require remodeling of current legislations. A summary of the perceived major inefficiencies of SKFs supply chain and each use-case scenario are found in figure 15, were several inefficiencies of the same type have been identified in all scenarios:

Counterfeiting	Remanufacturing	Export Control and Clerance	Warranty	Supply Chain
Marking of products and packages opens up for counterfeiting opportunitites and traceabiliy inefficiencies	Limited incentive for data sharing due to lack of trust in relationships	Regulations and legal framwork challenges	Long administrative lead-time	System fragmentation and limited system compatability and interoperability
Fragmented data and information storage	Fragmentated data storage "silos" and limited access which results in long leadtimes	Slow and inefficient administration processes of certificates and licences	Manual methods for data imput and sharing with customer	Limited visibility and insight between internal functions due to "Silo-setup"
Limited internal cross-functional linkage and data exchange	Limited internal cross-functional linkage and data exchange	Manual documentation and information sharing, leading to outdated duplicates	Fragmented storage of data and inefficient traceability	Information assymetries and desyncronization between supply chain actors
Slow and inefficient product authentication methods	Limited standardization of data formats and compatability	Limited internal cross-functional linkage and data exchange	Limited internal cross-functional linkage and data exchange	Limited Supply chain transparency and data sharing due to low level of trust
Long administrative lead-time due to involvement of multiple actors	Information assymetries and desynchronization between actors	Fragmented system and data access between actors involved regarding lincenses and certificates and contractual terms	Complexity in documentation and analysis activites	High complexity and limited efficiency related to traceability and conslidation of information
High level of manual documentation	Limited visibity, insight and transperency in actors external operations	Inefficient methods for communication	Limited incentive for data sharing due to lack of trust in relationships	

Figure 15 - Summary of the identified challenges adherent to the Supply chain of SKF and investigated scenarios

5. Analysis

5.1 Proposed analytical framework

As recognized, in order to analyse the gathered data and to achieve the purpose of the study, which is to evaluate how the utilization of blockchain technologies can enhance transparency and traceability of supply chain a framework for analysis had to be developed. In order to firstly evaluate if the blockchain technology is a suitable and potential option in relation the investigated case company as well as the identified inefficiencies in each scenario, the nature and characteristics of the same had to be analysed. In order to answer questions with regards to the above the method referred to as "*evaluation tree*" by Yaga et al. (2018) was used. In which a selection of questions was developed and answered in a structured sequence to determine the initial suitability of blockchain technologies in each use-case scenario.

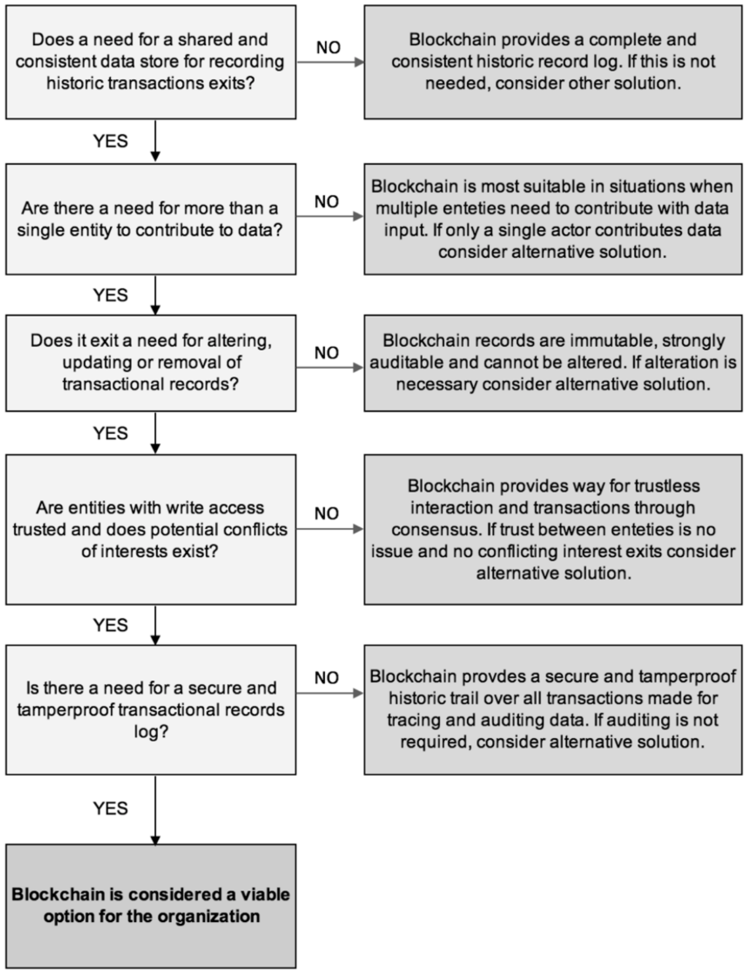

Figure 16 - Blockchain Technologies Suitability Evaluation Tree, adapted from Yaga et al., (2018)

To account for the fact that the study aim to evaluate how a nascent technology not yet broadly adopted in various industries and in where the existing knowledge base is limited but emerging will impact organizations in the future. It calls for an analytical framework in which uncertainty factors and assumptions can be incorporated. In line with Johnson, Scholes and Whittington

(2008) an adapted SFA (suitability, feasibility, acceptability) framework was used for analysing and evaluating what potential impact blockchain technologies have on the case organization's supply chain operations, as well as how blockchain technologies can enhance and secure a higher degree of traceability and transparency of the same. More specifically, the framework will be used to analyse and evaluate how blockchain technologies may enhance transparency and traceability within each of the four individual presented use-case scenarios, counterfeiting; warranty; remanufacturing and export control and clearance of dual-use goods. The SFA model have been used as it allow analysis from a generic and broad perspective with the higher degree of flexibility needed. The proposed SFA framework and chosen criterion that have been evaluation and analysed are illustrated in figure 17. The figure further gives a summarized overview of the more in-depth analysis presented in chapter 5.2. Each criterion in the framework has been analysed and weighted (e.g. scored with plus and minus or zero) with consideration to the individual context in each use-case scenario, the case company and the characteristics of blockchain technologies where informed inferences has been made.

Evaluation Metics	Scenario 1 - Counterfeit	Scenario 2 - Warranty	Scenario 3 - Remanufacturing	Scenario 4 - Export Control
Suitability (Strategic fit)	**4**	**0**	**2**	**2**
Incentive of SKF related to adoption and enhanced trust	+	+	+	+
Percived negative impact of problem	+	-	+	+
Is the problem growing?	+	-	-	-
Demand for enhanced transparency & traceability	+	+	+	+
Feasibility	**−1**	**4**	**2**	**0**
Level of resources required (e.g level of In-house expertise, money, time)	-	+	-	+
Complexity of implementation	-	+	+	+
Level of stakeholder incentive and involvement required	+	+	+	-
SKFs level of stakeholder influence	0	+	+	-
Acceptability	**2**	**2**	**2**	**0**
Percived potential for mitigating problems	+	+	+	+
Percived Benefits	+	-	+	+
Organizational risk involved (e.g finiancial or operational risk)	-	+	-	-
Stakeholder risks	+	+	+	-
Total Score:	**5**	**6**	**6**	**2**
Scoring model:	**+ = Positive impact**	**- = Negative impact**	**0 = Neutral impact**	
In the proposed SFA model, scoring is perfomed using + , - and 0. Where the same give indication of the level of impact or severity adherent to the individual metric. Plus indicates a positive impact, minus indicates that there is a negative impact and zero indicates a neutral or no impact. The total score indicate in what use-case scenario blockchain have the greatest potential. Where the calculation is performed by subtracting plus and minuses.				

Figure 17 - Proposed SFA framework for analysis of how blockchain technologies may impact the case organization, adapted from Johnson, Scholes and Whittington (2008)

5.2 Scenario screening and analysis

5.2.1 Counterfeiting

5.2.1.1 Blockchain evaluation tree

Since a problem with fragmented data and information storage regarding the counterfeit scenario clearly exits it shows that there is a direct need for shared and consistent data store. The counterfeit scenario is characterized by having multiple actors involved both internally and externally that needs to contribute with data and rely on existing data to be effective. In order to create a undisputable and tamperproof history of previous transactions related to a product chain of custody and origin, there is a need to be to add information regarding the product but not alter what has already been added in a consistent manner. In order to fight the growing issues of counterfeits, it is vital to share necessary information with various parties in a transparent and unalterable way. However these parties can vary depending on the situation and the necessary information that needs to be shared differs as well. SKF therefore need to be able to interact with other entities in an relationship environment where the level of trust is low and there may be conflicts of interests. Due to the nature of counterfeited goods there needs to be a tamperproof and reliable method for documentation of the product and log of the transactions it has been involved in (chain of custody). From the initial analysis of blockchain in relation to the counterfeiting scenario it can be concluded that blockchain technology would most likely present a viable and beneficial option based on the blockchain evaluation tree.

5.2.1.2 Suitability

There are strong indications that the current fragmented data and diversity in information sharing between internal and external supply chain actors might lead to inefficiencies and a high level of uncertainty in the existing data structure. The company´s incentive to adopt a blockchain solution would most likely be substantial as it potentially could make product and process information more trustworthy and available to the right parties involved in the supply chain, while at the same time increasing trust and enhancing transparency in supply chain actor relationships. Furthermore, depending on what blockchain configuration is used, it may also provide an alternative option for the company to enhance transparency while maintaining control regarding the extent of information that is to be shared among actors related to a specific product during the anti-counterfeit process. As indicated earlier blockchain could also increase the efficiency in governing intellectual property rights , where the use of blockchains might potentially lead to a decrease in administrative lead time while also saving company resources. This is mainly because the amount of time currently used to perform manual work (documenting, consolidation and auditing of data) could be decreased as blockchain digitally and automatically creates an undisputable log of all recorded transactions made on the blockchain in a distributed fashion. Furthermore, the characteristics of blockchain would also mitigate the issue of counterfeiters utilizing and taking advantage of falsified information, such as fake product barcode, as the network through a collective and semi-automatic process invalidate the transaction (change in chain of custody) due to lack of consensus. Meaning that, a counterfeit product would be detected before it could even enter the authenticated and real supply chain. The company´s incentive to adopt a blockchain solution will most likely increase due to the negative economic and reputational effects counterfeiting products may have on their business and company brand in the industry. The perceived negative impact of the problem is evaluated to be extensive as it can be considered to be an industry wide problem which affects all bearing manufacturers worldwide. Not only does it negatively affect company´s economically, where SKF is losing out on sales and revenue, it might also have negative impact on the company´s brand and reputation together with other company's brands using counterfeited SKF bearing products in various business application or final products, believing that these as the real deal as modern counterfeiters are skillful in deceiving. In addition, public safety risk increase dramatically in application where counterfeited products are used. Hence, the severity of the counterfeiting and piracy problem can be considered to be extensive as it has the potential to seriously harm the company in several different ways.

The problem of counterfeiting is considered to be growing partially as the industry is growing and thus can be considered more attractive for counterfeiters. Furthermore, customers are continuously expecting a higher quality level assurance from the products associate with the company´s brand. In addition, counterfeiters are becoming increasingly creative and resourceful with the ability to produce near identical versions of the real product making it increasingly difficult to detect counterfeits without advanced screening methods of the product itself but also for validating the authenticity of attached information.

The demand for transparency is considered as high and can be attributed to the need for enabling a more efficient process that more quickly can identify counterfeits in the supply chain. However this would require a high level of synchronization amongst the different data entities involved. Due to the fragmented data structure used today the transparency is compromised in several situations since data might be unavailable in the majority of situations. Requiring additional time consuming manual work in order to retrieve the relevant information needed for authentication from various databases. Furthermore, the multitude of supply chain actors involved in the manufacturing and delivery of a product, where individual parties hold isolated fragments of information but are unwilling to share, increases the difficulty in consolidation of relevant data for detecting counterfeits. The demand for enhanced traceability exists, as possible counterfeit products needs to be identified and removed prior to installation and use in any customer application. However, current methods are to a large degree relaying on time and resource intensive manual work which in far from optimal and incur unnecessary cost for the company and their customers. Hence, there is a high demand for an overall enhanced transparency and traceability in order to counter counterfeiting and piracy in the supply chain of the manufacturing industry.

5.2.1.3 Feasibility

The blockchain consensus mechanism and cryptographic techniques make the blockchain highly secure and without the need for a trusted central authority. However in order to maintain the blockchain it requires a significant amount of energy in the form of electricity. In the case of counterfeiting, depending on the blockchain type and model SKF would pursue, the resources required for development, implementation and maintenance would probably be quite significant.

In addition the blockchain is immutable, meaning that once blockchain solution have been developed its characteristics and features cannot be altered, hence numerous demands encompassing both internal and external participants will have to be considered. This would in turn require time for proper consideration of needs and implementation approach, where actors also have to establish and agree upon the governing authority of the same. The complexity of the implementation is highly dependent of the number of stakeholders involved as they need to be coordinated around the specific details of the IT-system used for implementation. The complexity would further be affected by the internal functions and resources that are affected by the implementation, in the case of counterfeiting it could therefore be rather complexed as manufacturing is a large function within the company.

The level of stakeholder incentives can be deemed to be high, due to the many different stakeholders that are negatively affected by counterfeiting. Counterfeiting is an illegal act with major economic implications and it is therefore in the interests of government agencies and law enforcement to properly manage this issues. Furthermore, customers can also be seen as highly motivated to stop the flow of counterfeited products in the marketplace. This is mainly due to the danger that counterfeited goods might pose to their business applications since the quality in counterfeited goods are known to be substandard and the risk for malfunction or functional issues are high. That also in turn could have serious economic and health consequences, damaging their reputation and brand as the promised quality or safety standards cannot be delivered. Serious competitor in the industry are also likely to want to limit counterfeiting due to the same reasons as SKF. The different stakeholders' involvement is likely to vary depending on the specific blockchain solution and which stakeholders are to be involved. Thus, the complexity caused by their involvement would depend on the extend they are to be able to interact with the blockchain.

SKF's level of stakeholder influence is to be considered as limited, however as previously stated, the issue of counterfeiting is perceived to be affecting several supply chain stakeholders in numerous ways. Therefore there should be a collective incentive for pursuing development and utilization of blockchain based solution as it provide an efficient means for dealing with this problem. In addition, SKFs relationships with their customer as well as with other supply chain actor in the area of counterfeiting is collaborative and more long-term which could mean additional influence power for SKF. Hence, SKF could potentially act as an initiator while successfully pushing other actors to further invest and devote resources towards the development and implementation of a blockchain.

5.2.3.4 Acceptability

The perceived potential of using blockchain technology to mitigate the current problem of counterfeiting can be attributed to the enabling of improved access to vital information in the different aspects of the counterfeit scenario. Both in making product related information more easily traceable through the organization and its various functions, but also in allowing the company to share vital intelligence more easily with external supply chain actors involved in anti-counterfeiting processes. Hence the main value in relation to above mentioned is attributed to the possibility for improving efficiency and visibility of data transactions between supply chain instances.

The expected perceived benefits from blockchain technology in relation to counterfeiting within the company is that it will lead to a higher degree of visibility and insight into their operational activities. Thus, possibly creating an improved and more simplistic oversight of current business operations, in which it will be easier to detect and evaluate possible counterfeited products. It would also potentially lower the obstacles for parties to efficiently get access to necessary information in the various situations where there is suspicion of counterfeit. The benefits received by blockchain in the scenario is directly related to the number of external actors that has the ability to add and read information of the blockchain. Hence, the perceived overall benefits are therefore considered to be positive.

The organizational risks involved are primarily related to the complex nature of implementing IT solutions and the difficulty of perceiving the financial benefits of implementing it. Any implementation of a new IT-system requires the involvement and effort of internal resources and will affect the daily operations. In order to implement it there is a need to keep the current operations going which potentially might cause disturbance. When implementing blockchain in a case such as counterfeiting, it may be difficult to assert the overall direct financial benefits as it requires the involvement of multiple actors while there is uncertainty in the potential in the specific solution. This would in turn require individual consideration of the isolated benefits and risks perceived by individual actors, including resources available. As well as a collective and eco-system evaluation of the benefits and risks related to the entire supply chain.

Furthermore, a perceived risk can be attributed to potential conflicts of interest among the stakeholders, where conflict arise in relation to the governance of the blockchain. Another risk can also be attributed to potential disturbance in business operations while development and integration of blockchain is performed which could result in additional down time costs. In addition, blockchain may not contribute to any significant value in the process of counterfeiting, where the significant investments made in data storage facilities and energy would be lost. However, the risk related to the above is to be considered as limited.

5.2.2 Warranty

5.2.2.1 Blockchain Evaluation tree

In order to evaluate products in the warranty claim process there is a need to know the historical data surrounding a specific product´s chain of custody, including shipment. Since the product is likely to have been handled by several actors, both internal and external, there is a need for them to be able to contribute with various sets of data. Depending on the specific case some information related to the product cannot be allowed to be manipulated if it is to be considered reliable. In warranty cases there is an commonly some kind of inherent conflict of interest between two or more of the actors involved. In cases where certain information is required to settle some form of dispute, it needs to be based on reliable sources that have not and cannot be tampered with. Hence, based on the blockchain evaluation tree there is a potential fit for blockchain in the warranty scenario.

5.2.2.2 Suitability

Blockchain technology could be used for enhancing transparency and traceability in relation to storing, sharing and use of material certificates from suppliers, customer specific certificates and customer operational documentation. The increased transparency and traceability through the use of blockchain, auditing of data related to performed activities, quality standards and practical use of products in applications could be performed the parties involved. Resulting in improved efficiency in resolution of conflicts between supply chain actors in terms of identifying the source of origin for a potential malfunction of quality issues. As well as establishing who carries the responsibility for such issues. In turn minimizing use of resources and time consuming gathering and consolidation of information as the relevant and necessary information is directly accessible on the blockchain. Additionally, there is potential for using smart contracts to automate information and monetary transactions, such as refunds, to increase transactional efficiency, while minimizing the need for back and forth communications. Furthermore, in some instances there is a need to share intellectual property information with customers when solving warranty cases. Here blockchain has been suggested as an efficient governing these intellectual property rights. Hence, there are positive incentives to use blockchain technology within the warranty process.

The perceived problem of today is related to the limited traceability of documentation on the warranty cases since a lot of information is stored separately in a fragmented manner in various databases. In addition, the warranty claim process partially relies on manual methods for data input, searches and sharing, both between internal functions and external supply chain actors. That in turn causes prolonged administrative lead times and increased difficulty in capturing the required information for analysis of warranty claims. In addition, the lead-time for warranty cases is highly dependent on the expectations of the customer and thus a reduction of lead-time may have a positive impact on customer satisfaction. Furthermore, the problem is relatable to the quality of the products manufactured and to what the extend reclamation cases becomes an actual warranty case. In relation to previously stated, there is a limited number of reclamation cases and disputes that enters the actual warranty process and are directly dependent on the circumstances of the claim and the contractual terms between SKF and the individual customer. The overall carrying costs of warranties are also perceived as limited. The amount of negative impact of the problem today can therefore be considered to be relatively moderate. In regards to the future development of the current issues, it’s difficult to make an direct assessment. However as the number of warranty cases is currently limited in conjunction with the high quality standards that SKF maintain, the problem cannot be considered to be growing in relation to today’s business.

The demand for transparency and treatability is important both internally at SKF and also towards the customer in order to have a trustworthy and reliable warranty process that is efficient. An increase in transparency and traceability has the potential to make documentation more easily available and thus improve the process.

5.2.2.3 Feasibility

The consensus mechanism and cryptographic techniques allows for highly secure and trusted transactions between actors. However, a potential blockchain solution requires a significant amount of energy to sustain its functionality, hence it might not be beneficial from a feasibility perspective in the case of warranty. Furthermore, depending on the type of blockchain and model SKF would pursue the resources required for development, implementation and maintenance would probably be quite moderated due to the relative limited amount of external stakeholders involved. However, the level of internal know-how and technological knowledge have not been extensively mapped and might thus require additional resources for development and utilization.

The complexity of the implementation can be relatively small as a blockchain solution could start of on a smaller scope and then successively be scaled up if needed due to warranties being dealt with separately, as there is little to no correlation between different cases. Furthermore, it would require the involvement of a number of functions within SKF and customer with warranty claims, potentially increasing the complexity as different needs have to be considered. Another requirement is that the blockchain has the access rights to the required documentation, where various business and support systems utilized by both internal functions as well as external supply chain actors need to be integrated. Thus the overall complexity for implementation and use in the warranty scenario is deemed to be relatively big.

The level of stakeholder incentives and involvement is depending on the specific implementations and its extent. If the blockchain solution is based on certificates as suggested by the DQC it is likely crucial to get access and acceptance from the involved stakeholders to store their certificates and that internal units related to the warranty process are allowed to read it and use it in the daily operations. In addition it is important to have an agreement of the final scope and its purposes, where fundamental needs are met. Therefore the level of engagement from stakeholders can be considered to be minor. The possibility to influence the stakeholders does not seem to be problematic due to their limited required involvement. Today they already are communicating their certificates and with the addition of blockchain technology their efforts will most likely decrease.

5.2.2.4 Acceptability

The perceived potential for mitigating current problems and issues in the warranty use-case scenario with a blockchain solution could be attributed to possibility that the technology allow for a more efficient internal process, encompassing both analytics and administration, as information becomes more easily accessible due to the transactional history provided by the blockchain. Furthermore, blockchain might have the potential to mitigate current problems by reducing the amount of work needed to locate all the necessary data from various databases related to the warranty cases as all actors rely on a single point of entry for input and access. The perceived benefits from introducing blockchain technology in the warranty process would thus be significant reduction in costs and improved efficiency of the process. And as previously stated, the utilization of a blockchain based solution could also improve lead time while increasing customer satisfaction. Hence, there are potential major benefits to be captured.

The organizational risks involved would primarily depend on getting the right access to the necessary data related to the specific warranty case which requires that actors involved are willing to provide the necessary data. Where required investment (financial and know-how) in a blockchain solution would potentially not contribute to an acceptable increase in value compared to current methods used. However due to the limited complexity involved in implementing a blockchain the organizational risks are deemed to be relatively low. The stakeholder risks involved are potentially related to the information they are willing to share with SKF. However, by using blockchain technology external stakeholders might be able to get additional quality assurances from SKF and therefore their risk will decrease.

5.2.3 Export control and clearance

5.2.3.1 Blockchain Evaluation tree

The export control scenario is primarily characterized by heavy required documentation due to the sensitive nature of the products. The export control and clearance process further require solid documentation of both historic and new data and communication transactions related to the dual-use products for approval and renewal of licenses. As well as transparent sharing of the same, where policies from government authorities and regulations have to be strictly enforced. Furthermore, there are several supply chain actors are commonly involved in the process where information related to the products such as certificates of origin needs to be easily audited for compliance purposes. Hence, there is a clear need for a shared and consistent data store.

There are multiple functions within the company that needs to be able to contribute with information to provide a complete set of the necessary documentation required by the authorities. This involves functions such as customer support, manufacturing and logistics. If outside stakeholders are to trust the information added, there is a requirement that the added information during the process cannot be altered or manipulated. The entities involved cannot per se trust each other due to the regulatory nature of the scenario and therefore conflicts of interests cannot be ruled out. Thus, there is a need for a tamper proof transactional record of the product information and the involved communication that spans from that the order is initiated until the customer receives it, guaranteeing a reliable track record through the process. This concludes that the fundamentals of blockchain technology can be a viable and potential option in the export of military and dual-use goods.

5.2.3.2 Suitability

The incentives for SKF in the export of military and dual-use of goods scenario is to make the process more efficient and to simplify the consolidation and transaction of data between the involved actors. Blockchain might be attractive since it could allow for a larger degree of traceability in the process as it could make the logistics operations more transparent. Blockchain and smart contracts has also been suggested to have a positive impact on cross border trade as it could digitize and automate various trade processes, such as customs clearance and administrative tasks. The blockchain is also described as being capable of handling the sensitive information that is involved in the export of sensitive goods. The process also involves some internal activities, where manual paperwork are conducted, which can be seen as an inefficiency and be considered unreliable. Thus, there are incentives to adopt blockchain technology as a suitable means for provision of enhanced transparency while trusted and secure transactions between peers could also be ensured. Ultimately also ensuring a high level of compliance through simplified auditing.

Some of the current difficulties can be attributed to the need and of keeping track of the continuously changing political environment around the world. As well as keeping the systems updated with the latest information regarding blacklisted countries and other hindrances for conducting business. Furthermore, it is crucial that information related to the export of dual-use goods are stored within the Swedish borders and are not allowed to be shared outside the country borders without explicit permission by authorities. Existing issues of fragmented data storage in multiple systems where data access between the involved parties are limited. In conjunction with current methods for communication (e-mail) it makes the process more difficult and rather time consuming than it has to be. Potentially also resulting in heighten uncertainty related to what documentation or data is required in license applications and export operations. The inefficiencies and constraints are thus having an negative impact on the performance of the process. Furthermore, the nature of the problem, although somewhat uncertain, indicates that in the future scenario the problem will not have grown in comparison to today.

There are also indications for an increased demand for enhanced transparency and traceability. At the company´s end it relates to the ability to keep way from claims stating that products have been sold to customers under sanctions, damaging the reputation. In addition, there is an increased need and requirement from authorities of being able to more easily verify that the company is enforcing rules and obligations dictated by the government agencies for export control and clearance. Hence, several benefits could potentially be captured with enhanced transparency and traceability.

5.2.3.3 Feasibility

The consensus mechanism and cryptographic techniques allows for a highly secure and trusted process, however it requires a significant amount of energy in the form of electricity and computer power to sustain its functionality. In the case of export control, depending on the type of blockchain and model SKF would pursue the resources required for development, implementation and maintenance would probably be quite moderated due to the relative limited amount of external stakeholders involved.

The complexity of the implantation can be related to the relative few stakeholders and internal functions involved. The process itself is relatively straight forward which allows for a simpler implementation. The characteristics of the export and clearance process allows for a stepwise implementation. However, due to an uncertain level of technological knowledge, legal framework and acknowledgement for blockchains from government institutions the complexity might be higher as these hindrances must also be overcome. The complexity of implementing blockchain in the scenario is thus considered to be moderate.

The incentives from the various stakeholders and their involvement is presumably limited since the main expected benefits received from a blockchain implementation would primarily benefit SKF's internal processes. In an ideal scenario, the government agencies would be able to partake in the blockchain initiative but that might however be difficult and unlikely due to previously stated. The involvement from third parties, customers or government agencies, is necessary as it would allow for an improved and simplified consolidation and sharing of data. Actors could thus read or write data on the blockchain collectively, enabling a more efficient data exchange. The incentives are highly dependent on what benefits a blockchain solution might bring and can therefore limit their willingness to participate in the initiative. Therefore, both the individual needs and benefits must be considered and clearly communicated. SKF could of course capture benefits from internal use, however due to the heavily involvement from government instances, it can be seen as a requirement that these actor partake.

Influencing the involved stakeholders are presumably going to be difficult due to their lack of current incentives, where the limited level of knowledge could be a major barrier for adoption. The government agencies involved might be the most difficult to influence since they are communicating through standardized communication channels and thus might be unwilling to change. The SKF level of influence over external parties is thus considered to be low.

5.2.3.4 Acceptability

There is a high level of efficiency potential in the internal processes in relation to a blockchain solution. Switching from manual methods of performing activities, to a fully digitized approach and providing a digitized information flow through the same communication channels could potentially make documentation easier. The lead time required could potentially also be reduced, while the quality and robustness of data could be enhanced. Thus, there is potential in mitigating the present difficulties within the export control and clearance scenario.

The perceived benefits are primarily that the internal efficiency could increase. This would be allowed by shorter internal administration times by having easier access to important documentation and a reliable track record of the transactions that are needed through the process. It would also allow for a better overview of the flow of products and information. The perceived benefits are thus considered positive.

The organizational risks involved are relatable to the negative consequences and severity of error that characterizes the scenario. Wrongdoings in the dual-use goods scenario are compared to the regular sales process severe since they can result in hefty fines and legal actions. The risks involved are thus somewhat extensive. There are no direct stakeholders' risk that have been identified and therefore the overall stakeholder risk can be considered to be limited in scope.

5.2.4 Remanufacturing

5.2.4.1 Blockchain evaluation tree

The future state of the remanufacturing scenario is characterized by requiring a large degree of documentation and operational information regarding the products. In order to be able to evaluate the conditions and the extent of required remanufacturing more data about the product is beneficial ant thus there is a need for a shared and consistent recording of historical data. In order to reach its full potential everyone who is in contact with the product would need to contribute with data of various types, thus there is need for more than one entity to contribute with data. In order to attain a reliable transactional history for each product involved in the future scenario of remanufacturing information needs to be able to be added without being altered afterwards. Due to the multiple actors involved and their different interest there are needs for trusted interactions which blockchain could provide. There is also a need for a secure and tamperproof transactional log of records since the products will travel between different entities that has low incentives to fully trust each other. The conclusion is thus that blockchain can be a viable option in the case of remanufacturing.

5.2.4.2 Suitability

The incentives around adoption and enhanced trust is to a large degree based on SKF's future vision surrounding the potential of expanding the remanufacturing segment. Blockchain could thus play a crucial part in enhancing trust between the different supply chain actors involved in the future scenario. More specifically, a blockchain solution could enable trusted transactions between SKF and customers without first establishing a long-term relationship. It could also promote increased current and new customers willingness to share application data directly on the secure blockchain. Where only relevant parties have access to critical data due to the ability to restrict reading and access rights. This would be highly beneficial in relation to potential increase in size of the remanufacturing segment in a future scenario. The remanufacturing process is also characterized by a heavy information flow, where substantial data needs to be captured and to perform certain operations and analysis and will most likely remain so in the future as well. Hence the incentives to adopt a blockchain solution are considered as major.

The current issues can be perceived as a lack of information related to the remanufactured products. A major hindrance today is the lack of an effective way for customers to share information about applications containing a bearing that can be remanufactured. This could be related to lack of trust or limited interoperability of available systems in which sharing of data efficiently is difficult due to the limited standardization of data formats and compatibility. The negative impact of current issues of today's remanufacturing operations will most likely not becoming more severe in the future. For the remanufacturing to reach its full potential in a future scenario there is a demand for enhanced transparency and traceability related to the process. An enhancement would allow for an easier overview of the products available for remanufacturing as well as making it easier to know to what extent a product is to processed in the remanufacturing process. An enhancement would also potentially allow for a higher degree of trust between the parties as a full transactional history would be available. Accessibility to the relevant information could be considered to become easier. Thus, there is a high demand for enhanced transparency and traceability in the remanufacturing scenario.

5.2.4.3 Feasibility

The consensus mechanism and cryptographic techniques allows for the to be highly secure and trustless while the trade-off is that it requires a significant amount of energy in the form to sustain its functionality. In the case of remanufacturing, depending on the type of blockchain and model SKF would pursue the resources required for development, implementation and maintenance would probably be high due to the relative limited amount of external stakeholders involved.

The complexity of implementation is depending on the extent to which blockchain is to be added to the scenario. In the optimal solution every bearing on the market would be recorded on the blockchain. Although this would require the involvement of a relatively large number of stakeholders and would thus be a highly complex endeavor. However, benefits could be captured from implementation on a smaller scale as well, where SKF could use blockchains for only some of the products. In turn simplifying the complexity of implementation, allowing benefits such as a transactional history of the specific product. Due to the possible stepwise implementation process the complexity of the implementation can be considered to be moderate.

The stakeholder incentives are primarily related to the possibility of decreasing costs and enhancing sustainability since remanufactured bearings can allow for a lower production cost as well as shorter delivery times and lowered environmental impact. As information becomes more available, stakeholders can also make better decisions in regards to what bearings are available and in what time frame can they be remanufactured. Thus allowing for an improved visibility of available bearing products in the market.

Furthermore, the required involvement from customers would primary be attributed to the willingness to share operational data on the blockchain regarding the bearing products and their applications in which the same is used. Their willingness to do this is a critical and determining factor for the potential of the scenario. Additionally, adding a blockchain application could be considered to be fairly easy in this case. Thus, the conclusion is that the incentives are positive towards blockchain. The potential for SKF to influence external stakeholders will most likely be determined by the potential positive benefits and added value that could be provided, versus the perceived negatives that the use of a blockchain might bring in the future. It can thus be considered highly important that the blockchain application is evaluated as a trust creating tool that allow SKFs customers to decrease their operational costs and sustainability level while providing increased end customer value. The solution would most likely also have to be fairly simplistic for customers to implement and use as well.

5.2.4.4 Acceptability

The issues with a lack of accessible and trustworthy information hinders the remanufacturing scenario to reach its full potential. There is potential to transform the manual work with physical documents to a more digital documentation storage solution, which will serve as an enabler for the ambition to aggregate data in the remanufacturing area. As well as creating a full transactional history for products that would open up new business opportunities for SKF.

The perceived benefits for SKF are that blockchain might provide new business opportunities and incorporating remanufacturing as a viable alternative to manufacturing new products for all customers on a industry wide scale. These opportunities are primarily related to the enabling of SKF to increase their offerings within the service and maintenance area. With improved trust enabled by the blockchain sharing of information could increase. This will have a positive impact for all parties involved, improving cost efficiency, enabling quality assurances and open up for potential business commitments in the long perspective. Internally, a blockchain solution could also provide improved learning as knowledge and solutions developed can be more easily be shared between functions, reducing resources used for developing several solution for a common problem. Thus, the perceived benefits of blockchain in the scenario are major.

Organizational risks may involve the development and implementation of a blockchain solution which does not fully consider the future strategic development of remanufacturing as a prominent business segment. Where the complexity and uncertainty related to how this remanufacturing process will function in the future is to be considered extensive. Several key factors first need to be considered prior to the development and implementation of a potential blockchain solution. Such as how the acquiring and collection of products subject to remanufacturing will look like, what actors will be involved et cetera. Blockchain as stated previously is immutable, hence these kind of uncertainties have to be considered as the otherwise impose added risk. Hence the overall risk with implementation of a blockchain solutions is currently evaluated as big due to the uncertain conditions in the future.

The external stakeholders in the future scenario of remanufacturing are able to lower their risks as the remanufacturing scene opens new possibilities and allows a better overview over the bearings market. In addition, there is a potential to have lower lead-times for bearings which can benefit their daily operations and lower uncertainty. This would allow them to have better information to make decisions on and easier access to reserve parts. This concludes that the stakeholder's risk will decrease.

5.2.4 Supply chain of SKF

5.2.4.1 Blockchain Evaluation tree

In evaluating blockchain technologies for SKFs supply chain one must first consider that there are an extensive number of actors which are to be considered as linked together through the interdependent on the access and sharing of the same data and information regarding each other´s business operations in the supply chain. As SKF rely quite heavily on outsourcing for certain business activities and will most likely do so in the future as well there is a need for extensive and continuous auditing of operations performed which requires sufficient and solid data. Furthermore, as stated the supply chain encompass several different actor layers having different roles and functions, which all contribute with data in the overall flow of information. In addition the relationships are mostly characterized by long-term commitments collaborations in which consciousness interactions take place over an extended period of time. Hence there is need for having a shared and consistent data store of transactions where multiple actors will most likely contribute to the data input to ensure the high quality standards of SKF is met and maintained.

The information flow involves many entities contributing in various ways through the supply chain and thus there is a need to continuously add information and transactional records to the supply chain, in some cases there is a need for this to be undisputable. Due to the large number of different actors involved in the supply chain there is essentially a relatively high uncertainty amongst the different actors thus leading to a low level of trust and to potential conflicts of interests. The supply chain consists of a series of transactions flows between actors and the need for a tamper proof log of transactions varies between different cases but as shown in the various scenarios there is a need for a secure and tamperproof transactional log. The blockchain evaluation tree analysis displays that blockchain can be a suitable application within the supply chain.

5.2.4.2 Suitability, feasibility, acceptability

SKF focus more today on developing the service business of the organization than pure production, where SKF uses partners for delivery and production abroad which limit the insight into the supply chain and related business operations performed by third-parties. In addition, the overall level of outsourcing will most likely increase in the future, further adding to the complexity of the current supply chain and thus increasing the pressure for finding a fitting solution which can secure a sufficient degree of traceability and transparency in order to maintain a high level of trust in relationships.

The current organizational structure, which is characterized by large decentralization and functional specialization has "silo disadvantages" in terms of spatial access to specific databases, is leading to limited visibility and high fragmentation of data throughout the entire organization. In which information asymmetries have emerged that in turn leads to unnecessary long administration lead times and slow responsiveness. Due to independency of each function, knowledge and information sharing becomes limited, making coordination of cross-functional supply chain activities and problem solving as well as organizational learning more difficult.

The issues related to the above can potentially be mitigated by utilizing a blockchain based solution as blockchain enable sharing of information and data in a decentralized and distribution fashion, where all functions and actors on the blockchain only have one entry point data for input and output. In addition, this would also help mitigate internal and external desynchronisation and information asymmetries in the supply chain as all actors would have the latest update of the ledger at all times.

One of the main aspects highlighted in relation to the limited level of transparency was limited trust between supply chain parties as well as the fear for unwanted access to confidential information. Where the utilization of blockchain enables a trustless environment in which trust lies in the blockchain network itself, hence conflicts of interest and opportunistic behaviour can be mitigated. In terms of sharing confidential information, SKF could alternatively choose to develop, incorporate and utilize various blockchain for different purposes. And for transmitting and sharing of confidential information a private of consortium blockchain would suffice as a suitable solution as it would allow increased control over read and write access. But where a public blockchain could be used for sharing of non-sensitive information which would be beneficial to for all parties to have easy access to which the blockchain providers.

The overall feasibility of developing, implementing and utilizing a blockchain technology based supply chain must be considered in the light of SKF being an individual large global incumbent. Where it can be assumed that SKF already possesses or is being able to acquire the necessary financial and technical resources as well as know-how and expertise required for such an endeavor if it was to be used for internal purposes only. However SKF supply chain is currently characterized by having a largely disintegrated structure where a multitude of actors are involved in the transactions and performing of various supply chain activities.

SKF and its supply chain partners are currently highly dependent on the utilization of IT technologies for communication and transactions of data and is perceived to be even more so in the future. Furthermore, communication systems such EDI-systems for tracking and tracing information related to products and performed activities in the supply chain is critical for maintaining a sufficient level of performance. It is stated that an enhanced level of transparency and traceability will be of utmost importance for conducting business in the future in relation to the Supply chain of SKF due to increased sustainability pressure from the customer's end as well as from politics. Where real-time updating and access to critical data and information in operations such as logistics and transportation. The features of blockchain technologies can provide a complete historic record, where all participants will have real-time access to the latest version of the shared ledger, which would allow SKF and its partners to collaborate more efficiently while at the same time enhancing the overall supply chain performance.

6. Conclusions

This research study have examined how the utilization of blockchain technologies can provide enhanced transparency and traceability in the supply chain of firms in the manufacturing industry. Furthermore, blockchains potential for mitigating inefficiencies of the generic supply chain and four blockchain use-case scenarios, warranty; counterfeiting and piracy; export control and clearance of dual use goods; and remanufacturing has been investigated. This research thus contribute to a deeper understanding of blockchain technologies for supply chain transparency and traceability. It further provides a foundation for further research from an exploratory perspective, by answering, how blockchain could hypotactically be utilized in supply chains in the manufacturing industry, while also pointing towards its business potential within the four stated use-cases.

The increased complexity from the globalization of markets is concluded to be adherent to the introduction of new IT solutions and new emerging demands from various stakeholders as well as from an increased level of outsourcing and disintegration of supply chain activities. This development have resulted in transparency and traceability issues due to the multitude of actors and business operations involved. Ultimately resulting in poor collaboration and lowered overall supply chain performance. Where the arrival of blockchain technologies will most likely have a significant impact on the manufacturing industry.

Blockchain technologies have been understood to be in its basic form, a shared decentralized and distributed ledger technology in which transactions can be recorded in a peer-to-peer network in a secure, immutable and tamper evident fashion. Where blockchain enable valid and effective and full traceability. Furthermore, the blockchain technology builds on cryptographic and consensus mechanisms, enabling transmission and verification of transactions in a highly secure fashion and without the need for any trusted central authority or intermediaries. Thus the blockchain facilitates transparency and trust among actors while a higher degree of efficiency can be achieved. Furthermore, blockchains concluded to be best suited in business contexts in which multiple actors are involved in transactions that require transparency and trust. The study further identifies several potential business application areas of blockchain, supply chain transparency and traceability, documentation and record keeping as well as automated transactions through smart contracts. The study also shows existence of various types and setups of blockchains with different characteristics such as public, permissionless, private, permissioned, and consortium blockchain, in which all have different benefits, limitations and areas for potential use. However, its concluded that no standardized blockchain configuration exits, where a solution must be adapted in consideration to the specific needs and requirement in each individual use-case.

The empirical results and analysis provided several key insights. Several inefficiencies and issues are imposed on the supply chains of companies in the manufacturing industry due the limited transparency and traceability and increased complexity and disintegration in the supply chain. These has been indirectly identified through the investigation of the four use-case scenarios and are adherent mainly to, information asymmetries, fragmentation of data, desynchronization between actors, and reduced overall supply chain performance. That in turn results in reduced and poor supply chain actor collaboration and cooperation due to limited trust. Reduced delivery reliability, lowered supply chain responsiveness, increased difficulty in enforcing quality standards and higher incurred cost due to the need for extensive auditing, and missed opportunities for improvements.

Furthermore, internal supply chain issues related to transparency and traceability in four case company specific use-case scenarios emerge due to firstly, the current disadvantages stemming from large decentralization of organizational functions and fragmented storage of data in various databases. Secondly, fragmented access to databases currently makes consolidation and sharing of information highly difficult. Thirdly, limited cross-functional collaboration, integration and interoperability of the various IT systems used, as well as a high level of manual documentation. Resulting in longer lead times in administration related to processing of warranty claims, remanufacturing request and export control and clearance inquiries.

The study also establishes that efficient traceability and a high level of transparency in supply chain operations will be of increasing importance in the future as the supply chain constellations grows and increases in complexity. Furthermore, blockchain technologies may have several use-cases for establishing enhanced transparency, traceability in the supply chain of firms in the manufacturing industry. Specifically in the areas related to counterfeiting and piracy of goods; warranty; remanufacturing; as well as export control and clearance of dual-use goods. In supply chain operations, blockchain could hypothetically enhance traceability through the provision of a secure alternative for recording and auditing transactional data and information between actors. While improving data and information transparency, where existing issues related to fragmented data storage and information asymmetries between internal functions as well as between SKF and external supply chain actors could potentially be mitigated. Thus resulting in reduced administrative lead time, incurred costs and resource usage, while facilitating cross-functional collaboration, and improved data tracking.

Furthermore, blockchain have the potential to mitigate fraudulent and opportunistic behavior or activities as it provides a robust and tamperproof solution with full auditability of historic transactions. Certificates of origin can be easily validated, while other product or service related data can be authenticated. In turn making it more difficult for fraudulent actors such as counterfeiters to take advantage of the current inefficiencies of current systems. The use of blockchains might also have a positive impact on sustainability aspects as less resources are required for auditing of supply chain actors as well as validation of products in the product flow. In addition, blockchain might provide new opportunities in remanufacturing operations related to improved traceability, transparency and trust. Blockchains enables multitude of supply chain actors to securely record and access data and information related to the condition of bearing products in real time. Allowing for efficient tracing of the products progress in remanufacturing operations and related costs as well as provision of more complete data related to the use and functionality of products in customer applications. In turn resulting in reduced downtime and costs for unplanned stops, while at the same time allowing for identification of product and process improvement. Furthermore, blockchain provide enhanced transparency and trust through the distributed and decentralized nature, where all actors have a copy of the blockchain ledger containing all information at all times.

Blockchain technologies could also potentially improve efficiency in the administration of warranty claims, where the same provide opportunities for increased security and simplified processes in which verification and validation is improved, while speed and transparency are also increased. Where companies can more easily and efficiently track and trace the chain of custody of products, while at the same time the root cause from which potential quality issues might have originated from and who is liable as all information and data related to processing activities and enforcement of quality standards in the supply chain can be fully traced on the blockchain. Blockchain in conjunction with smart contracts could possibly increase the efficiency in the export control and clearance process as it has been suggested as a way to efficiently handle cross border trade and related administrative tasks. Blockchains are further suited for this activity since they are said to be capable of handling the sensitive information involved in the export control and clearance process. However it would require the cooperation of government stakeholders to provide value and their faith in the technology.

Hence the study concludes that blockchain technologies could enhance transparency and traceability while having a positive impact in addressing the identified inefficiencies of current supply chain and within the four use-case scenarios investigated. It can also be concluded, that while each use-case scenario have been evaluated separately, several of the identified inefficiencies are present in all scenarios, where it might be possible to mitigate all through implementation of standardized blockchain configuration. From the empirical results and scenario analysis it can further be concluded that long-term relationships will continue to be of importance in the future in all four scenarios, with trust as a critical lubricant. Where participation, collaboration and collective incentive from the all involved supply chain actors will be an important take full advantage of a blockchain based solution in the future. Especially for overcoming some of the inherent technological constraints of current blockchain solutions related to interoperability and creating a direct link between the physical and digital world in which physical goods and materials can be tracked. Lastly, it can be concluded that blockchain by itself may not present a complete solution for mitigating all of the identified inefficiencies in the study, but that it will rather act as an interface, through which various IT systems, goods and actors becomes interconnected.

Through the evaluation of blockchain technologies, its various business potentials in conjunction to the inefficiencies identified in the generic supply chain and the four company specific use-case scenarios the research questions has been answered. The purpose, which have been to evaluate how the emerging blockchain technologies can provide enhanced transparency and traceability throughout the supply chain of companies in the manufacturing industry of the research have thus also been achieved. The study thus contribute to a deeper understanding of the opportunities that blockchain provides in four use-case scenarios affected by issues related to supply chain transparency and traceability of a large global manufacturing firm.

7. Discussion

In this section the empirical findings are discussed in relation to blockchain technologies, its potential for providing enhanced transparency and traceability in the supply chain as well as important limitations and benefits adherent to the same. Furthermore, in relation to previously stated, important considerations and managerial implications for future development and implementation of a potential blockchain in the investigated use-cases are highlighted. Lastly interesting areas for further research are presented.

The empirical results and analysis provided an indication that a blockchain solution had higher potential in two of the four investigated use-case scenarios, being warranty and remanufacturing. However, it's important to consider that this result was based on a specific set of evaluation metrics specific to the case company's context. If alternative metrics would have been chosen and used, it could have resulted in a different outcome. It also of importance to states that utilization of a different or additional analytical framework than the SFA and evaluation tree would potentially provide a different outcome.

Furthermore, in evaluation of the four use-case scenarios, counterfeiting and piracy, remanufacturing, warranty and export control and clearance of dual-use goods, future utilization of blockchains shows promising potential for solving several of the current inefficiencies and constraints related to information asymmetries, desynchronization between actors, fragmentation of data and low overall supply chain performance. Blockchain technologies could thus also provide additional sustainability opportunities within the same as enhanced transparency in regards to business operations performed by supply chain actors can be achieved. Where honest and environmental friendly behavior would be incentivized, while a heightened level of accountability could also be ensured. That in turn could result in lowered costs for establishing provenance of goods and services, while at the same time enforcing of quality standard would be simplified and thus requiring less resources for auditing of actors and activities.

Blockchain could provide increased positive environmental and economic benefits as data and information could be made more accessible while improved management of the same, removing the need for physical paper documentation. Lastly, as blockchain could mitigate potential information asymmetries and fragmentation of data, it would in turn enable improved learning capabilities and cross-functional collaboration as new information and learnings can be effective distributed throughout the organization.

However, in order for manufacturing companies like SKF be able to take full advantage of blockchains potential, there is a need to overcome some of the inherent technological barriers and limitations attributed to especially interoperability and scalability. One issue that arises with a blockchain solution as of today is related to the trade-off between transparency and control. Where the features and characteristics of public or permissionless blockchain have the ability to enable greater transparency. However these blockchain may not be well suited for sharing of sensitive or confidential information and data Where´s permissioned blockchain, private of consortium blockchains gives increased control over read and write access and are thus more suited for record keeping and sharing of information and data of confidential nature. However at the expense of transparency, visibility and trust as these configurations rely on a central governing authority for validation of transactions as well as imposing restrictions on read and write access. Hence, companies must properly evaluate their needs and what type of configurations that is most suitable in the specific use-case.

Issues also arises with the current interoperability constraints of a blockchain solution, where current blockchains don't support interlinkage between different blockchain configurations, meaning that for a blockchain solutions to be beneficial in a wide scope context setups such as in the global supply chain, the various stakeholders needs and requirements have to be mapped out and taken into consideration, while all actors also have to agree upon a common interface and features to be included in the same. The development, implementation and maintenance of such a solution would most likely require substantial investments form all involved participant, unproportionate to the potential benefits, thus limiting the incentive to pursue this type of solution in the first place.

Another issue of blockchains limited interoperability capacity is related to the current impossibility of establishing a link between the physical flow of products and the digital flow of information and data. Thus even though blockchain creates fully transparent and complete historic trail of digital transactions related to the information about the material and goods, but not the goods itself. Meaning that a blockchain solution will not be able to mitigate the issue of counterfeiters simply putting a counterfeit product in the original package of the real thing for example as the material and goods declared in the blockchain cannot be validated to be the same. This issue further relates to the fact that manufacturing companies such as SKF does not use marking or records keeping of products or items on the individual component level. However, these constraints could potentially be circumvented through the integration of various support systems such as EDI, RFID and barcode marking systems.

In addition, even though a blockchain solution could potentially provide a complete historic transactional record which is shared among all nodes and thus allowing for full traceability of various transactions made on the blockchain at all times. And in turn mitigate issues related to information asymmetries and fragmentation of data and trust. However, the issue related to falsified or incorrectly inputted data still remains, as the is no efficient way to ensure the accuracy, authenticity and validity of data, and therefore all transaction recorded on the blockchains is evaluated as correct and valid. Therefore, a blockchain solution is not a good fit in use-case applications where ensuring the accuracy and validity of information and data is critical. Evaluating a blockchain based solution in each use-case scenarios from a constraints perspective only, the blockchain technology is to be evaluated as too immature at this stage for practical and wide scale implementation. However, looking at the rapid pace of technological advancements and development, especially in the area of blockchains technologies, where new types of blockchain based solutions have emerged and where implementation and exploration of potential use-cases have exploded during the last few years. It is deemed highly likely that this development will continue in the future as well, where the inherent technological barriers and limitations of current blockchain solutions have been resolved.

An important driver and a necessity in enabling this future development is increased collaborations between various actors in the supply chain. Where efficient and transparent communication of the individual needs and requirements as well as potential benefits that can comes from this new technology will have to be mapped in order to create the collective incentive needed to pursue further investments and where the combining of the collective resources and know-how would most likely be of importance. In addition, incumbents such as SKF should to a broader extent consider forming new and closer partnerships with firms having extensive knowledge and expertise in relation to the field of blockchain technology and its practical use such as IBM that are already working closely with the practical implementation and utilization of the same. In the case of developing and utilizing blockchain solutions in the areas of export control and clearance of dual-use goods as well as in counterfeiting and piracy, a critical driver and of utmost importance is closer collaboration with regulators and regulatory institutions such as customs and the police in order to enable development of new regulatory framework that can substantiate the legitimacy of blockchains and smart contracts.

Lastly, another important aspect to consider is that the individual supply chain of companies in the manufacturing industry are likely sharing some common characteristics and features as well as inefficiencies. However, it's important to consider that the level of vertical integration and scope of outsourcing and involvement of individual supply chain actors and activities might differ significantly. Where the actual needs and requirements in relation to transparency and traceability are not the same. And where a distributed and decentralized ledger technology such as blockchain might not provide any significant benefits in the individual business context. Companies eager to pursue this so called magical formula also need to understand that each blockchain solutions needs to be tailored to their specific needs, where the same needs have to be carefully considered in order to develop a blockchain based solutions that will provide significant benefits.

7.1 Further exploration and research

The focus of this research study have been towards investigating how blockchain technologies can be utilized in the generic supply chain of firms within the manufacturing industry for enhancing transparency and traceability. This study have more specifically outlined and evaluated four use cases of blockchain in relation to the supply chain, blockchain technologies, transparency and traceability. The study have also evaluated blockchains potential in the four use-cases from a generic and strategic perspective, where a direction for further investigation and potential implementation is provided. However, the study have not encompassed a framework or perspective for practical implementation and use of specific blockchains in these individuals settings. Nor have the actual effects from implementation of a blockchain solution in any of the highlighted use-cases been investigated and thus provide an interesting path for further research.

Another continuation of the research could potentially also be to evaluate and map how practical implementation could or should be performed in regards to the several and complex variables of supply chain transparency and traceability through for example pilot testing. Where, changes in form of introduction of new information technologies in the supply chain will inevitably affect the various actor relationships, individual actor needs and overall network dynamics and should therefore be mapped and considered more in-depth. Further research is also required on how various types of blockchains may be utilized in order to provide the most appropriate fit in relation to the four use cases. Lastly, the state of blockchain technologies in conjunction with the overall needs for transparency and traceability is to be considered as dynamic in nature. Meaning that they´re constantly developing and changing within each industry. The study have only considered blockchain for the presented use cases in relation to the manufacturing industry. Hence it would be valuable to see if the same need for transparency and traceability exists in related industries as well and how blockchain technologies can provide as suitable business solution in the same.

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