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LOG950 Logistikk

Exploring blockchain technology potential in Norwegian timber industry. Embedded mixed method case study.

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Preface

This thesis is written as the final part of Master program within the field of Logistics at Molde university. It completes a two-year long study titled as Master of Science in Logistics with specialization in Supply Chain Management (SCM). Both authors/students ended up completing Advanced SCM as the sub variant, where focus is weighted towards the qualitative aspects involved in the management of value chains. It emphasizes strategic processes and decision-making concerning and impacting economy, information and communication technology, business administration, organization, and management.

During this thesis we are exploring opportunities to optimize- and identify inefficiencies in timber supply chain, an industry previously unknown to us. We are excited to get an opportunity to analyse and understand important issues from a wide strategic perspective. It turns out we were dealing with an innovative, well organized and technologically advanced industry. We can see clear signs it is driven by sustainable development and facilitates towards collaborative industry efforts.

The topic of choice is challenging as it involves alternative thinking around how to solve existing problems, practices, and processes through an emerging technology that has not yet reached its potential. It requires comprehensive research just to get a modest understanding of its basic functions. The objective is rather directed towards blockchains capabilities and opportunities.

We thank everyone involved for contributing with valuable information and answering all the questions we had. We are grateful towards Skogdata for granting us the interview and letting us use the information without restrictions. Thanks to our supervisors for supporting us and keeping us motivated and challenging us with their perspective and knowledge about this complex topic and industry.

Abstract

The purpose of this study is to contribute towards the literature on feasibility of implementing blockchain technology in timber industry. With exploratory perspective, the purpose is to examine blockchain's potential in the context of five supply chain performance elements to determine implementation suitability. Further, the study explores existing industry solutions to establish present system landscape and its implications on blockchain potential.

In order to investigate blockchain potential within timber industry, an embedded mixed method case study was conducted on Norwegian timber industry and corresponding system providers. Research design consist of both qualitative and quantitative approach with semi-structured interview and tailor-made survey developed as data collection methods.

Skogdata have been identified as the main system provider in Norwegian timber industry, but due to ownership profile and industry structure, decision making is collaborative, also concerning implementing technological solutions. This opens up the opportunities towards considering blockchain as a possible contributor. However, due to existing efforts, current system structure and downstream industry needs, the potential role of blockchain implementation is diminished. This is visible when matchings current industry needs with blockchain capabilities and when analysing overall current system structure from supply chain perspective including production and marked needs. Some potentials are identified towards improving proof of origin within element of sustainability which could be a use case for blockchain.

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1.0 Introduction

1.1 Motivation for topic selection

Studying logistics and SCM involves obtaining knowledge about all areas of business. From understanding- perspective of all stakeholders, marked structure, financial impact and customer needs to developing strategies and implementing these. For us, main objective is to learn how to identify success factors involved in managing supply chains. Likewise, we find it important to find ways to contribute towards innovative and sustainable development we see in today's business communities. Technologies and digitalization are a big part of that as they drive forward ideas that can contribute towards creating efficient collaboration between actors. We want to put ourselves ahead by paying more attention to digital and automated solutions, both existing and emerging.

One difficult aspect about being student is dealing with limited information, as often when doing case related work, companies are not willing to share what they feel is sensitive but for us would be key relevant information. Similarly, from personal experience this is an issue internally within the companies where it depends on own working conditions such as positing or department of employment. Not everyone has access to the same information even though this would be highly beneficial. From that, we can take an educated guess that we will encounter same issues when having responsibilities in handling B2B related concerns when acquiring various positions. Businesses are not willing to share information (due to different reasons) that could be of decision-making importance to others.

Not only do we see a trend that modern supply chain managers need to have advance ICT knowledge to analyse opportunities leading to best possible optimized supply chains. but also, a sign that they need to find better ways to access valuable information. Some technologies can make a big impact on business operation, such as blockchain. Many believe it can lead to next generation of ICT where it can fundamentally transform current practices, e.g., leading to new business-model opportunities. By taking on a topic involving blockchain technology we can gain new perspectives, potentially helping us adapt to fast changing business environment. We can easier contribute to support initiatives towards implementation efforts involved in optimizing supply chains. We feel that chosen topic will let us investigate strategically important areas of SCM and likewise let us strengthen business performance once we engage in such course of action.

1.2 Research questions

This exploratory case study aims to research- and closely investigate blockchain capabilities that can be considered applied in the context of timber supply chain. We aim to closely look into industry specific use cases and utilize these as part of the overall analysis. When comparing that to current situation within Norwegian timber industry and combining it with downstream needs, it should give us an indication how blockchain can improve supply chain performance. This can be viewed as an important step towards successful implementation projects when considering blockchain as a possible solution. Based on that, we will focus on answering one main research question:

Main RQ: *What are the underlying circumstances that might determine blockchain implementation in the Norwegian timber industry?*

Being an embedded mixed method case study, we separate main research question into two sub questions based on qualitative and quantitative methods. The main point of such research design is that each sub question can be treated and preferably published on their own. Skogdata is responsible for providing systems to the industry. Their role is to address challenges in the supply chain by developing solutions actors can use. It is of interest to know details around decision making and factors that are most prominent in this setting. One of the main objectives of research question is to explore possibilities surrounding blockchain suitability from perspective of the whole industry, involving opinions from key technology solution provider. This involves exploring current system offering and matching them with what blockchain has to offer. The qualitative sub question is:

SubQ1: *How can blockchain contribute to improve performance of Norwegian timber supply chain?*

Downstream part of timber supply chain is the utilizer of raw materials, powering the sustainable national development. This research question is investigating needs from end of supply chain perspective where the demand of materials is deriving from. Blockchain technology has capabilities to offer improvement to important parts of the supply chain. What has to be considered here it the actual need to implement such technology, as we believe it has to come from those having issues within these areas of supply chain. The goal of this quantitative sub research question is to get an idea to what extent the issues are visible in the timber industry.

SubQ2: *What are the most valid supply chain elements of concern that can be considered improved?*

1.3 Structure of the thesis

This thesis follows monography structure and guidelines provided by Molde university. From here on we start with a theoretical introduction to SCM and blockchain as these are our main areas of concern. Section describing SCM focus on its role and challenges in terms of dealing with technologies and digitalization. Section describing blockchain explores and represents it as an opportunity to SCM. Here, we provide our own take on blockchain rather than focusing on describing its technical characterises as many of the other authors usually end up doing. Next sections contain two literature reviews. One preliminary review conducted in conjunction with proposal phase to evaluate blockchain in the context of logistics and SCM, and another review containing industry specific research. It is in these two reviews that we extensively investigate five SCM performance elements and how blockchain is capable to improve these. After each literature review, we provide a theoretical section addressing these in detail. From there we move on to describe Norwegian timber industry from a case perspective where all major aspects are incorporated, involving the main provider of ICT solution and its product portfolio for the industry. Further on, research method and data collection process are described, along with our approach, design and techniques used. Analysis part contains several steps where we start with clarifying and interpretating the five elements in terms of their purpose, importance and challenge. We continue with analysing blockchain capabilities in the same context, where we focus on what we consider to be the key findings from second literature review. From there on we move to analyse main system functionalities currently used in timber supply chain. The analysis section ends with a quantitative analysis of questionnaire data collected. All these factors contribute to build our understanding and sets a basis for discussion section around blockchains role and implementation possibilities in timber industry. Throughout discussion we try to compare system capabilities and incorporate downstream industry needs that are part of the embedded method structure. At the end, we provide our conclusion based on research questions and make recommendation for further research. Appendix section contains descripted semi-structed interview with Skogdata's representatives and copy of Likert scale questionnaire developed and uses for purpose of collecting quantitative data.

2.0 Theoretical introduction

2.1 Supply chain management

According to last known conducted systematic scholarly literature review (Shukla et al., 2011) on the matter of collecting SCM definitions and providing a common understanding state that:

"SCM encompasses the entire value chain and addresses materials and supply management from the extraction of raw materials to the end of useful life".

Encompassing the entire value chain involves coordination and collaboration with channel partners which requires ability to utilize the knowledge of each stakeholder. To successfully address materials from extraction to end of useful life, planning and controlling of total movement of flow from place of origin to the point the end-product no longer serves any usefulness. Suppliers, intermediaries, third party service providers, and customers are constantly involved in this process. SCM responsibility is ultimately to integrate supply and demand across business activities which sounds simple but requires powerful tools and knowledge. It involves several important decision-making factors that cannot be fully understood by analysing interoperation of SCM. The definition presented lacks complexity based on present day challenges. In the next section, we aim to provide extended context to these challenges and connect it to the topic of this thesis.

2.1.1 Challenging decisions

SCM involves improving relationships and engaging in schemes to attain, implement and better maintain activities with upstream and downstream actors. Increased pressure and complexity to succeed depends on ability to create visibility across the whole network. Successfully coordinating all activities depends on ability to efficiently communicate, spread and share information. The way this connectivity is set up between all stakeholders depends on how its incorporated into supply chain to utilize its potential. Selecting suitable technologies is therefore important part of supply chain decisions in this new digital era we are a part of. There is a need for robust interconnection to operate efficiently and increase overall performance. Supply chain managers should always strive to find ways to improve their business activities to gain maximum value for its stakeholders.

2.1.2 Complexity of SCM

Research application, scope and field of study are constantly evolving (Movahedipour et al., 2016). New types of emerging supply chain distinguishment such as Green Supply Chains Management (GSCM), Closed Loop Supply Chains (CLSCs) and Circular Supply Chain Management (CSCM) contribute to segregate focus of SCM. Cohesive with evolvement of concerning areas is the evolution of the term sustainability in the business world. This unrolls focus on triple bottom line, as sustainability aspect addresses economic-, environmental- and social goals. This provides wider perspective to be incorporated into business dimension, pushing towards overall business performance. As such, resulting in the development of more significant integration approach and wider range of scope to be addressed for supply chain practitioners (Khan et al., 2021).

2.1.3 SCM and ICT

Information and communication technology (ICT) and its technical implementation to integrate, strategically plan and coordinate business processes across supply chain actors has a dominating presence within area of SCM powered by industry 4.0 (Zekhnini et al., 2020). ICT is a key driver of integrated supply chains, ensuring that material- and information flows work in practice internally and externally (Harrison et al., 2019, p. 235). The modern digital era contributes to evolvement of supply chain management, its role, ability to solve problems, create opportunities and gain competitive advantage. Technical developments are transforming the way supply chains are exchanging data and information from traditional systems to real time interconnected networks (Garay-Rondero et al., 2020). Distribution of reviewed papers by (Zekhnini et al., 2020) indicate that blockchain is one of the most relevant enabling technologies discussed in the field of SCM.

2.1.4 Risks of digitalization

Companies are digitalizing their supply chains to streamline their processes to increase values for themselves and their upstream and downstream actors. Having these technologies in every day operations contributes to create many advantages but implementing these is challenging. Significant time-, resource- and monetary investments have to be deployed. Factors such as lack of internal knowledge and technological immaturity within organization are some of the barriers to overcome when it comes to practical implications (Arunachalam et al., 2018). When companies convert to digital supply chains, they face new type of risks.

These risks include malware, cyberattack, spyware and data alteration, where hackers can modify, steal or delete important data. These elements are all connected to information risks in a supply chain concerning confidentiality, privacy and integrity (Colicchia et al., 2018). Avoiding and securing against these risks is a challenge. Companies are recommended to focus on identifying, measuring and analysing these risks in order to be able to reduce negative impacts (Zekhnini et al., 2020). In a multiple case study (Colicchia et al., 2018) found no visibility of plans for investments or improvement initiatives on cyber and information security present within interviewed companies.

2.2 Blockchain technology

In the world of blockchain "the more you read the less you understand" seems to be the moto based on personal encounters. There are indeed often misconceptions found in the available literature surrounding blockchain technology, something Norwegian researcher discovered (Ølnes, 2021). When describing blockchain, fundamental technical aspects are more than often found incorrect or only partly correct. Due to lack of common terminology, there are misconceptions and widespread formation of unrealistic expectations about what underlying blockchain technology can achieve (Rauchs et al., 2018). This thesis does not aim to question whether blockchain is secure or advanced enough for enterprise adaptation or goes into details how to implement blockchain based on its technical functionalities. We have seen enough evidence that blockchain, through use cases found in the available literature, can be applied across diverse industry sectors in various settings and is able to refine an array of problems. We find it more sufficient to focus on addressing blockchain capabilities, its purpose and opportunities it provides when it comes to improving supply chain challenges. This section aims to explore, explain, simplify, and clarify some of the main blockchain characteristics. The structured aims to hold practical perspective as a fundamental relevance to case study approach.

2.2.1 Fundamentals of blockchain technology

Blockchain is built on distributed ledger technology (Rauchs et al., 2018) which is based on different technological premises and solves transactions between actors in a different way than current systems businesses are using. It stores, exchanges, shares, protects and facilitates flow of information between stakeholders in a different way than traditional centralized databased systems (*OECD,* 2019). It disrupts the "hub-and-spoke" model of

databases and provides an alternative solution to existing problems, practices, and processes (Maull et al., 2017). Current way to conduct business and achieve visibility is considered costly and challenging, being manual and labour-intensive reconciliation between trading parties (*OECD*, 2019). Every business operates its own ERP system that connects all internal units, but it is not developed to efficiently transact with other actors in supply chain. Distributed ledger technology has the ability to bring together database, network, access and workflow of today's mental and technological silos (Maull et al., 2017). This is exiting because in our own opinion this gives a new perspective on the purpose of supply chain management, and how to seek overall efficiency. Today, creating synergy with other enterprises to gain visibility in the supply chain is cumbersome and inefficient in many ways. Figure 1 presents blockchain as a "solution" or "challenger" to existing supply chain system distribution.

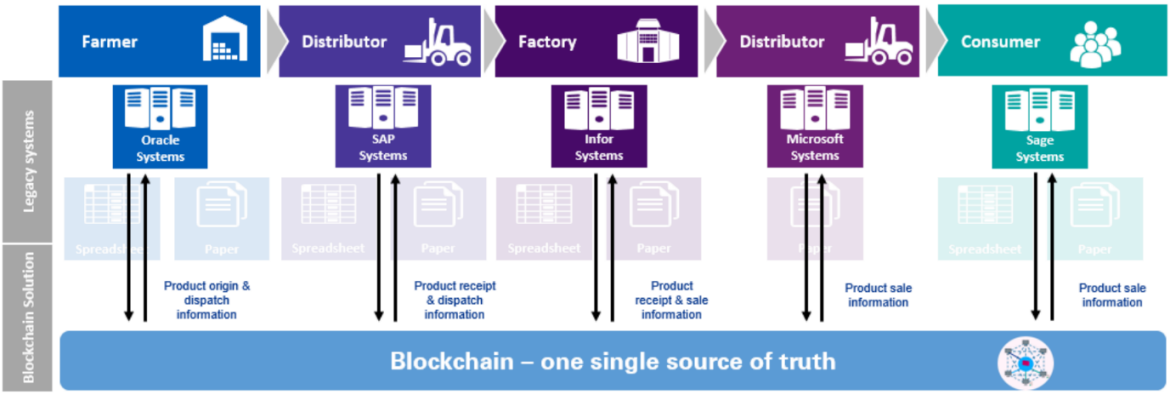

Figure 1 - Blockchain solution to current supply chain information flow. Source: (OECD, 2019)

2.2.2 Types of blockchain

From general reading, we notice that there are several segments of blockchains (frameworks/platforms) depending on formal consent or permissions around who can access, add and in many ways use the available information. This is important when it comes to actual implementation and integration with existing IT systems (*MongoDB*, 2022) but is an information trap when it comes to explaining the purpose of blockchain. As technology and usability progresses, there are so-called hybrid solution where blockchain and traditional databases are combined to create a secure and immutable chain of blocks (*MongoDB*, 2022). It is out of this context to distinguish between these. Most important observation, deriving based on underlying technological "layer" design, is that all necessary components are there

to allow flexible integration with existing enterprise infrastructure (*MongoDB*, 2022; Rauchs et al., 2018). It's a matter of defining use case requirements (Rauchs et al., 2018) when engaging in planning of an project implementation which is beyond the scope of contemporary theoretical description.

2.2.3 Blockchain opportunities

The way blockchain is designed opens up for opportunities to digitalizing contracts, transactions and the records of them (Lakhani & Iansiti, 2017). It can be viewed as an information transmission system (Hader et al., 2021) where every agreement, every process, every task and every payment would have a unmodified digital record and signature (Lakhani & Iansiti, 2017) which would in turn diminish need for assistance from lawyers, brokers and bankers. These statements are generally supported and indicate that blockchain has a lot of potential to create new foundations for building efficient business platforms. In another words, it involves fundamental transformation of how organizations operate (Williams et al., 2020). We often find statements such as "*Blockchain is already contributing to remodeling traditional business models and creating new opportunities across the entire supply chain*" (Wamba & Queiroz, 2020). That sounds promising but arises a set of questions that might be asked. We would like to have answers to many questions, such as; how is blockchain being utilized in the real world?, what area of supply chain is it able to improve? and what is the most likely future aspect when it comes to integration with current systems structure? It is not easy to figure out which direction blockchain is taking and how enterprises around the world are adapting its use. Blockchain is still new and complex technology with potential and capabilities to substitute and transform today's business infrastructure (Lakhani & Iansiti, 2017). It comes apparent that blockchain is not fully developed yet to be the sole end-to-end supply chain solution. It is rather a supporting tool or a solution for enterprises, governments, industries and supply chains that aim to digitalize, innovate and simplify their activities. It is a part of a larger initiative to create a reliable and efficient system. In our current view, it has to find its role in the existing system complexity and be incorporated in those areas of supply chain that fit best for it use case. (Banerjee, 2018) describes benefits of blockchain integration with WMS and MES and provides examples of companies that develop solutions on how to interconnect blockchain with ERP. Blockchain implementation has to be conducted with careful consideration based on its

capabilities and applied through well-organized projects. As a complete supply chain solution, it often takes a bundle of technologies to deliver the final solution.

2.2.4 Blockchain for (smart) supply chains

Rather than saying blockchain is a wide-open developing field that can enhance supply chain performance as a supporting technology, we find it inherent to provide an example of a functioning blockchain based system. One of the most relevant, emerging areas where blockchain is being consistently applied to enhance supply chains is related to Industry 4.0 and smart manufacturing (Zekhnini et al., 2020). Modern instruments are deployed to utilize potential of manufacturing processes and supply chains. (Li et al., 2020) describe in detail blockchain based systems technical feasibility and the methods of transitioning between the current approaches to a blockchain-oriented platform. One such solution is developed by Syncfab and their distributed manufacturing network (Hopf, 2018). As figure 3 depicts, it is a platform that facilitates interactions between buyers and manufacturers to streamline production processes.

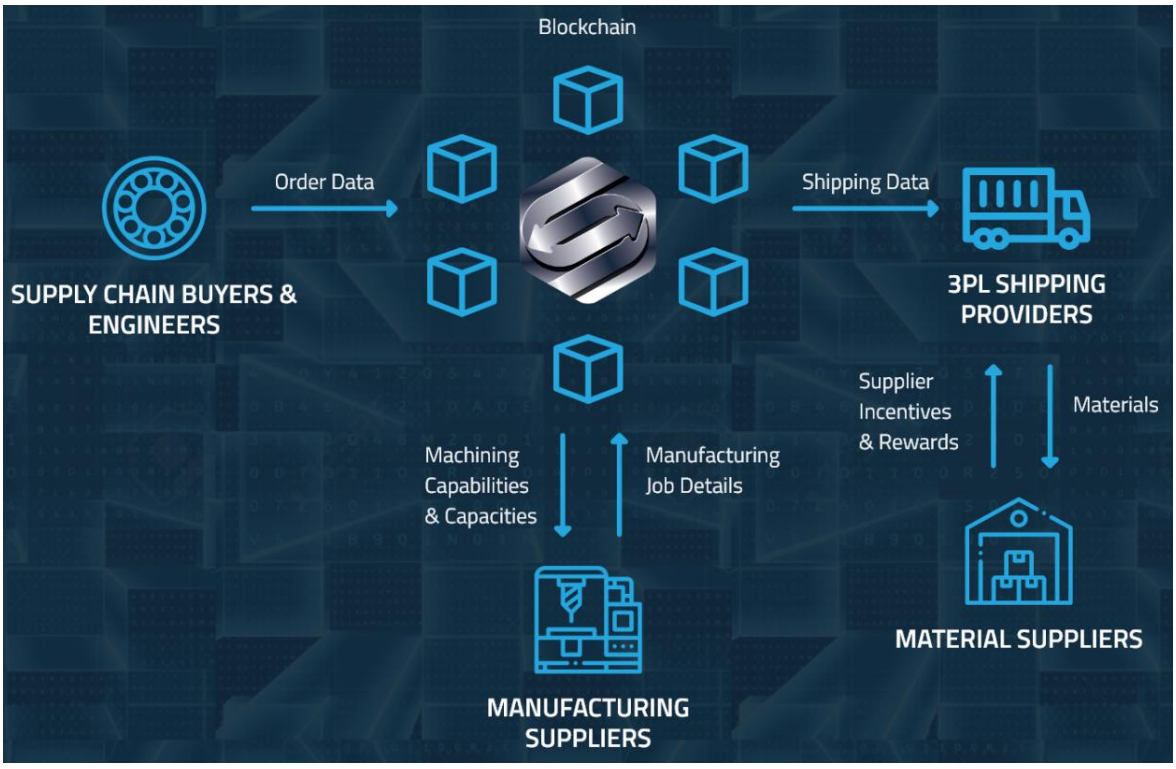

Figure 2 – Syncfab blockchain manufacturing solution. Source: (Syncfab 2022)

It provides integration of all parties involved in the distributed manufacturing network. Smart contracts are arranged to create a platform where manufacturing resources can be

shared between companies (Shukla, 2018), e.g., opening up opportunities for globally dispersed small to medium size specialized firms to gain accessible manufacturing equipment and connect production efforts without use of intermediates (Hopf, 2018). Digital resources (tokens) are used to provide incentives for participants and can be used to create custom rewards as these represent a stake in the network that grows in value as the network grows (Hopf, 2018). More importantly, this blockchain solution connects MES and ERP, which enables controlled exchange of information with security and compliance (Banerjee, 2018), something previously seen as a major barrier to end-to-end integration in manufacturing 4.0 (Hopf, 2018).

As we understand, this is just the start of opportunities for innovative collaboration in supply chains through blockchain based solutions.

3.0 Literature review

3.1 Preliminary literature review (part 1)

Literature review presented in LOG904-101 revealed three main categories conducted within the perspective on blockchain application relevant to the general context of logistics and SCM: (1) Research with logistics processes and supply chain perspective (2) Research with implementation details (3) Research with review perspective. These categories provide wider view for the academic reader, providing insight within which area of research our potential thesis work contributes to. In this section these are revisited.

3.1.1 Logistics processes and supply chain perspective

Research with logistics processes and supply chain perspective either describes general benefits and challenges of blockchain technology or explores specific content, such as creating overview within an industry sector (Gatteschi et al., 2018; Wu & Tran, 2018) usually with already available case(s) perspective. With use of conceptual framework (Litke et al., 2019) focused on providing detailed analysis of blockchain fit for supply chain industry in general terms, including some supply chain performance characteristics. Others, such as (Dobrovnik et al., 2018) explored blockchain applications that provide potential to increase operational efficiency or even transform elements of e.g. logistics and transportation sector. With special emphasis on blockchain technology in logistics (Tijan et al., 2019) identified the main factors associated with supply chain transparency, where sustainability aspect was incorporated

3.1.2 Research with implementation details

Research with implementation details is a few steps further away from just focusing on benefits and challenges of blockchain within supply chain management. It is often a platform-based concept developed into a functioning or semi-functioning prototype with a practical implementation effort. The work is initiated based on a single case approach where theoretical background usually concerns elements of supply chain performance (Mahyuni et al., 2020). More than often, either directly or indirectly, sustainability and cost efficiency are a subject within these papers. (Mao et al., 2018) provide a study focusing on increasing and optimally distributing profit margins for all actors involved to create a credible trading environment, as this is often an industry specific concern within upstream part of food

markets. In other industries, such as timber/wood, possibility for more efficient use of resources and streamlining of operations is found to be an outcome (Figorilli et al., 2018). The application of blockchain within the supply chain is clearly a potential tool to solve many logistical concerns such as a monitoring system that provides an open and immutable history record for each transaction in the supply chain (Helo & Hao, 2019).

3.1.3 Research with review perspective

Research with review perspective is a collection of academic literature articles with dissimilar objectives. Most of the papers provide systematic review with deeper description of blockchain technology based on use cases or knowledge gained by comprehensive theoretical analysis conducted through collecting of available information. This is usually followed up by discussion of current research gaps, open problems and identification of future potential areas that require more attention. (Chang & Chen, 2020; Gonczol et al., 2020) focused on gaps concerning technical limitations and digitalization of supply chains, requiring more scenario oriented and quantitative studies. On the other hand, others such as (Wang et al., 2019) call for more conceptual and empirical research to understand technical aspects of blockchain applications. Moreover, to assess the need of current intermediaries and their role as supply chain actors, while considering the possibility that a new breed of emerging intermediates can add more value from sustainability perspective. Furthermore, to address trust potential as it has a positive innovation impact and supply chain performance. With its sustainability performance perspective (Paliwal et al., 2020) mention interactions between various stakeholders where blockchain technology potentially can replace intermediary tasks and evaluation of supply chain relationship as factors that can be tied to supply chain performance (Mahyuni et al., 2020). In a recent re-examination of blockchain studies (Chang & Chen, 2020) explain the gaps in the research after discussing factors such as transparency, traceability, stakeholder collaboration and supply chain integration. The gap associated with the need of empirical research and evidence is mostly concerned with providing results from effectiveness of blockchain-supply-chain adoption which can provide solutions to long term uncertainties and guide managerial practices.

3.1.4 Short review summary

Table 1 provides a summary of three main categories, providing practical/theoretical relevance associated with general area of blockchain and logistics/scm. Research and findings from (Mahyuni et al., 2020) were of particular interest as it provides framework

that can be used to navigate potential blockchain application to improve supply chain performance. This is specifically related to five issues: transparency, traceability, trust, sustainability, and cost-efficiency. The framework details are addressed later on with extensive description.

Research with logistics processes and supply chain perspective	Adressed practical relevance
Tijan et al., 2019	Provides general information
Hackius and Pettersen, 2017	Survey - collection of industy opinions
Litke et al., 2019	Platform and implementation recommendations
Dobrovnik et al., 2018	General recommendations
Francisco & Swanson, 2018	General recommendations
Wu & Tran, 2018	Provides indusry overview (Energy sector)
Gatteschi et al., 2018	Provides indusry overview (insurance sector)
Abeyratne & Monfared, 2016	Review of technology and applications
Reseach with implementation details	**Adressed practical relevance**
Mao et al., 2018	Trading model based on algorithms
Appelhanz et al., 2016	End customer perspective
Sunny et al., 2020	Penalty based Proof of concept
Figorilli et al., 2018	Prototype App and RDIF tracking
Helo & Hao, 2019	Blockchain based logistics monitoring
Research with review perspective	**Adressed practical relevance**
Gonczol et al., 2020	Provides a foundation for practitioners and researchers
Wang et al., 2019	Blockchain technology's future influence on supply chain
Mahyuni et al., 2020	Provides a framework for blockchain application within scm
Paliwal et al., 2020	Framework for litterrature classification of new energing technologies
Chang & Chen, 2020	Reexamination of recent blockchain studies in the SCM context

Table 1 - Preliminary literature review findings (categories and practical/theoretical relevance)

3.2 SCM performance elements

According to (Mahyuni et al., 2020) there are five performance elements that blockchain potentially is able to greatly improve within supply chain management. The question we can ask is why these elements are an issue in the context of supply chain and why do they need to be improved. This section aims to address these questions. Each element is treated separately in the following section, presenting relevant theory, rules and regulations.

3.2.1 Transparency

Businesses today operate with complex supply chains, with many actors involved, often outsourcing their operations and production to low-cost countries. This has led to limited or

no knowledge about processes and conditions under which purchased goods are created. Procurement processes consist of systems to constantly evaluate, audit and monitor first tier suppliers, but going beyond dyadic relationships is challenging. There are barriers that makes it too difficult to resolve implementation of multi-tier information sharing systems (Kembro et al., 2017). Businesses usually only extend these efforts with first tier suppliers and logistics providers they trust, in order to achieve operational efficiency (Christopher, 2016, p. 179). Even though it can be difficult for businesses to acquire information about their own second and third tier suppliers, this is becoming increasingly more important, even soon to be enforced by the law in Norway (Transparency-Act, 2022). The demand to have knowledge about upstream activities derives from external actors in form of governments, end consumers and, industry- and civil organizations. Duty to provide relevant information to these is enforced by the transparency act in conjunction with financial accounting law ("Regnskapsloven," 1999). The value of transparency associated with enabling these actors with valuable information contributes to informed decisions about purchases and investments, and other efforts that take into account the social impact of businesses (Committee, 2019). This greatly benefits fair competition. The journey products undergo through supply chains greatly affects ethical standards. Information about working conditions might be manipulated or held back from public interest, giving society less power to influence and demand improvements. Supply chain actors need access to accurate information in order to meet these requirements.

Two decades ago, empirical research showed that optimal dyadic relationship was achieved when partners shared information on a selective and justified basis, which lead to shared knowledge and collaborative abilities, being the definition of transparency (Lamming et al., 2001). Today transparency have a broaden purpose, that is to integrate and extend supply chain visibility beyond the boundaries of the organization and its suppliers. It is connected with strategic thinking to gather, systemize and share detailed information with both internal and external actors (Montecchi et al., 2021).

3.2.2 Traceability

Not all businesses have systems in place to efficiently trace their products to the place of origin, something Norwegian students discovered when asking store chains to provide them with information where fresh fish they bought comes from (Igesund & Rognstad, 2021). For an end consumer, it’s a prolong and troublesome process of acquiring this type of

information as it requires going back step by step and asking for information from individual actors. It is difficult for end consumer to know the origin of the product, its quality and process its been through, even though there are rules and regulations business are obligated to follow. "One up and one down principle", or having information on the closest tier is no longer sufficient (Igesund & Rognstad, 2021), even though these long have been industry standards in Norway (Matlovsforskriften-article-18, 2010). Slow tracing abilities can have major consequences. According to the regulation, the company itself selects the delimitation of devices for tracking (how accurate the tracking system should be). When unwanted incident occurs, such as related to food products, it's a comprehensive task to pinpoint cause of contamination (FHI, 2014). Such tracking requires collaboration between the authorities and relevant companies and industries, as required information is not easily attainable.

In the timber industry there are EU regulations (EU-995/2010) to combat illegal logging and related trade activity, implemented by Norwegian government (Timber-regulation, 2015). The regulation applies to timber and timber related products that are imported into Norwegian market. Obligation of traceability are placed towards those responsible for trading activities, particularly those being the first to place the product on the market. According to article 5 (EU-995/2010), throughout the supply chain, traders shall identify: 1) the operators or the traders who have supplied the timber and timber products, and 2) where applicable, the traders to whom they have supplied timber and timber products.

3.2.3 Sustainability

One of the biggest issues risen in the twenty-first century is the term sustainability. To truly make an impact, it have to be incorporated into every aspect of the business, across entire product cycle, from product design to end-of-life disposal (Christopher, 2016, p. 296). EU and United Nations are the biggest promoters and goal setters for sustainable future. Enterprises have to find ways to comply with adopting new strategies and look for opportunities towards more viable business models. Emerging business models such as circular economy are powered by the force of sustainability. This goes beyond the triple bottom line perspective, to not only reduce but to re-design the way business is operationalized and find ways to eliminate what is considered waste and pollution (Rossi et al., 2020). This is developing into increasingly strict regulatory- and industry specific standards, requiring interconnected supply chain processes and information sharing amongst stakeholders (Zhang, 2019).

Often businesses experience mismatch between demand and supply at different stages of supply chain. Non-perishable unsold items end up being returned or shipped to different locations. This increases inventory and transportation costs and requires greater coordination- and consolidation efforts. This can be viewed as waste. It satisfies end consumers delivery requirements and return policy, buy is not viewed as environmentally friendly practice. Business desire to reduce the negative environmental and social impacts of their supply chains. The aim is to address returned products from end-users to re-use, repair, remanufacture or recycle these and sustain circularity of resources (Mastos et al., 2021). This puts pressure to design and operate such supply chains.

End consumers are becoming more aware and might have sustainability as an important criterion when conducing purchases. Research show existence of purchase barriers concerning eco-friendly products, where timber is used as raw material (Appelhanz et al., 2016). In this context, mistrust is related to the environmental impact where labelling might be viewed as strategic marketing tool to influence consumer behaviour (Panico et al., 2022), lacking fulfilment of intended purpose.

3.2.4 Trust

Trust is viewed as an essential factor for building effective supply chain networks. Successful supply chains are those that are manged by a constant search for win–win solutions based on shared trust (Christopher, 2016, p. 323), encourage mutual interest-seeking behavior and sanction opportunistic behavior (Zhou et al., 2015). In this context it takes long time to build trust, as trust is achieved through high level of collaboration. Distrust between actors is a major obstacle. Asymmetric information creates boundary between trust and commitment, as supply chain partners can only make full use of shared information through synchronization of business processes (Christopher, 2016, p. 142). Exchange parties primarily rely on third-party intermediaries to serve as agents of trust and to verify their transactions (Zhang, 2019). Incoming data verification is a factor that can be related to the element of trust. As digital supply chains evolve, use of IoT devices (tags, sensors) are increasing. A key challenge in verifying the trust of these devises is to reliably authenticate the source of the product (Zhou et al., 2019), reason being product tampering, modification or mishandling, where counterfeit products could easily be inserted into the supply-chain.

3.2.5 Cost-efficiency

Many businesses aim to improve cost-efficiency of their supply chains but fail to achieve sustainable competitive advantage due to their focus on speed and costs but not on agility, adaptation and alignment of their business process and interests with their partners (Lee, 2004). This alignment often requires use of intermediates. Examples can be to find reliable supplies when working in unknown parts of the world, monitor and conduct audits, take risks to import products, manage complex relationships with downstream buyers etc. This is dramatically increasing operational costs and complicates overall process efficiency.

Disintermediation (the process of bypassing traditional linkages in the distribution channel) and remediation (introducing new intermediaries into the value chain) can be difficult to initiate in a supply chain network (Caldwell et al., 2013). Biggest opportunities for reducing costs lies at the interfaces with other partners in the supply chain. According to (Christopher, 2016, p. 267) three such main cost drivers can be identified. 1) both visible and hidden costs associated with activities that are involved when companies do business with each other (transaction costs) 2) costs deriving from inefficient process alignment causing discontinuities and duplication (process costs) 3) costs arising from lack of knowledge about customers requirements, and lack of confidence in predicting supply and demand (uncertainty costs). All these costs can be reduced by more collaborative working towards creating efficient supply chains, supported by modern B2B ICT solutions and tools.

3.3 Literature review (part 2)

The preliminary review (part 1) helped us to identify which particular area our thesis contributes towards. The structure and topic of interest is related to the category (1) research with logistics processes and supply chain perspective. Here the focus is on investigating blockchain capabilities, understanding its area of usage and determining if it is right for any type of scenario within the industry specific supply chain. When these decisions are made, the detail implementation efforts can be perused, such as determining platforms, roll out pilot projects, setting long term goals, analysing the results etc. The first step is therefore critical as it assesses the actual need and opportunities for the technology.

The first part of literature review does not directly address industry specific context this thesis explores. It rather provides a guideline for the second part that aims to conglomerate blockchain, supply chain performance indicators and timber/wood industry as shown in figure 3.

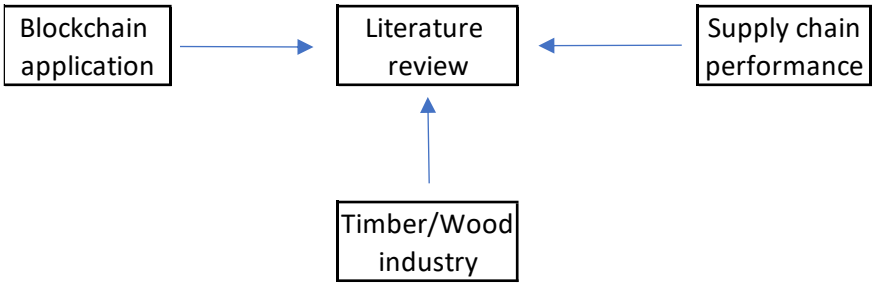

Figure 3 - Industry specific literature review

Search was done using google scholar. Two search attempts were conducted. First using combination of "supply chain" and "blockchain" and "timber industry" and "performance indicator". The later was swapped between the five performance elements blockchain is known for improving within supply chains (Mahyuni et al., 2020). After the duplicates were removed, 34 articles were further assessed. The second search was conducted using "blockchain" and "timber" or "wood" and adjusted to yield overview articles only, giving the result of 64 articles. In the next step we developed a set of criteria to be meet for articles to be a part of the review: (1) It had to have a case- or survey- or some type of implementation perspective (2) it had to be about blockchain (3) timber/wood/forest-products supply chains had to be the main focus or give a convincing contribution to the industry. These criteria were set in order to eliminate articles with too wide perspective that do not give appropriate value to this review. Likewise, pure theoretical articles were not considered as relevant. Results are shown in table 2 where 10 articles are presented.

Source	Perspective	Blockchain or mulitple technologies	Timber industry main subject
Ahmed & MacCarthy, 2021	Case study	Multiple (RFID, IoT +++)	Upstream supply for textile/apperal industry
Dieckmann, 2020	Case study thesis	Blockchain only	Upstream supply for Pulp and paper industry
Emberson et al., 2021	Case/survey analysis	Blockchain suggested as a solution	Forestry + pulp and timber processing
Komdeur & Ingenbleek, 2021	Survey/case study	Blockchain only	Timber/wood suppy chain
Kropivšek & Grošelj, 2020	Survey	Multiple	Wood industry
Düdder & Ross, 2017	Proposed implementation	Blockchain	Timber industry
Figorilli et al., 2018	Implementation prototype	Multiple (RFID, IoT +++)	Timber and wood supply chain
Nikolakis & Krishnan, 2018	Industry implementation framework	Multiple	Forest products supply chains
Ahl et al., 2020	Survey	Multiple	Upstream supply for woody biomass industry
Hultgren & Pajala, 2018	Case study with hypotetical approach	Blockchain and RFID	Upstream supply for wooden window manufacturer

Table 2 - Literature review part 2

In the following step we extended the review by measuring three attributes: (1) how many performance elements based on (Mahyuni et al., 2020) articles extensively discuss (2) what perspective articles had (global or national) and (3) the role of blockchain. We are seeking confirmation that performance indicators are achievable or relevant topic within the timber/wood sc/industry. Moreover, the discussed issues within the articles are interesting

from the perspective they have on level of physical location they cover. This may or may not play a role for the blockchain applicability for Norwegian actors. Lastly, we looked into blockchain motivation behind each article. Table 3 displays these attributes.

Source	Contain performance elements	Global/National perspective/sc	Blockchain motivation
Ahmed & MacCarthy, 2021	3 out of 5	Global	Ensure product authenticity
Dieckmann, 2020	2 out of 5	National (Germany)	Avoid fraud, ensure reliability
Emberson et al., 2021	1 out of 5	National (Brazil)	Combat illegal logging and slavery
Komdeur & Ingenbleek, 2021	2 out of 5	Global	Encourige purchising from certified sustainable forests
Kropivšek & Grošelj, 2020	0 out of 5	National (Slovenia)	Industry implementation needs
Düdder & Ross, 2017	2 out of 5	Global	Develop tamper proof digital system
Figorilli et al., 2018	2 out of 5	National	Track complete product supply chain
Nikolakis & Krishnan, 2018	3 out of 5	Global	Achieve sustinability (consumer perspective)
Ahl et al., 2020	4 out of 5	National (Japan)	Effective sustainability timber tracking
Hultgren & Pajala, 2018	4 out of 5	National (Sweden)	Support sc transparency and material traceability

Table 3 - Attributes measured during industry specific literature review

3.3.1 Findings part 1 (search chriteria)

As implied by (Ahmed & MacCarthy, 2021) there is a lack of empirical cases discussing blockchain application in supply chains to examine adoption across industry sectors in order to understand how technology can be deployed more extensively. Often more testing is needed to confirm the results, such as required pilot study (Hultgren & Pajala, 2018) or upstream sc extension to downstream blockchain enabled solution (Ahmed & MacCarthy, 2021). We found lack of empirical cases in the context of timber/wood supply chains based in our search results. Only 10 out of 98 articles supported all relevant criteria to be part of the review.

As table 2 indicates, timber is raw material for a vast range of industries, such as textile/apparel, pulp and paper, biomass, and window manufacturing. While reviewing the papers, we found distinction between industry- and sc perspective. Sc perspective is concerned with processes involved with the physical and information flow, while industry perspective involves governmental view or suggesting how governmental rules are regulations can be incorporated to make improvements. This usually involves certification schemes (Dieckmann, 2020; Emberson et al., 2021; Nikolakis et al., 2018) that are good alternative to outdated chain-of-custody (Düdder & Ross, 2017). In this context the goal is to combat illegal deforestation by developing timber blockchain solutions (Düdder & Ross, 2017; Emberson et al., 2021) or extend the terms to ensure that sustainability requirements are met (Dieckmann, 2020; Nikolakis et al., 2018). Sustainability concerns are here often

related to sourcing practices (Dieckmann, 2020; Düdder & Ross, 2017) and the social and environmental impact of production (Ahmed & MacCarthy, 2021). (Nikolakis et al., 2018) developed a framework for global forest supply chains products to illustrate how blockchain can enhance sustainability by providing information to consumers about the origin of products. This is to address illegally harvested timber to be bundled together with certified wood in complex value chains where evaluations and audits are paper based. It aims to interact with laws, regulations, and non-state market driven governance.

The last criterion we made is the requirement of blockchain to be addressed in the articles, preferably as a focal point. Beside that we also noted if authors discussed or used any other technologies in their studies. The findings suggest that blockchain is often combined with other technologies, such as RFID tags and sensors. These are deployed to collect and store data about products, processes, and services across the supply chains (Ahmed & MacCarthy, 2021) as blockchain alone cannot fulfill the need of real-time tracking (Hultgren & Pajala, 2018). (Figorilli et al., 2018) performed a study using Blockchain and RFID tags to track trees from forest to sawmill plant, while downstream activities included use of QR-codes, barcodes and near-field-communication (NFC).

3.3.2 Findings part 2 (measured attributes)

In this section we are taking a closer look at attributes we found relevant to assess. We measured performance indicators based on direct referencing as these elements have not been defined yet. Survey article from (Kropivšek & Grošelj, 2020) was the only one that did not mention any of these. The purpose of their content addressed importance of digitization activities in the strategic plans of companies on general terms. Findings indicate that biggest obstacle to implementing technologies such as blockchain are related to investment- or maintenance costs and lack of digital competencies among older workers, while biggest motivation is to develop “smart” solutions and digitalized business models to increase global competitiveness.

Blockchain motivation was the most interesting part as it emphasizes the real purpose of the papers. Objectives are directly related to most of the performance elements, where trust is found to be a more indirect aspect, such as when creating tamper proof digital systems (Düdder & Ross, 2017) or gain consumer trust through sustainability (Nikolakis et al., 2018). Only two articles extensively address trust as an own element of their study (Ahl et al., 2020; Komdeur & Ingenbleek, 2021), while other just mention trust in context of addressing other

elements such as accountability (Ahmed & MacCarthy, 2021), certification schemes (Düdder & Ross, 2017) and, verifiability and enforceability (Nikolakis et al., 2018). Likewise cost efficiency is not an element that is clearly defined. Findings suggest it is associated with efficiently creating confident transactions in an untrustworthy environment (Figorilli et al., 2018), dealing with inefficient certification- and administrative costs (Dieckmann, 2020; Nikolakis et al., 2018) and achieving benefits from improved operational efficiency (Hultgren & Pajala, 2018) as blockchain enables transparency and traceability.

3.4 Case findings

In the following section we are looking at specific case findings, based on each element of supply chain performance frame. Table 4 indicates which article is connected to each element based on our analysis. Case findings represent key industry features. These form the foundation for developing a set of question to be used as a questionnaire. All actors that use timber as a raw material are relevant to participate.

Source	Transparency	Traceability	Sustainability	Trsut	Cost-efficiency
Ahmed & MacCarthy, 2021	x	x	x		
Dieckmann, 2020			x		x
Emberson et al., 2021			x		
Komdeur & Ingenbleek, 2021			x	x	
Kropivšek & Grošelj, 2020					
Düdder & Ross, 2017		x	x		
Figorilli et al., 2018		x			x
Nikolakis & Krishnan, 2018	x		x		x
Ahl et al., 2020	x	x	x	x	
Hultgren & Pajala, 2018	x	x	x		x

Table 4 - Reviewed articles connection to performance indicators

3.4.1 Transparency case findings

Transparency, along with information sharing is believed to be promoted by decentralized blockchain architecture. In turn this is beneficial for globally dispersed industries with complex supply networks, such as with case of Lenzing, a fiber producer (Ahmed & MacCarthy, 2021). After deploying a downstream blockchain solution, it is believed that transparency could be implemented upstream to transform forestry industry by capturing all the information related to upstream woodcutting, logging, and transportation. Transparency can be increased in industries that suffer from opacity, where concealing unethical practices occurs (Ahmed & MacCarthy, 2021). Actors who do not comply with legal requirements, contravenes fees, taxes and duties, and those linked to organized crime can be detected on blockchains platform (Hultgren & Pajala, 2018). With transparency, upstream suppliers may better understand downstream prices and demands, and vice versa (Ahl et al., 2020). Transparency can be created through smart contract function, with clear roles and responsibilities of different actors within the value chain (Nikolakis et al., 2018). This would provide better mechanisms to cope without third parties to resolve disputes. In the case of Japan's woody biomass industry, blockchain is believed to be a solution contributor to social and technical challenges (Ahl et al., 2020). Expert interviews indicate that transparency can be achieved by allowing open information sharing at early stages of supply chain.

3.4.2 Traceability case findings

Some enterprises operate with complex downstream supply chains with high demand fluctuations. Blockchain traceability solution can be used as a platform to create visibility for those situations. In case of Lenzing, traceability was a crucial tool to protect innovative product design, educate customers about sustainability practices and fight counterfeiting of its products (Ahmed & MacCarthy, 2021). Material traceability needs to be supported by complementary technology. (Figorilli et al., 2018) demonstrated that blockchain traceability system (referred to as wood infotracing) can be developed for the whole supply chain, from standing trees to the final product. Possibilities uncovered are related to real-time monitoring using RFID tags from pre harvesting to sawmills, early timber evaluation opportunities of precisely defining areas of interest and quantities to be cut before reaching the market, and ability to detect particular valuable trees (e.g., size, quality or species). The value of traceability would increase by measuring quality parameters at each point of wood conversion, such as moister and condition of the timber, preferably shared along supply

chain in real time (Ahl et al., 2020). From a different perspective (Düdder & Ross, 2017) suggest a timber tracing blockchain solution that follows the physical product and combines governmental policies, ecolabel certification schemes, due diligence systems and commercial companies' sustainability practices. This solution would enable fraud protected volume control, contribute to more efficient and trustworthy sourcing, allow businesses to source responsibly from areas normally perceived as high risk and safeguard forest areas from being converted into other source of usage such as agriculture.

3.4.3 Sustainability case findings

The problem of ensuring sustainability in supply chains was found to be a particular interesting case for the use of Blockchain technology (Düdder & Ross, 2017). Focal companies rely on the certifications of its suppliers to ensure sustainability of wood products purchased for production usage (Ahmed & MacCarthy, 2021). The certification process is necessary to adhere growing (EU) timber regulations such as from Forest Stewardship Council (FSC), but this is costly, requires substantial resources and have weaknesses (Dieckmann, 2020). The latter refers to possibility of forgery, i.e. documentation falsification. Blockchains technology makes it difficult to falsify information and could be a digitalized way to help ensure sustainability in supply chains. Blockchain have capabilities to replace certification bodies by resolving issues related to resources required to request and review all the paperwork showing the supply chain for the material (Hultgren & Pajala, 2018). The certification issues can be enforced through blockchain by issuing sustainable timber production to the owner of forest parcel (Komdeur & Ingenbleek, 2021). With this solution, an embedded code of harvested timber can be connected to the certificate, allowing traceability and ownership recording. Parties can in this way verify if the certificate is valid.

Moreover, it's becoming increasingly important to be fully recognized by brand retailers and/or end customers. Companies rely on independently certified "ecolabels" to verify legality, environmental and social sustainability of products (Düdder & Ross, 2017). These ecolabels are not fully trusted by end consumers. Increasingly number of corporate strategies highlight sustainability. Promoting new emerging business models such as circular economy and fully validating these can be challenging. It's becoming important to create supportive institutions for sustainable integration of technological systems (Ahl et al., 2020). Traceability is a tool that can be used to support sustainability, both upstream and downstream. This applies to ensuring the authenticity and sustainability of products through

blockchain solutions (Ahmed & MacCarthy, 2021). Blockchain can help to resolve information and governance problem in supply chains, and support better compliance and enforcement of sustainability representations (Nikolakis et al., 2018). A forest value chain (FVC) can be created based on the five-layer EVE-framework (Nikolakis et al., 2018) that incorporates internal and external supply chain actors into one blockchain based system for timber trading with automation of the decision making based on smart contracts.

3.4.4 Trust case findings

Blockchain technology can help to mitigate typical buyer-supplier related issues. These issues grow as supply chains are increasingly getting more complex. This greatly affects purchasing decisions of timber materials. In their study, (Komdeur & Ingenbleek, 2021) investigated relationship between the trading relationship and the purchaser's trust. When acquiring timber products, the correlation is stronger if the supplier comes from a country with a solid legal structure. Sourcing responsibly is challenging without trusty infrastructure. Blockchain technology has potential to open the market to a wider variety of raw materials while ensuring environmental- and social sustainability (Düdder & Ross, 2017). Stakeholder trust between the supply and demand sides can improve when information of material flows and prices in the supply chain are available (Ahl et al., 2020). In untrusty environments where credibility is an issue, element of trust can be enhanced by letting downstream players be empowered via access to information on forest resources and material flows. Blockchain is a common register where data can be exchanged seamlessly. It seeks to overcome the problem of data being trapped in siloed organizational systems (Ahmed & MacCarthy, 2021). (Nikolakis et al., 2018) suggest that blockchain, through concept of verifiability can distribute power and trust equally through supply chain network. Verifiability relates to the ability to efficiently comply with various legal and non-state requirements, ensured by different supply chain actors through transactions. It is further argued that effective distributed governance processes need to be placed to ensure the validity and accuracy of blockchain data (Nikolakis et al., 2018). With smart technology applications (e.g., IoT devices) added to the early stages of data collection, this implies need of control to ensure quality of the data, and information it provides (Ahl et al., 2020). Specific blockchain industry solutions can create trustworthy supply chain environments through platforms that allows product transaction flow control such as using TG-fibercoins to distribute available resources (Ahmed & MacCarthy, 2021).

3.4.5 Cost-efficiency case findings

Business alignment is difficult to achieve. It often involves high level of integration and coordination of business processes with others. As complexity increases, the more accessible communication is required to interconnect all information between actors. Likewise, understand issues at each step of the process, and what uncertainties and risks they impose. Intermediate parties are often required to remove the uncertainty and mitigate the risk factors. It's often a costly and time-consuming process to successfully complete the transactions. Blockchain technology has capacity to transform use of intermediaries and more efficiently manage transactions (Figorilli et al., 2018). Some intermediates have supportive role, such as governmental laws and regulations. Others support the physical movement of the products such as transportation companies. These cannot be easily removed or replaced. Blockchain is a platform that can create a safe peer-to-peer economy. It can theoretically remove those providing information exchange, non-governmental control entities and financial intermediates (Hultgren & Pajala, 2018). This might involve avoiding complicated paperwork, and rather through blockchain allow any participants to precisely find the source of any timber, in any product created during the activities in supply chain (Düdder & Ross, 2017). Certification entities such as FSC and PEFC track the origin of timber through paper-based trails, where many of the written approvals by auditors are paper-based (Nikolakis et al., 2018). These can be digitalized through blockchain and improve the reliability of certified forest products. FSC have themselves launched a verification project for high-risk supply chains ("Blockchain beta," 2021). Blockchain does not allow history of the information to be changed, which in timber industry can ensure an even more closed chain of custody and avoid frauds (Dieckmann, 2020).

4.0 Case description

In this section we will provide information about the Norwegian timber industry, actors and their roles, laws and regulations, and systems/products used the industry. We aim to approach blockchain with suitability and implementation view that connects supply chain performance elements with adaptation of technology.

4.1 Norwegian timber industry

In the last decade, Norway has taken some strategic measurements towards sustainable development with goals to increase value creation for national economy, following up the (*SKOG22-report, 2015*). According to the report, resources from the forest can replace fossil raw materials. It is believed that every product made from crude oil can be made with climate-neutral materials. Norway's aim is to facilitate towards developing technology and creating industry based on use of green raw materials and energy inputs. Today, this is powered by pulp- and paper industry sector (including biorefineries and production of fibreboard). Moreover, the report is setting goals for other areas, mainly to increase the competitiveness of tree as building material. Norway's aim here is to increase- human competence and pace of innovation for wood industry. This involves actors from lumber industry, glulam factories, element manufacturers, impregnation plants and manufacturers of other wood-based building and packaging products.

Pulp and paper and wood industry are well organized and supported by the governmental entities. There are both large main organisations (*Treforedlingsindustriens Bransjeforening*; *Treindustrien Bransjeorganisasjon*), regional/local clusters (e.g., *WoodWorks!*) and associations (e.g., *Norges Skogeierforbund*) all working together to achieve common goals. There are measures through collaboration across industries involving enhancing the value chain for forest and wood industries (*Valuechain report*, 2018). Main industry actors share common ownership on supply chain solutions provider that supports all links of the process (*Skogdata AS*). This provider has a key role when it comes to technologies adaptation through systems and products.

4.1.1 Laws and regulations

Laws and regulations for Norwegian forestry usage are set by The Ministry of Agriculture and Food with ("Forestry Act, 2006 ") and ("Regulations on sustainable forestry," 2006) as

most important policies. The formal is a law for commercial utilization of forest resources, including rules for environmental considerations. The later contain specific provisions on how various forms of forestry activities are supposed to be carried out. These rules and regulation set the basis for further process of timber supply chain.

To ensure legal and sustainable sources, environmental certifications of the forests are mainly issued mainly through PEFC and sometimes through FSC. The formal is set as standard through ("Regulations on sustainable forestry," 2006). These certification entities use a chain of custody system, where all supply chain actors, such as manufacturers and retailers must be traceability certified in order for the system to function. Next section explains more detail about this practice with PEFC.

4.1.2 PEFC Certification

Forest certification systems are designed at national level in each country so that they can be tailored to national laws and regulations while also meeting the needs of local stakeholders (pefc.no). Once a country has built a national forest certification system that meets PEFC requirements, the system is subjected to a rigorous evaluation procedure by independent consulting firms before being approved. PEFC Norway's certification system is a comprehensive system that includes organizational policies for forest standards with sustainable forestry requirements, traceability, labelling, and control procedures. The PEFC certification enables supply chain actors to document that timber or product originate from sustainable forestry, as seen in figure 4. This means that end-customers and consumers can be confident that the materials originate from forests that are sustainably managed. A forest standard and a traceability standard are the two primary components of the PEFC system. The Norwegian PEFC Forest Standard is a national standard that outlines how Norway's forests should be managed, while the PEFC Traceability Standard is a global standard that outlines how wood should be tracked along the value chain, independent of national boundaries. The process is controlled by an independent contractor who verify that current standards are met. These 3rd party entities must be accredited by national accreditation bodies.

Forest owner must comply with PEFC standards, containing 27 specific forestry requirements. Everyone involved in forest operations and timber harvesting must receive specialized training to ensure PEFC standards are met. Timber traders must be certified

according to their distinct rules, which requires, among other things, a contract with the forest owner. Timber traders must also ensure that forest owner complies with PEFC forest standards. Traceability certification is required for every actor in the value chain. The traceability chain is broken if a supply chain link is not certified, and the end product can thus not be sold as PEFC certified. Buyers are always provided with paperwork verifying that material was sourced from sustainable forestry. The product will be PEFC tagged with the manufacturer's certification code for sale to end-customers.

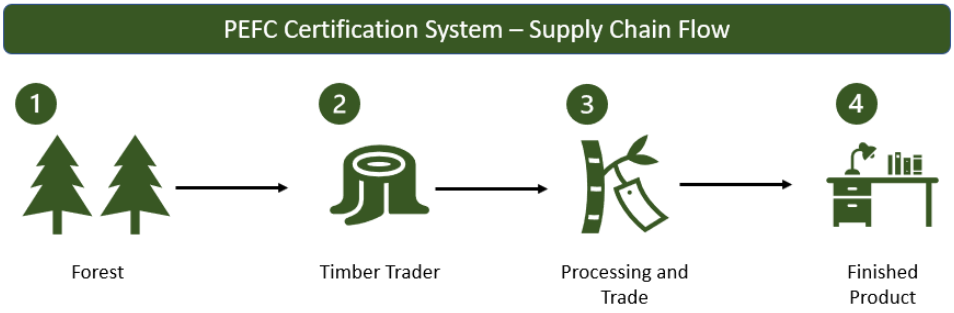

Figure 4 - PEFC Certification System. Source:(pefc.no, 2022)

4.1.3 Timber raw materials

Three main types of timber raw materials are deployed toward downstream producing industry: logs, pulpwood and wood fuel. Logs are turned into products for building materials by wood industry. Pulpwood, wood fuel and surplus materials from wood industry are utilized by the pulp- and paper industry to create a wide range of products. Raw material and end product description is depicted in figure 5.

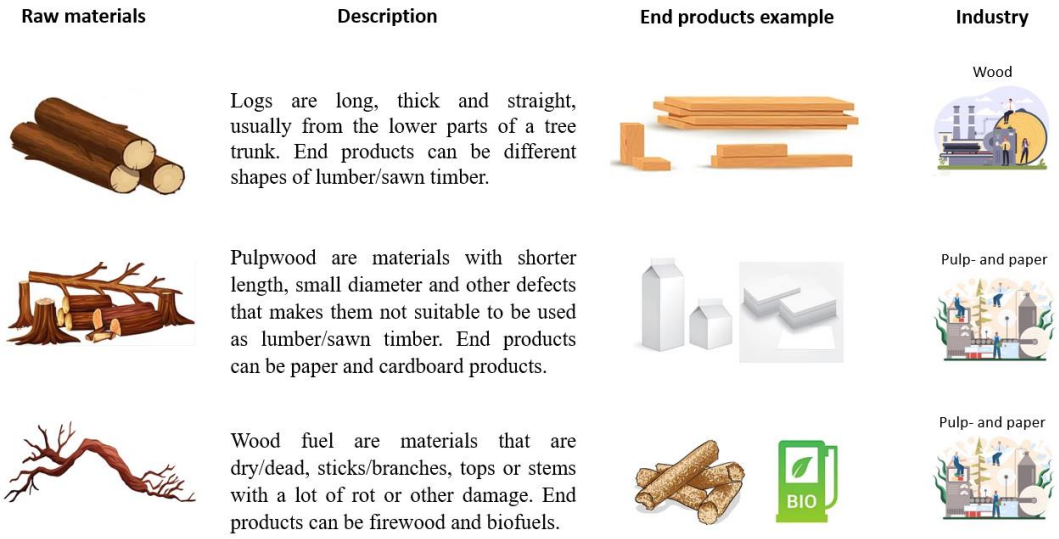

Figure 5 - Illustration timber materials/products in Norwegian industry

4.2 Timber supply chain

Norwegian timber industry stretches from forest owners to industrial activity where it's divided between wood- and pulp and paper sectors. Main actors are shown in figure 6 and described in this section.

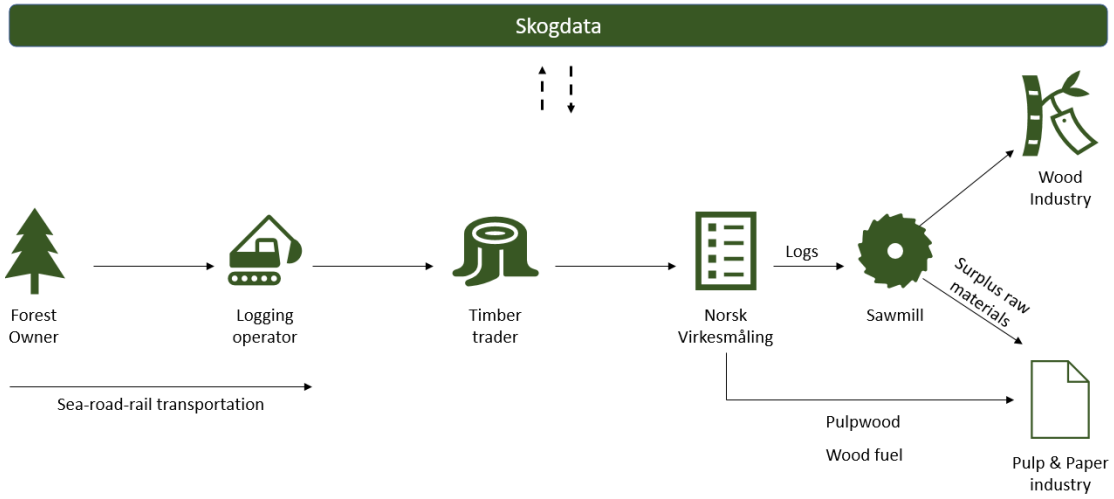

Figure 6 - Timber supply chain

4.2.1 Forest owner

According to (*SSB*, 2021) there are 125485 forest properties in Norway. These are mostly privately owned. Forest owners can apply to proclaim their properties as protected based on their natural values or to leave them as productive areas. Before tree felling process can be started, forest owner must initiate a forestry management plan and apply for environmental registration of their forest properties. This involves mapping of forest resources, which may include overview of age distribution and volume in the forest. Forest owners are usually a part of a larger member association. These provide owners with information, guidance and counselling advice about forestry operations and other activities to complete the timber sales process. At the end, forest owner must ensure a regulatory method of regeneration as a part of rejuvenation of the forest. This is done through planting, natural rejuvenation, sowing or field preparation. The Ministry of Agriculture and Food provide subsidies to forest owners to stimulate increase sustainable value creation of the industry.

4.2.2 Logging operators

Logging operators harvest timber. They use machinery and equipment to fell, skid, process and move trees to collection point for further transportation. Modern harvesting equipment

has the capability to automatically measure desired timber parameters and process trees according to buyers requirements. A part of the operation is to construct temporary road access and plan harvesting to meet environmental regulations. This must be well planned and be publicly approved. There are different types of logging operations depending on the terrain, tree species in question and how the area have been treated before. Felling method can be crucial for financial reasons and future opportunities. This depends on forest owners objectives.

4.2.3 Timber trader

Timber trader acts as an intermediate between forest owner and downstream producing industry. Their main task is to buy timber which they resell to sawmills and pulp- and paper industry. There are four mayor actors conducting this type of activity, covering the whole country besides northern region of Finnmark where forestry is protected. These actors are owner by forest owners through local/regional associations. In addition, there are several smaller timber traders (*Nortømmer AS*; *SB Skog AS*) operating around the country. Towards forest owner, their role is to find a suitable logging operator and transportation provider. In many cases, they provide extensive services and can take on the tasks forest owner usually is responsible to conduct. This includes creating forestry management plans and accomplish environmental certification. Formal can be offered as a digital solution (*AT Skog* 2022). Towards producing industry, timber traders role is to make sure harvested timber reaches the right buyer according to pre-defined specifications. These four intermediate actors have subsidiaries and partial ownership within serval areas associated with forestry. This can be companies within real estate investment, infrastructure construction, logistics, logging, sawmills, production, product development, international sales, leisure activities etc.

4.2.4 Norsk Virkesmåling

After harvesting process, timber is measured to obtain a neutral settlement basis between buying and selling parties. Norsk Virkesmåling is the entity providing this service. Forestry Act obligates buyers and sellers to measure all forest timber that is used for processing sales or export. Timber is measured at physical stations or via tools developed for transportation providers. Length, diameter, bark thickness and overall quality determine which raw material category timber is classified into. This entity further engages in quality control activities which are vital towards final settlement.

4.2.5 Sawmills

Sawmills treat logs and transforms them into lumber/sawn products that is further used by actors in wood industry. Logs are purchased from timber traders and sold to actors in wood industry, while surplus materials from production are sold to actors in pulp- and paper industry. Sawmills can be quite modern, with use of advanced measuring and optimization equipment. These have capabilities to create a wide range of products according to downstream industry demands. As an example. x-ray sorting of the logs can be used to determine to what purposes timber is best suited for. Raw material demands and other quality parameters are forwarded towards a timber trader. In many cases, sawmills are vertically integrated by actors in the wood industry.

4.2.6 Pulp and paper and wood industry

Downstream producing industry actors transform raw materials and/or semi-finished wood products into end products. Pulp and paper industry aims to satisfy national and global long-term ambitions through utilization of every part of tree as raw material. It is being driven by climate neutrality, sustainability goals, bioeconomy and product innovation. For wood industry goals are to increase competitiveness and value creation, achieve sustainability goals and engage growth towards circular economy. Wood industry foster a large research institute in Norway (*Treteknisk*) with goals to promote up to date knowledge and develop production processes, processing methods and application of wood as a material. Both downstream industry's main objective is to sustainably utilize every aspect of timber as a raw material.

4.3 Skogdata AS

Skogdata is one of the oldest IT companies in Norway, founded as an initiative by the actors and associations of timber industry. Company operates exclusively for the purpose of providing technological solutions to a variety of actors throughout the supply chain. Many of industry actors are end-to-end integrated as owners. Stakeholders of the company include associations in both downstream (e.g., *Treforedlingsindustriens Bransjeforening*) and upstream (e.g., *Norges Skogeierforbund*) part of the supply chain. Their product portfolio supports the complete industry supply chain – from forest owners to pulp and paper industry. The systems are used for a variety of functions, including acquisition and sale of forest timber from landowners to forest industry businesses such as sawmills, pulp mills, chemical

plants, and sheet metal manufacturers. Company develops and administrates systems for various purposes related to technological solutions/applications.

4.3.1 Industry use of Skogdata applications

Skogdata´s systems are integrated through the timber value chain. There are five major solutions for the industry. (1) VSYS Virkeshandel is used for trade between the timber seller, logging operator, and timber buyer, where purchase- and sales orders are the main document types involved. Norsk Virkesmåling uses (2) VSYS Innmåling to deliver their measurement services, while the system (3) VSYS Pris & Avregning is used by the industry for correct material pricing. (4) VSYS Transport is Skogdata´s system for planning and performing transport of goods within the industry and is used by transportation contractors. (5) VSYS Register is used by various actors up and down the supply chain and contains master data necessary to perform day-to-day operations. All members apart from forest owners can access the register. Applications provided for the industry are displayed in figure 7.

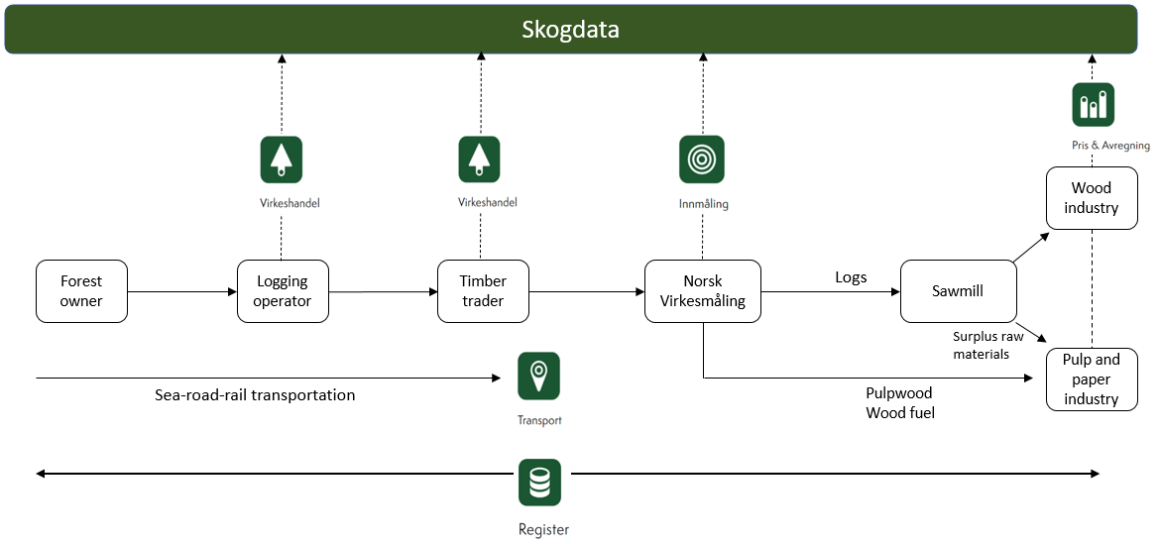

Figure 7 - Industry use of Skogdata applications

In general, the system is built on a Microsoft platform. The applications developed are usually integrated with users ERP systems through API. This allows users to run alternative interfaces on Skogdata´s applications. A detail description is found below.

VSYS Virkeshandel is the core module for purchasing, sales, and production in an IT system that handles all aspects of the forestry timber trade. The solution comprises an independent module for sales of either logs or excess raw materials, which can communicate

with other modules such as transportation and timber measurement. All data between the different modules, throughout the supply chain, are communicated utilizing standard messages, and all actors connected to the system receive their own data through a solution for reporting and analysis. The objective is to deliver high quality information to all supply chain actors, ensuring the best foundation for decision-making. Virkeshandel uses purchase- and sales orders for trading, with the timber buyer registering a purchase order which is sent to the seller and displayed as a sales order. The system is maintained centralized at Skogdata´s datacenter, with every client running the system on a dedicated server. As the fundamental module, users have the possibility to extend the system with new modules depending on their needs. All modules are loosely integrated and based on data transfer through standardized e-documents, ensuring that users have access to their required functions.

All purchases of raw material are handled in the purchasing module. There are two document types: (1) *Purchase from supplier* which indicates that the purchase initiates a trading process, eighter by purchasing timber from the forest owner or a regular supplier. (2) *Resales* include all purchase orders which are not directly connected to the original supplier. Purchase orders can also be used to post available assignments, in example delivery or measurements of goods. As with purchasing, all sales are handled through an own module. There are four categories of sales documents, depending on the nature of the sale. (1) *Sales from storage* is the document type used for sales of raw materials and indicate the initiation of a sales process. (2) *Resale* is used for sales without any internal processing of the goods. (3) *Small sales* are the document type for sales to external customers using another system that Skogdata´s. (4) *Services* is the sales instrument for services such as logging. The different document types make the system suitable for a variety of supply chain actors, enabling a widespread use of the system within the industry. The final module in Virkeshandel is production with several features for production planning and logistics. Production can eighter be performed internally or outsourced to subcontractors, whereas subcontractors can gain access to sellers' client in the system. Here, subcontractors can pick up, report on, and follow up their assignments. Data collected by the harvesting machine and forwarder can automatically update the system, ensuring that all involved actors have access to the latest developments. The system allows for batch-level traceability between actors upstream, in example tracing a specific shipment back to the warehouse. Figure 8 illustrates trade between three supply chain actors, all utilizing Virkeshandel by Skogdata.

As the figure displays, the purchasing document is the main trading instrument between parties involved.

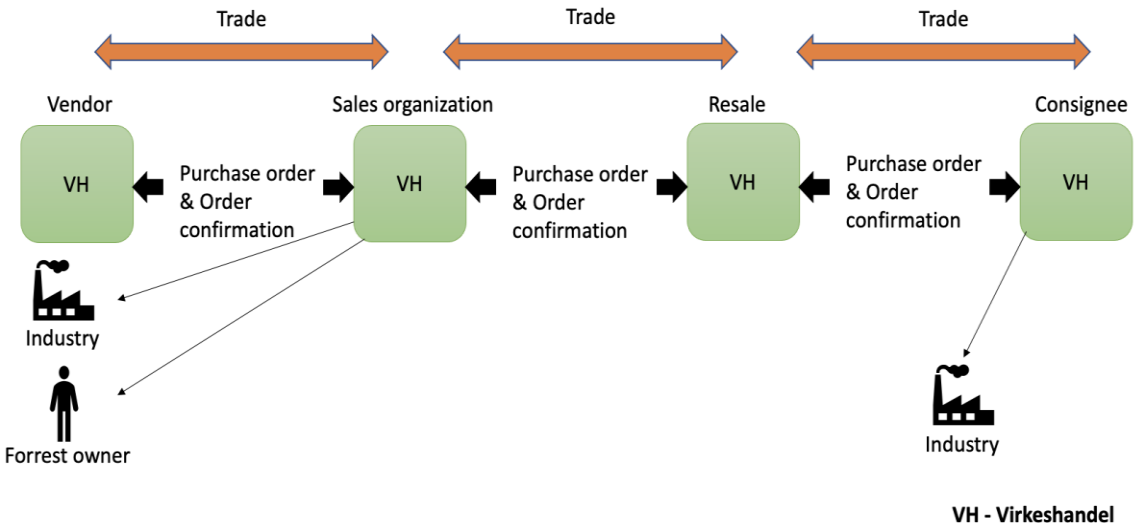

Figure 8 - Industry trade with Virkeshandel. Source: Skogdata AS

VSYS Register is master data for the Norwegian timber industry. The registry contains neutral information (publicly available) about industry actors, products and classifications, pick-up and delivery points, and code associated with trade of timber goods. Data is collected through publicly accessible registers, such as Brønnøysundregister and Matrikkelen. The users are responsible for ensuring that registered data are correct, with Skogdata performing system maintenance of the register. Supply chain actors are registered once in the system but can be assigned various roles depending on their business, i.e., buyer, seller, forest owner and transportation. Name and address are collected from Brønnøysundregisteret, but no further information is collected on behalf of clients. Fixed shipping- and delivery points are in use over a period of time, typical examples are logistics terminals and shipping doks. These are registered with additional information such as their geographical location and connected with industry actors as shipping or delivery points. The industry also uses several temporary logistics points, in example temporary storage of wood in the forest. However, these are not registered as part of the database, but are instead connected with the contracts used for trade in the industry. Assortments are used to name timber products, and there are two categories depending on the trade. Trade assortments are used for purchasing through the value chain, with examples including 100 – spruce pulpwood, 200 – plywood pulp, and 300 – sawdust of spruce. As the quality is determined at the measuring station, the goods change material number depending on measured quality.

The goods proceed to change assortment to settlement within the register, however the new material ID is linked with the previous trade assortment number.

VSYS Transport is the system supporting logistics through the industry. The application is responsible for arranging shipping, controlling the shipping process, and handling the settlement at delivery. The application consists of three modules, (1) TrLeder for governance of assignments, (2) TrSjåfør for drivers and transportation centrals. Reports are submitted through this module. (3) TrOppgjør is the module responsible for settlement to the carrier. The application is used by a variety of supply chain actors within the industry, ensuring standardization of the shipment process within the industry. The system is accessible by different units, with alternatives for iPad through apps in the Appstore.

VSYS Innmåling is a tool for measuring timber and delivering results to the parties involved with the timber turnover. The tool is used by the Norsk Virkesmåling. Skogdata has also developed a separate app for load measurement that can be used by general measurement organizations. Who is to carry out the measurement is decided in the last stage of trade, as these are the actors that process the material.

VSYS Pris & Avregning handles economy and invoicing for actors in the timber value chain. All settlement solutions are based on a measurement document of the goods as a basis. In practice, this means that no one receives compensation/invoice for goods or services before the goods have been delivered and measured at the goods recipient. New measurement documents are registered every night for pricing calculations, and a copy is made for every actor involved in the timber trade. Settlement is performed once a month and collects all measurement documents from the period on an invoice document. The measurement document also contains information related to other processes (pricing- and settlement, transport settlement). Changing information in the document therefore leads to credit/debit postings for all transactions where the document is used as basis, even in specialist systems that are not affected by the change in the first place. The results of settlement are electronically transferred to actors involved for final processing within their ERP-systems. Price lists are updated in VSYS Pris & Avregning. A price list has a unique number that is linked to one or more business partners. The use of the price list is limited to these business partners.

5.0 Methods and data

5.1 Research

Research is a process of seeking answers to certain questions which have not been answered so far, with goal to arrive at a dependable solution (Devi, 2017). According to Cambridge dictionary, it is a detailed study of a subject, in order to discover new information or reach a new understanding. An important aspect is that research answers should not be available in current literature. Engagement should be devoted towards finding unknown facts which have not been exposed (Mishra & Alok, 2017), that can purposely be used to build knowledge on a topic. Answers should be sought following a procedure, through planned and systematic collection using analysis and interpretation of data. This includes using techniques for gathering evidence and various ways of proceeding in gathering information, referred to as methods (Nayak & Singh, 2021). Term "scientific" is used when research contributes to a body of science and follows the scientific method. Our work is the final assessment with granting title as "Master of Science in Logistics" contributing towards academic literature. We recognize the importance of adequate building of the thesis structure, documenting every step and approach, combining both theoretical and empirical levels into one purposeful reasoning.

5.1.1 Scientific research

Exploratory, descriptive, and explanatory are the three main types of research that are recognized as scientific. These are distinguished based on the purpose of research, with their own set of objectives and characteristics. Exploratory research attempt to discover something new and interesting by going through a research topic (Swedberg, 2020), investigating a problem that has not been studied or deeply investigated in the past. Descriptive research is based on making careful observations, identifying problems that exist in particular set of condition that can be used to examine variations in an already known environment (Siedlecki, 2020). Explanatory research seeks deeper understanding of observed phenomenon to connect the dots in already known circumstances to identify causes and reasons beyond the portraying topic (Nayak & Singh, 2021).

Research with objective to achieve skillfulness with a trend or to get novel opinions into it, can be termed as exploratory (Mishra & Alok, 2017). Chosen scientific research direction of our thesis can be viewed as exploratory in nature. It explores blockchain possibilities

within Norwegian timber industry, which has to our knowledge not yet been investigated. Blockchain technology is not implemented in any area of the industry, it is unknown what role it may have, what elements of timber supply chain it may help to improve or premise of its implementation feasibility. Based on that, our research cannot be pursued as descriptive or explanatory.

5.1.2 Exploratory research

This section provides a deeper understanding of what exploratory research offers, its objectives, characteristics, and association with our topic.

Exploratory studies can take a number of different forms. According to (Nayak & Singh, 2021), the objectives can be three-folded with goals to; (1) scope out the magnitude or extent of a particular phenomenon, (2) generate some initial ideas about the phenomenon and (3) test the feasibility of undertaking a more extensive study regarding that phenomenon. Being viewed as an enabling technology, blockchain suitability is heavily discussed in the field of SCM. It is an emerging area of interest to many business sectors. Through literature review findings, we tried to gain familiarity with this phenomenon. It's been demonstrated that blockchain has capabilities to improve supply chain performance. The scope of the magnitude has been limited with adopting elements from (Mahyuni et al., 2020) as a general framework. Working within this scope, the ideas are formed on the basis of acquiring insight into specific industry characteristics on a global/national scale. With goals to map blockchain motivation based on each case finding, blockchain achievements can be fitted to each supply chain element. More precise problem formulation is generated on assessing how the Norwegian timber supply chain function, where possible key enabler of blockchain was found. It is stated that exploratory research may not lead to a very accurate understanding of the target problem, but it scopes out the extend of the problem to serve as a precursor to more in-depth research (Nayak & Singh, 2021). We believe our approach can open doors to further research on the topic as it provides new information, data and insight into Norwegian timber industry in the context of blockchain suitability.

5.2 Research design

In simple terms, a research design is the logical and systematic planning that directs the research to achieve its objective in a valid way (Asenahabi, 2019). A plan is adopted by a researcher to translate a research problem into data for analyzing the results and ultimately provide legitimate conclusions. Research design is divided into three groups: quantitative,

qualitative and mixed methods. Quantitative research is the numerical representation and manipulation of observations for the purpose of describing and explaining the phenomena that those observations reflect (Sukamolson, 2007). Quantitative research can be used to summarize characteristics of a data set (descriptive) or to make predictions regarding an outcome (inferential). Qualitative research is about gathering detailed in-depth insights on complex topics that are not well understood (Creswell & Poth, 2016). Main purpose is to generate meaning from opinions and experiences of participants as it deals with non-numerical data (Mishra & Alok, 2017). Mixed methods are the combination of quantitative and qualitative research design. The approach is suited for the broad purposes to enrich the understanding of empirical research using integration of both forms. There are several benefits related to using mixed methods. Results from one method can be complementary to the findings from the other, results from one method can be used to develop another method, and range of inquiry can be expanded with use of different methods, i.e. breadthen information seeking process (Molina-Azorin, 2016). The research design choice regarding this thesis is use of mixed methods, as we believe it fits well with exploratory study approach. There are several types of mixed methods design available. These are described in the next section.

5.2.1 Types of mixed method designs

There are several sources in the scholarly literature that systematically classify mixed methods. Each of them use their own distinctive dimensions, which are based on integration between quantitative and qualitative research (Guest & Fleming, 2014). We represent typology from (Creswell & Creswell, 2017) where there are six distinguished mixed method designs. These are described in table 5. There are different ways the data from each method can be used together. Researchers need to consider how the mixed methods integration of the two databases are going to be connected, merged or embedded, which determines the method design. Data from each method can be used sequentially (one data analysis builds on another) or concurrent (bringing results together). Chosen research design of our thesis falls under embedded mixed methods. Detailed about this structure is described in the next section.

Convergent parallel mixed methods is a mixed methods strategy in which a researcher collects both quantitative and qualitative data, analyzes them separately, and then integrates them in the interpretation of the overall results.
Explanatory sequential mixed methods is a mixed methods strategy that involves a two-phase project in which the researcher collects quantitative data in the first phase, analyzes the results, and then uses the results to plan (or build into) the second, qualitative phase.
Exploratory sequential mixed methods is a mixed methods strategy that involves a two-phase project in which the researcher first collects qualitative data and then follows up or builds on this database with a second quantitative data collection and analysis.
Transformative mixed methods is a form of mixed methods design in which the researcher identifies one of the qualitative theoretical frameworks (e.g., indigenous populations, females, racial and ethnic groups, disabled individuals, and so forth) and uses the framework through the mixed methods study, such as to establish the research problem, the questions, the data collection and analysis, interpretation, and the call for action. It is used in conjunction with explanatory, exploratory, and embedded designs.
Embedded mixed methods is a type of mixed methods design that nests a convergent, explanatory sequential, or exploratory sequential method within a larger design (or strategy).
Multiphase mixed methods is an approach to mixed methods research in which the researchers conduct several mixed methods projects, sometimes including mixed methods convergent or sequential approaches, sometimes including only quantitative or qualitative designs in a longitudinal study with a focus on a common objective for the multiple projects.

Table 5 - Six Major Design Types. Source: (Creswell & Creswell, 2017)

5.2.2 Embedded mixed methods

The core idea of this method is to embed one of the data sources (either qualitative or quantitative) into the other, to provide a supporting role in the overall design (Creswell & Creswell, 2017). Exploratory research is qualitative in nature as it often starts with reviewing available literature, and consist of collecting informative material and conducting interviews (Nayak & Singh, 2021). This yields qualitative data. Our approach involved conducing literature reviews to grasp on the subject of blockchain and how it related to SCM in general and likewise to timber industry, which further involved talking to downstream industry expert for information seeking purposes and conducting interview with key industry actor regarding our case exploration. Ideas generated from this context are therefore weighted qualitatively as the primary method of analysis, while the performance elements are quantified (through Likert scale) to add another aspect that is developed to support blockchain suitability analysis for the industry. In embedded designs, the supporting component may occur before, during or after the main component (Creswell & Creswell, 2017), meaning that research method may be implemented in a sequence or during the same phase of the study (Hesse-Biber & Leavy, 2010). In our case, quantitative component will be applied concurrent with the qualitative analysis. The same will apply for data collection, occurring around the same timeframe. Embedded designs are used when a researcher needs to answer two different questions that require quantitative and qualitative data (Creswell & Creswell, 2017), meaning that each sub question can be treated as their own analysis before

being brought together for final interpretation of main research question. This approach is depicted in figure 9.

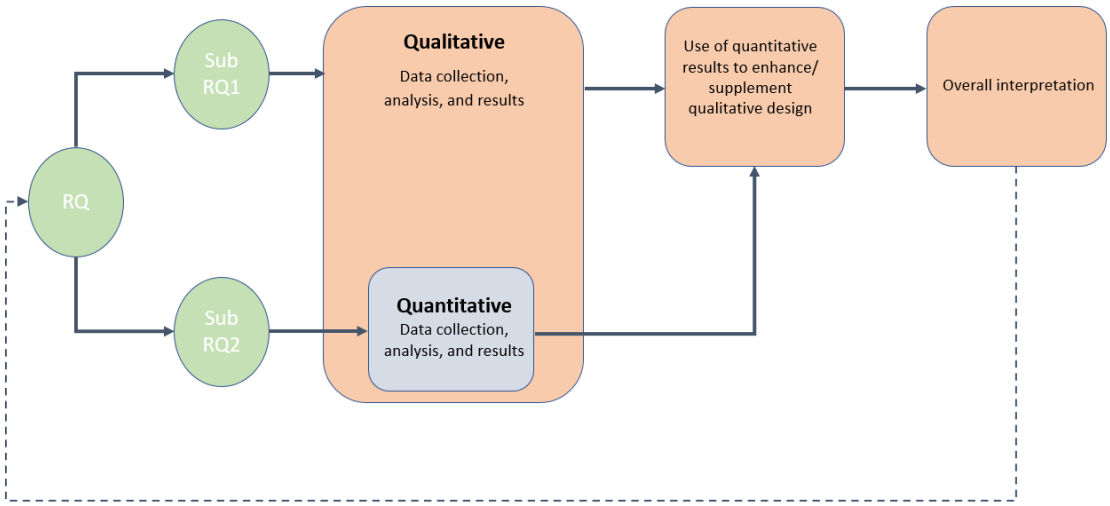

Figure 9 - Embedded mixed method applied. Adapted and modified from: (Hesse-Biber & Leavy, 2010, p. 372)

5.2.3 Qualitative approach

Table 6 represents alternatives in qualitative research. The perspective of our thesis is to closely investigate blockchain possibilities within a context of a specific supply chain environment.

Narrative research is a qualitative strategy in which the researcher studies the lives of individuals and asks one or more individuals to provide stories about their lives. This information is then often retold or restoried by the researcher into a narrative chronology.
Phenomenological research is a qualitative strategy in which the researcher identifies the essence of human experiences about a phenomenon as described by participants in a study
Ethnography is a qualitative strategy in which the researcher studies an intact cultural group in a natural setting over a prolonged period of time by collecting primarily observational and interview data.
Grounded theory is a qualitative strategy in which the researcher derives a general, abstract theory of a process, action, or interaction grounded in the views of participants in a study.
Case studies are a qualitative design in which the researcher explores in depth a program, event, activity, process, or one or more individuals. The case(s) are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time.

Table 6 - Types of qualitative research strategy/design. Source: (Creswell & Creswell, 2017)

At this level, the aim is first and foremost to explore a certain phenomenon and its potential to be applied in our field of interest. The approach involves interpreting current situation from the standpoint of industry actors and in the process analyse their potential needs. From there on, move towards comparing these two potentials, i.e., blockchain technology and industry needs to find out how they correspond to each other. We are focusing on blockchains unique qualities and to investigate these on a deeper level in the context of

Norwegian timber industry that shows lack of detailed preliminary literature. The applications are taken from a larger investigated field exploring its characteristics and benefits. We are threating this thesis as a narrowed down case study, exploring the usefulness of blockchain technology, and transferring its capabilities to practically applied setting.

5.2.4 Exploratory case study

The purpose of exploratory studies is to formulate a problem for a more precise investigation or to develop hypotheses (Nayak & Singh, 2021). This means that exploratory case study research is often regarded as little more than a preliminary step toward specific and focused causal research to generate required hypotheses (Harrison et al., 2017). We emphasize that before blockchain can be implemented, its usefulness must be identified and determined to solve a specific issue, but it also needs to be understood by all stakeholders involved, or at least its values must be known. In our case, it can be argued that potential blockchain capabilities or (independent) variables are identified, in form of five performance elements. However, these are not used as a conceptual framework and hypothesis testing. This option was explored at early stage. A professor at Molde University was asked for feedback regarding our research questions, where we sought advice towards finding appropriate research method. The professor has done extensive review on the topic and is a part of several ongoing projects. The comment was that blockchain can be implemented in almost every industry if there is a need. It is not the question of if technology works. It rather depends on the readiness of the companies. On that note, the suggestion was to apply readiness as the dependent variable and use inferential statistics to make conclusions. After doing extensive research on the topic and analyzing supply chain relations, it quickly came apparent that the industry is different from what would be a typical setting. Industry is unique in the sense that its well organized and interconnected by one main source, being Skogdata. In that regard, more investigation is needed to identify the circumstances around how the actor operate and make decisions regarding technological solutions. In other words, more data is needed for the formulation of valid hypotheses, and this is one of the main reasons we pursue the study as exploratory.

5.2.5 Quantitative approach

Table 7 represents alternatives in quantitative research. It is normal practice that mixed methods researchers look to many approaches to collecting and analyzing data rather than

subscribing it to only one way (Creswell & Poth, 2016). Researchers conducting exploratory study have a high degree of flexibility and independence with regard to the research design as well as the data collection (Harrison et al., 2017). Our research deals with specific variables, narrowed down by other researchers (Mahyuni et al., 2020), while at the same time having a qualitative approach. This is because these variables are not fully defined or identified to be used within the context of timber supply chain. Our research provides this translation, from theory to practical understanding. An important part of that approach is performed through quantitative method using survey design. Quantitative research is useful to quantify opinions, attitudes and behaviors and find out how the whole population feels about a certain issue (Sukamolson, 2007). Quantitative component of this study is needed to map issues provided by the chosen framework, with aim to gain knowledge of those involved into utilization of timber raw materials.

An **experimental design** in quantitative research tests the impact of a treatment (or an intervention) on an outcome, controlling for all other factors that might influence that outcome.
A **survey design** provides a plan for a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population.

Table 7 - Two main types of quantitative research designs. Source: (Creswell & Creswell, 2017)

5.3 Design for data collection

According to (Nayak & Singh, 2021) research design equips a blueprint for empirical research which must specify at least three processes; (1) the instrument development process (2) the sampling process and (3) the data collection process. These processes are activities and techniques involved in collecting data to satisfactorily answer research questions. In the next sections we will cover each of these processes.

5.3.1 The instrument development process

In this section we provide information related to qualitative and quantitative tools, in form of semi structured interview- and survey design. The section also provides a description concerning our approach using exploratory case study with qualitative method as the main component.

In qualitative approach, the researcher is the primary instrument in data collection rather than some inanimate mechanism (Creswell & Creswell, 2017). Large portion of the thesis work went into systematically analysing blockchain potential within supply chain environment. During the literature review stages, based on supply chain perspective, blockchain was organized according to its benefits, practical relevance, possible areas of implementation and its root motivation. While seeking how blockchain contributes through case findings we revealed details around its capabilities. We used supply chain performance elements to navigate through information complexity and arrange timber related supply chain aspects with specific blockchain improvement features. Our qualitative research design aims to utilize these findings and transfer the systematic review into a key part of the analysis. It will be conglomerated with information from key provider of technological solution (Skogdata) and embedded with industry needs from downstream part of Norwegian timber industry.

Information seeking process involved consisted of multiple stages, usually as a short contact depending on information need. We talked to various actors, such as a timber trader, cluster organization and downstream industry expert (using email and phone calls). This was important to map the flow of timber supply chain and details associated with industry challenges, but also to get comments about their view of blockchain. After collecting clues and reflecting on reactions surround blockchain, we worked on arranging a meeting with Skogdata.

5.3.2 Semi structured interview

The semi structured interview was the crucial part of the study as it provides key information, we can utilize to build the qualitative analysis around and address relevant research questions. In this setting, the interviewer has a clear list of issues to be addressed and questions to be answered (Nayak & Singh, 2021). In the preparation phase prior to the interview with Skogdata, we developed a presentation to be used during the Teams meeting. Presentation contained details around our research area, findings surrounding blockchain within the 5 elements, plan of action to reveal our overall intention (including examples from questionnaire), timber supply chain depiction with Skogdata's portfolio in mind, and a list of questions that were sent prior to interview start. The latter is available in appendix section. According to (Nayak & Singh, 2021), an important aspect of semi structure interviews is flexibility of topics and that interviewees are given chance to develop their ideas to speak

widely on the issues raised by the researcher. We believe this structure opened up for a valid discussion surrounding issues aimed to be addressed where participants could freely move back and forwards on presentation slides to elaborate their points.

5.3.3 Survey design

The purpose of the survey is to address one of the sub-questions, aiming to collect valuable information from downstream actors of timber supply chain. This information can give important clues about the current state of the supply chain, capturing main concerns that potentially might need to be improved in the future. The reasoning behind use of survey is the direct relation to supply chain elements deriving from blockchain capabilities. Survey is adapted to be used in the timber industry based on theoretical literature and empirical evidence.

For the indented purpose, we consider it satisfactory to carry out the survey as one-time observation acting as a snapshot into current situation. Downstream part of timber supply chain stretches into two branches, pulp and paper and wood industry. Since many of the sawmills are vertically integrated by the later, and being the first utilizer of raw materials, the survey will be carried out using participants from sawmills and pulp and paper industry. These features indicate that survey is cross-sectional, being the opposite of longitudinal (Rindfleisch et al., 2008).

For the purpose of collecting quantitative data, we intend to use a questionnaire as the survey instrument. A set of questions were developed by us, using adopted supply chain performance elements. Each of the elements contains 4 questions, using Likert scaling from 1 to 5. Questions are thoughtfully designed so that each question indicates participants should answer with high value if they worry about the issue presented to them. Complete questionnaire is available in the appendix section. To make sure questions are applicable, an industry expert from pulp and paper industry was asked to provide feedback. Timeline of the survey stretches from start to the end of April 2022. All variables in the questionnaire are considered independent, intended for descriptive analysis. The objective is to measure concerns participant have in regard to each variable. This will help identify current issues, which we know blockchain technology have capability to improve.

5.3.4 The sampling process

Sampling is the process of selecting segment of the population for investigation. Pulp and paper industry consist of approximately 15 large production companies and around 25 small actors within this sector. All these were contacted. Moreover, 30 sawmill actors were found and contacted during our searching stage. Selection of sampling method related to quantitative approach is based on convenience and judgement methods (Rahi, 2017). We relied on participants willingness to partake due to low- number of population and the accessibility of these actors.

In qualitative research the sampling technique will be non-random purposive sampling (also called non-probability sampling), because it will be choosing specific people for the sample who meets the criteria of the study (Nayak & Singh, 2021). The goal of the research is to explore and collect information to discover something of interest that can be useful in the context of blockchain and timber supply chain. The advantage of non-probability sampling is convenience it provides. It allows researcher to assemble a sample with little or no cost and/or for those research studies that do not require representativeness of the population (Nayak & Singh, 2021). This is related to our early information seeking process where we found convenient sources of information that could help guide us in the right direction. It helped us to build knowledge about the industry, its elements and features which contributed to strength our objective judgement.

5.3.5 The data collection process

Quantitative data was collected via pre-made questionnaire using digital tool (nettskjema.no) available to students at Molde University. Phone calls were made to find suitable company representative and continued by forwarding an email with link and instructions for correspondence to follow. We experienced that companies' representatives made promise to answer but we didn't receive as many answers as promises. To accommodate low response rate physical visits were made in the eastern part of Norway to encourage companies to conduct the survey. Here participants received a brief introduction to the research before being asked to take a closer look at the questionnaire. Identifying the right firm representative to respond was among the obstacles experienced during data gathering. Company representatives working in procurement or supply chain management were chosen to ensure the highest data quality given they have the most insight into supply chain issues and concerns. Some observations made during physical meetings included a

number of people responding that these concerns were not relevant as they rely on purchasing agreements negotiated by a centralized purchasing organization. As a result, instead of engaging local buyers, the focus was moved to approaching large, centralized logistics groups. Insufficient time and lack of relevance for their company were some of the other reasons related to response failure. In all, 14 answers were collected from 70 contacts, making it ~20% response rate. On average, participants spent just under 6 min to complete the questionnaire.

To collect qualitative data, participants were purposely selected during the information seeking phases. Both close-ended and open-ended questions were asked when collecting data. Often additional questions emerged during the conversations and required reflection around further direction surroundings objectives towards research questions. Semi-structured interview with Skogdata was voice-recorded and analysed several times. Personal information regarding the interview is approved by (NSD) and considered legal for publishing under their private policy.

6.0 Analysis

In this part we are taking a closer look into what blockchain technology can offer to timber supply chains. A detailed analysis is provided based on case findings from second literature review. It will later be compared to current system offering through Skogdata and ERP functionalities. When compared to current system offerings the analysis will embed findings from downstream industry actors (questionnaire) to analyse its necessity. In order to do that, we are first going to provide our interpretation of each supply chain performance element. This is a part that can be viewed as a missing link between theory and practice as there are no clear definitions and purposes from supply chain perspective provided throughout literature we came across during the research.

The steps for our approach are as following: (1) take a closer look at what each element represents in the context of supply chain and provide our interpretations based on collected theory (2) analyse how blockchain can improve each element based on literature case findings (3) analyse Norwegian timber supply chain system offerings and (4) analyse downstream industry results from questionnaire.

Later we will present these findings based on what is currently covered by Skogdata's product portfolio and discuss the necessity of each potential blockchain improvement in regard to industry needs. Findings will be presented based on matching comparison where Norwegian timber system offerings and blockchain capabilities will be the focal point, as well as incorporating factors that explore blockchain implementation (conversation with Skogdata's representatives).

6.1 Step 1 – Elements interpretations

Table 8 represents our interpretation of transparency as an element of supply chain management in timber supply chain. It is based on section that describes theoretical findings where e.g. (Transparency-Act, 2022) express the importance and connection to supply chains. The issue of transparency is related to having complete overview of what every actor involved in focal company's own supply chain is doing. When having such overview, it's possible to capture irregularities that do not correspond with own values, and control activities a company is involved into. The challenge is to have a system that captures all necessary information to have visibility across the whole supply chain.

SCM element	
Transparency	
What is it	**What is its purpose**
Visibility beyond the boundaries of the organization and its closest suppliers/customers	To openly systemize and share detailed information about actors, activities and processes
Why is it important	**What is the challenge**
To ensure working conditions, ethical guidelines and social responsibility	Fuction as a multi-tier information sharing systems

Table 8 - Transparency in supply chains

Table 9 represents our interpretation of traceability as an element of supply chain management in timber supply chain. Along with transparency, traceability is also about creating visibility. Here, visibility is related to materials as they move along supply chain and get altered into semi-finished and end-products. Traceability is the ability to trace information backwards related to a material/product when needed. For this to be possible, information about the same material/product must be tracked forward. The issue is that, as different actors perform different activities as part of their supply chain role, important information disappears out of sight if details are not shared. This can cause issues when due to some inconvenience, quick access to information is needed. It's difficult to gather all product information at once. The challenge many actors face is having all necessary upstream information and validate this towards the downstream part of supply chain.

SCM element	
Traceability	
What is it	**What is its purpose**
Ability to track and trace material/products and its condition along supply chain	Prevent loss of information and provide value-adding information
Why is it important	**What is the challenge**
Ensure viable information when needed	Have efficient system to track and trace product info and transform it into value adding info towards customers

Table 9 - Traceability in supply chains

Table 10 represents our interpretation of sustainability as an element of supply chain management in timber supply chain. Companies are dealing with pressure to incorporate sustainability into their business models. This implies to satisfy governmental rules and regulations, industry standards and customer needs. In the context of timber supply chain,

to reach its sustainability targes, origin of trees must be proven to not only satisfy next link in the supply chain but also to contribute towards preserving natural resources (forests environments).

SCM element	
Sustainability	
What is it	**What is its purpose**
Social, economic and environmentally friendly businesss operation	Evolve new business models
Why is it important	**What is the challenge**
Preserve natural resources	Satisfy every stakeholder

Table 10 - Sustainability in supply chains

Table 11 represents our interpretation of trust as an element of supply chain management in timber supply chain. In this context trust is viewed as relational factor between trading partners. Benefits derive from sharing information and knowledge (opposite of pursuing competing interests). Available trusted information gives less motivation to engage in contra-productive measures. The challenge is to detect unreliable activities through data received and have structured systems to support those actors who operate adequately.

SCM element	
Trust	
What is it	**What is its purpose**
Safe and fair trade between supply chain actors	Provide incentives to share cruital decision-making information
Why is it important	**What is the challenge**
Create market opportunities and mitigate opportunistic behaviour	Systematically capture untrusted data and asymmetric information

Table 11 - Trust in supply chains

Table 12 represents our interpretation of cost-efficiency as an element of supply chain management in timber supply chain, here defined as a strategy to reduce costs and allocate resources accordingly while doing business across supply chain. Finding ways to improve business processes is essential but difficult to fully achieve across whole supply chain. To reduce costs, companies must reduce risks associated with buying and selling. ERP systems are useful to optimize internal processes and to interconnect important information between

actors. Despite of that, they are rather dyadic in nature, acting as information silos when put in the context as a complete supply chain, only allowing buyer and supplier to communicate and share data based on their agreements. Other tools must be applied to connect and integrate trading partners but due to high costs and efforts it requires, only those closest are fully integrated (e.g., using same ERP systems), which reduces the potential benefits with overall performance in mind.

SCM element	
Cost-efficiency	
What is it	**What is its purpose**
A strategy to reduce costs and efficiently allocate resources	Reduce costs of doing business across supply chains
Why is it important	**What is the challenge**
To improve business performance	Have effective measures and digital tools to optimize whole supply chain

Table 12 - Cost efficiency in supply chains

6.2 Step 2 – Blockchain capabilities

Through literature case findings we have seen that blockchain has capabilities to address issues related to transparency in the timber industry. Some of these key findings are represented in table 13. Blockchain can be applied to capture all information of activities related to upstream woodcutting, logging, transportation etc., before it reaches a utilizer of raw material. This would in turn help detect all irregularities that if known would not be accepted by the focal firm, as well as those irregularities that do not comply with legal requirements. When everything is recorded by the same system and available to all supply chain actors, it would give less incentives to engage in illegitimate activities such as concealing unethical practices. When providing one common system, supply chain works connectedly through effective and secure information sharing. This yields several potential benefits related to all other supply chain performance elements.

	Blockchain transparency capabilities		
	Implementation area	**Key achievements**	**Sc improvements**
Main Objective	Whole supply chain	Effective information sharing	Overcome information silos
Timber supply chain case (Ahmed & MacCarthy)	From harvesting to consumer of raw metrials	Capture all information and activities related to each actors involvement with raw material	Detect irregularities

Table 13 - Blockchain transparency related improvements

Blockchain system can solve issues related to traceability by allowing more information (compared to dealing with limited information and silo-effect) about the materials/products as they flow across supply chain. It has capabilities to integrate entire supply chain network into one safe data source which enables verifiable trail that can be efficiency retrieved. Table 14 provides more details about traceability improvement areas.

Infortracing is an example of such system within timber industry where tags and other tools are used to record information at each step of supply chain. Material/product information can be recorded early by impregnating RFID devices into trees and logs, which allows automatic identification and data capture. Pre-harvesting data can be recorded and shared with demand side, such as quantity and quality of specific timber. System allows real time monitoring of location and condition (important when e.g., timber is being stored) which can be very useful when it comes to planning and coordinating production activities. From end consumer perspective, instant information about the purchase is available through QR-code from final product via smartphone.

Blockchain technology can be applied towards downstream supply chain in mind to ensure product authenticity of own products. This can be extremely important for those striving to innovate new products from timber raw material, which can capture new (global) markers. Blockchain can ensure that customers choose these products and e.g., not copycat products where proper processes have not been followed and trees have not been sustainability harvested.

	Blockchain traceability capabilities		
	Implementation area	**Key achievements**	**Sc improvements**
Main Objective	Across whole supply chain	Integrated seamless digital flow	Improved operational visibility
Timber supply chain case (Figorilli et al.)	From timber marking to end consumer (infotracing)	Incorporating tags and and other devices	Pre harvest knowledge Real time monitoring Consumer availability
Timber supply chain case (Ahmed & MacCarthy)	From producing user of raw material to end customer	Product authenticity	Increased product value and customer/end marked knowledge

Table 14 - Blockchain traceability capabilities

Blockchain can be turned into a timber solution that can combine governmental policies, ecolabel certification schemes, due diligence systems and commercial companies' sustainability practices. This can all function as one single, tamper-proof system designed to follow physical material/product for digital verification in global supply chain environment. Table 15 provides overview of these blockchain sustainability capabilities.
To make sure sustainability requirements are meet, its suggested that blockchain function as a system that reinforces use of certification schemes which can be devoted to the owner of the forest and digitally applied through blockchain. This would make it easy to verify source of the timber, no matter how many times it switches ownership along supply chain. Digitalized documentation on blockchain will make sure that illegally harvested timber does not enter or is bundled together with already certified timber in complex supply chains. It will make sure that origin of timber can be verified. This can in turn increase value of the products and help promote sustainable business models.

A whole blockchain based trading system can be created to incorporate all governmental and oversight agencies through smart contract function. This would support sustainable activities and provide a mechanism for consumers to enforce their sustainability demands.

	Blockchain sustainability capabilities		
	Implementation area	**Key achievements**	**Sc improvements**
Main Objective	Across whole supply chain	Incorporate external and compementary sustainability components	One global conglomerated trading system
Timber supply chain case (Komdeur & Ingenbleek	Early upstream (forest certification)	Issue and embedd a digital certificate	Verify timber source
Timber supply chain case (Nikolakis et al.)	Across whole supply chain (FVC)	Incorparate laws and regulations	Smart law based trading platform for timber

Table 15 - Blockchain sustainability capabilities

Blockchain can strengthen trust between actors in supply chain by providing a system that confirms every step of transaction during the trading activities. Uncomplete activities cannot be hidden, nor can processes be added without being somehow visible. This eliminates incentives to operate both illegitimately and inefficiently, and to share inaccurate-, duplicated- or modified data. Table 16 provides overview of blockchain trust capabilities.
Due to the trust it provides, it would be considered safe to source timber raw material from new global sources previously unavailable due to trust issues. This would allow wider range of raw materials to be procured. This can potentially drive product innovation and open up new market opportunities for those willing to evolve their product portfolio.

Blockchain can create a controlled trustworthy environment where digital tokens (e.g., fibercoins) can be developed to represent physical product amount that can be distributed to other supply chain members and be used to set a cap on available amount of resources. Such a solution captures any discrepancies in the balanced volume during the transactions towards customers.

	Blockchain trust capabilities		
	Implementation area	**Key achievements**	**Sc improvements**
Main Objective	Across whole supply chain	Transaction visibility	Trusty trading system infrastructure
Timber supply chain case (Düdder & Ross)	Global trade availability	Drive innovation	Responcible sourcing
Timber supply chain case (Ahmed & MacCarthy)	Specific supply chain platform	Use of industry specific asset (Fibercoin)	Trustworthy coordinated supply chain

Table 16 - Blockchain trust capabilities

Table 17 provides overview of blockchain cost-efficiency capabilities. With blockchain platform, supply chain actors are integrated into a single system for trading purposes where all essential information is visible. This can be used as objective to create incentives for better operational performance. There are high costs to verify information associated with flow of materials/products and all other tasks involved in ensuring compliance. Implementing blockchain technology doesn't necessarily imply removing intermediate actors, but due to system infrastructure there is less necessity to control activities that usually require a lot of resources. Blockchain can simplify these processes. For timber supply chains this means easier verification of raw materials between trading parties, less pressure on and from governmental regulators to engage in costly controlling activities and ensuring sustainability practices.

Acting as one common register for data exchange which allows transaction data visibility for supply chain partners, blockchain can optimize logistics execution time. These capabilities can reduce time, costs and risks of business operations, contributing towards business alignment. Through blockchain, partners have equal access to data, clear roles and responsibilities, and terms on which they can share risks, costs and rewards for improving supply chain performance. Discovered through preliminary literature review, its known that blockchain can be used to impose penalties when e.g., condition of raw materials are not meet. All these aspects increase incentives to deliver on time and according to quality parameters in order to receive expected payment.

	Blockchain cost-efficiency capabilities		
	Implementation area	**Key achievements**	**Sc improvements**
Main Objective	Across whole supply chain	Common data exchange platform	Reduce complexity, risks and costs
Timber supply chain case (Düdder & Ross)	Across whole supply chain	Simplify control processes	Reduce complience costs
Timber supply chain case (Figorilli et al.)	Across whole supply chain	Reduce transaction time Impose penalty	Reduce operational risks and costs

Table 17 - Blockchain cost-efficiency capabilities

6.3 Step 3 – Current system analysis

In this section we are providing an analysis of Norwegian timber supply chain system offerings through Skogdata and ERP. It is an extended system analysis based on case description section about VSYS systems and other findings. The aim here is to find out how current system offerings are dealing with the five performance elements. As mentioned, conventional ERP systems are utilized in conjunction with Skogdata systems via API´s, providing opportunities and constraints from a supply chain perspective. Figure 10 illustrates how Skogdata and ERP systems provide data trails throughout the supply chain. The process is usually initiated by the creation of a Purchase Order (PO) document, containing relevant information about the purchase. The document can be created using the VSYS Virkeshandel or ERP systems. The PO document initiates the physical process, starting with timber harvesting by a contractor. Data from the harvesting machine can then be transferred to one of Skogdata solutions, providing a transparent overview of the harvesting process. Further, the materials are eighter transported directly or stored temporarily before being measured. Data subject to material properties are collected on the measurement document provided by Skogdata and forms the basis for any further transactions. The measurement document, closely depicted in figure 11, is then distributed to relevant supply chain actors, functioning as the basis for invoicing and payment. Transportation of materials are documented on the delivery document, which is shared with relevant actors. As an example, data recorded include driver ID, routes and timestamps. This ensures that the delivery process is performed according to agreement.

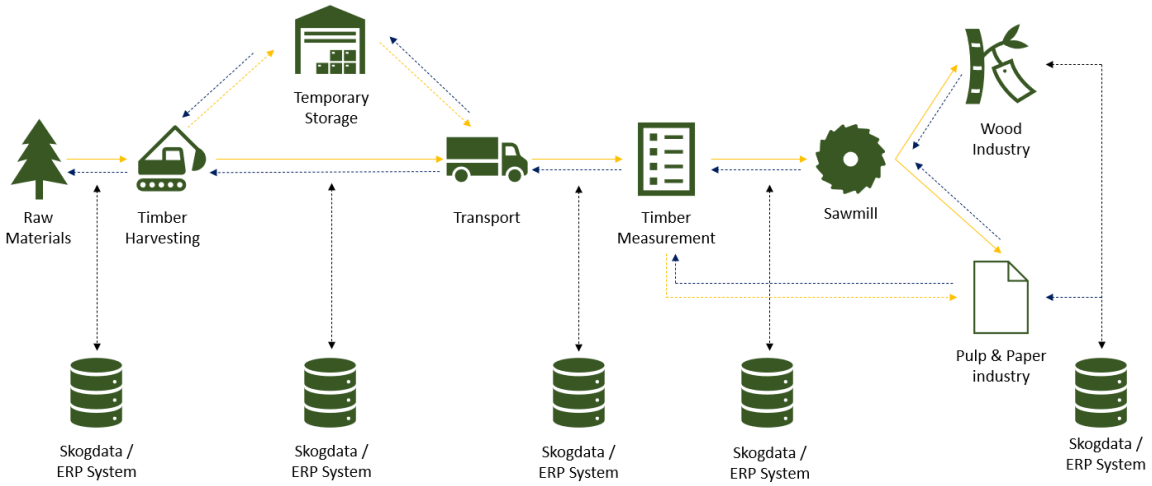

Figure 10 - Current system use in Norwegian timber industry

Upstream operators, such as timber traders, use Skogdata's measurement document for the purpose of collecting relevant data for the supply chain process. No financial compensation can be paid out under the current system before the materials are measured, validated, and delivered to the buyer. The data from participating supply chain actors is recorded on a single document and made available to all supply chain actors in order to ensure a transparent process, particularly in terms of the financial settlement. The document is also designed to accommodate revisions, as any alterations to the common measurement document would result in financial postings, thus making any changes visible to others. By using the measurement document as a tool to capture information and activities related to each actors involvement with raw material, it indicates a systematic approach to ensuring a transparent process for all parties involved.

Figure 11 - Measurement document applicability

To track the progress of materials along the supply chain, current systems combine a series of documents and application to connect physical goods with the information flow. This is illustrated in figure 12. Information is recorded at each point of movement. At early phases, information about- harvested volume, volume transported from forest to the road access point, stored amount at each point, volume under transportation, volume at the measuring stations, and amount measured is registered and known by Skogdatas systems. For further movement, past measuring activities, visibility depends on downstream actors practices and needs. Their requirements towards this are usually supported by their ERP system.

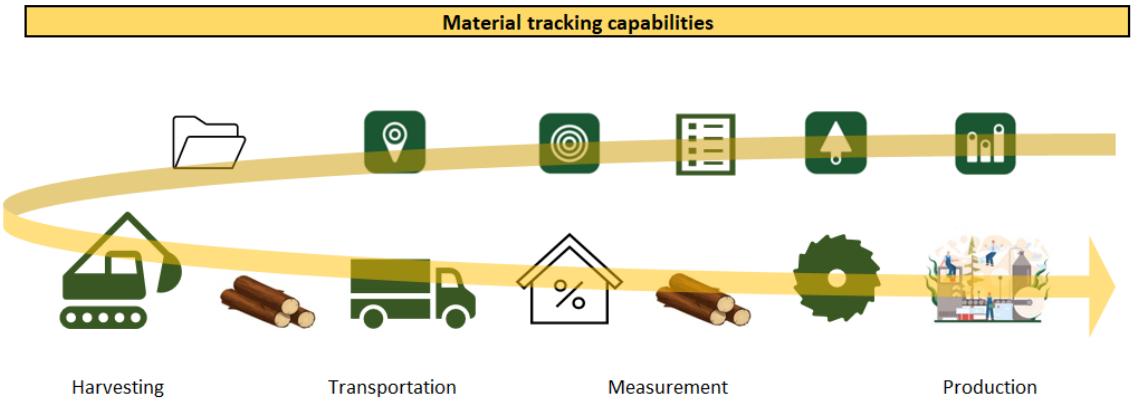

Figure 12 - Raw material tracking along Norwegian timber supply chain

Figure 13 illustrates how track and trace process can be enhanced by an ERP-system, in this case SAP S/4HANA as an example. Material documentation can be shared between supply chain participants. Before goods are transported to the next supply chain actor, relevant material information can be added to a Certification Record, thus providing details on material properties before shipment. The process continuous with transport before arriving at the goods receiver. When performing goods receipt, materials are checked against information on the Certification Record to ensure that materials fulfil requirements. The Certification record is updated by the receiver and can be reused in further business transactions. The objective of the certification function in SAP is to have a common solution where material properties can be communicated across supply chain links.

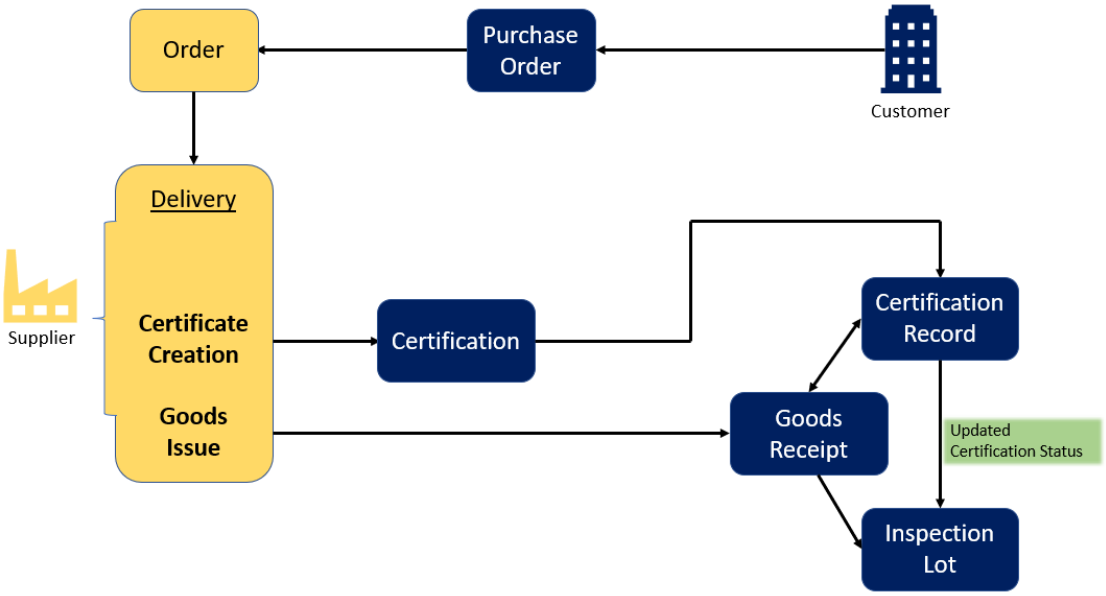

Figure 13 – ERP track and trace support through SAP

Raw material quality demands between timber trader and their buyer (e.g., sawmills) are defined through measuring specification. Quality parameters such as log length, diameter and accepted moisture levels are defined and forwarded to Norsk Virkesmåling for quality control before settlement occurs. Norsk Virkesmåling performs controls through taking various samples and judges the overall quality. When quality issues occur, it usually results in lower price classification. Moreover, these quality specifications are embedded in a file (called "apteringsfil") and forwarded to machine operators, which than have access to these data when performing the actual harvesting of the trees. Pulpwood and wood fuel have different quality requirements then logs, which cannot always be integrated into harvesting machines. These have to be inspected by whoever is defined as receiver by the trading agreement. Figure 14 depicts this procedure.

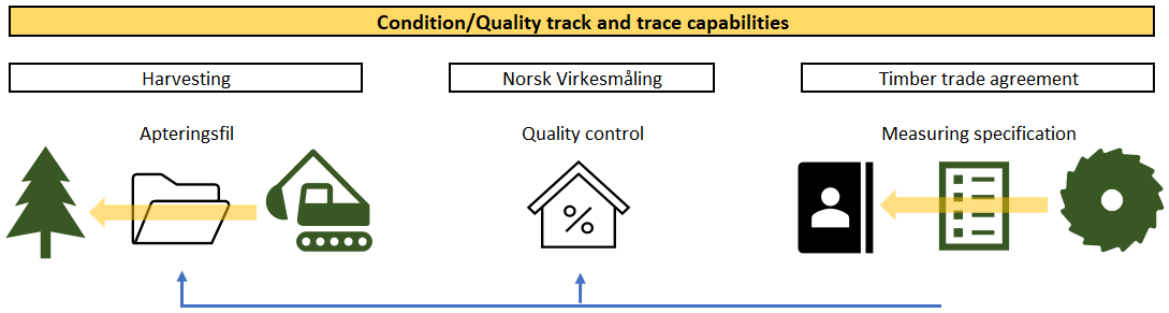

Figure 14 – Track and trace for material condition

Figure 15 briefly illustrates how certification scheme works in conjunction with forestry practices and trading process from a seller's perspective. When buying and selling PEFC certified materials, documentation with the following information is required for each delivery: (1) Supplier's name (2) Buyer's name (3) Product specification, (4) Delivered quantity, (5) Date/time for delivery (6) PEFC declaration and certificate number. Material documentation can be communicated in the form of invoice, delivery note or equivalent. Proof of valid PEFC certificate is verified on PEFC's website through the certificate number. Companies must have routines to document responsibilities and authorities, goods movements, and other processes necessary to comply with standards. ERP systems can be configured to comply with these regulations, where the invoice document is most commonly used. Several industry actors have configured invoicing templates in their ERP system that comply with these regulations, thus making the certification part of routing communication.

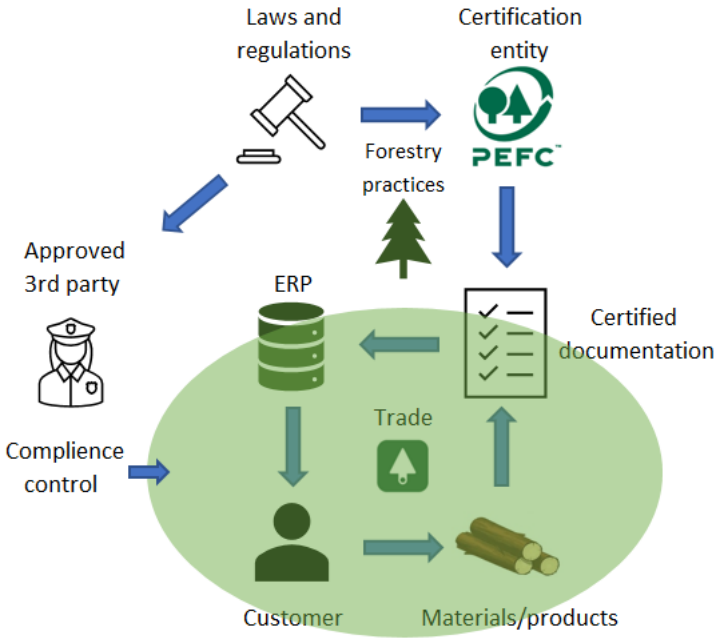

Figure 15 – Certification documentation trading process

6.4 Step 4 – Quantitative analysis

The objective of analyzing questionnaire data is to find the most relevant concerns that Norwegian downstream industry actors may have in regard to the five performance elements. Using descriptive statistics, the aim is to summarize the most important characterizes and provide ground for further discussion surrounding our research.

The average value (mean) of each question is presented in table 18. Highest values are marked/depicted, e.g., when it comes to transparency, question 3 is the one with highest average. This gives an indication whether a particular question is of concern from a collective perspective.

Transparency				Traceability			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1,36	1,50	2,00	1,36	2,14	1,79	2,79	2,07

Sustainability			
Q1	Q2	Q3	Q4
3,71	1,64	2,93	1,64

Trust				Cost-efficiency			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1,57	1,79	1,64	2,00	2,07	1,79	1,21	1,86

Table 18 - Average values results from questionnaire

Measurement of frequency or count indicates number of times an answer was chosen. Participants answered based on a Likert scale ranging from 1 to 5. Some answers occurred more than others, these are marked/depicted in table 19. As an example, participants chose score 1 twelve times (score 2 one time and score 5 one time) within question 1 about transparency issues.

Transparency				Traceability			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
12	10	6	10	5	8	3	3
1	2	4	3	5	2	5	8
0	1	3	1	2	3	0	2
0	1	0	0	1	1	4	1
1	0	1	0	1	0	2	0

Sustainability			
Q1	Q2	Q3	Q4
2	9	4	9
1	3	3	1
3	1	0	4
1	0	4	0
7	1	3	0

Trust				Cost-efficiency			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
10	8	8	6	5	8	12	8
2	3	3	5	5	3	1	2
0	1	3	1	3	1	1	2
2	2	0	1	0	2	0	2
0	0	0	1	1	0	0	0

Table 19 - Result range frequency from questionnaire

Measure of dispersion or variability indicate how much scattered the results are. In other words, how spread are the answers from the mean based on each question. It can tell us whether participants agree about the severity of an issue or not. Based on frequency analysis, we have already seen that 12 out of 14 participants picked score 1 when it comes to first question about transparency issues. This means that results are not highly spread as indicated by histogram in figure 11 and standard deviation (SD) outcome calculated. In comparison, we can see that question 3 about transparency shows that participants picked more divergent answers. This means that they don't agree about the severity of the issue, something we might need to take into account when discussing the results. In general, the larger the SD value, the more variability it is in the results. In this case, with narrow Likert scale range as basis, we find it equally sufficient to navigate results based on visual interpretation.

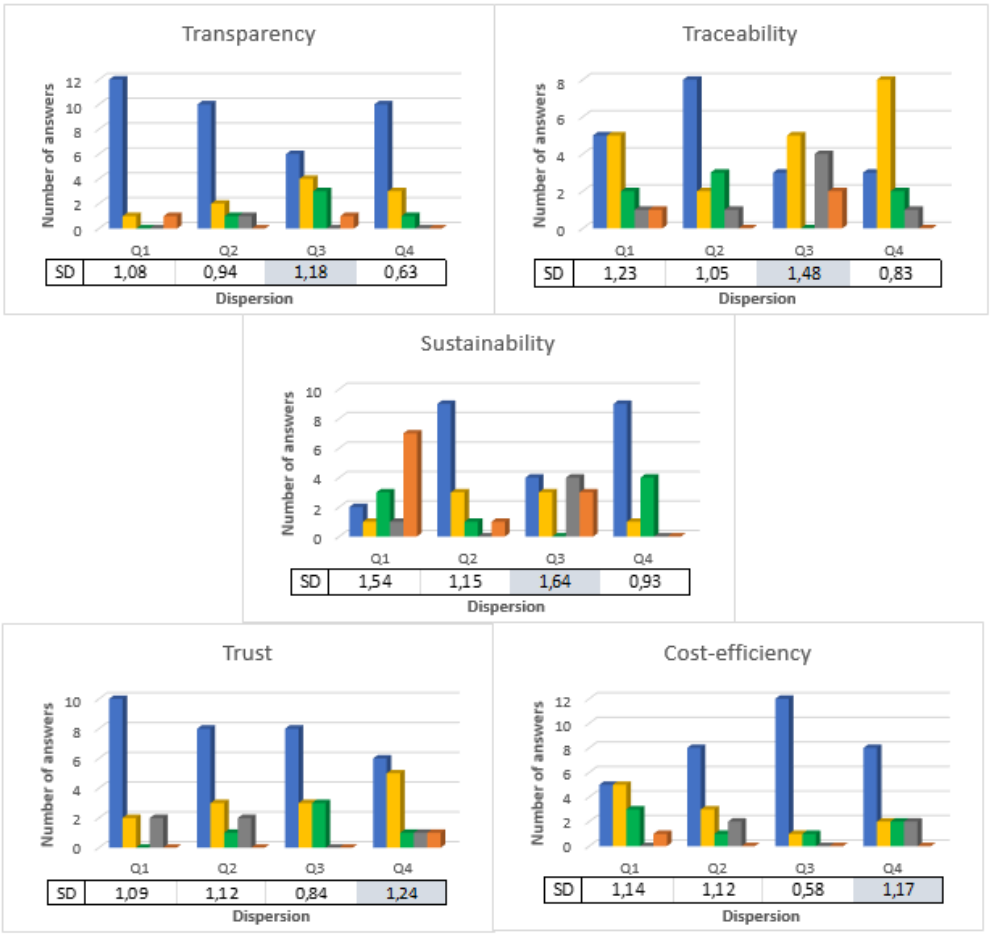

Figure 16 - Measure of variability

7.0 Discussion

We are starting the discussion section by asking: How does current systems satisfy supply chain transparency compared to what blockchain has to offer? This question is assumed asked for each element. By matching Skogdata's product portfolio with blockchain capabilities we can potentially discuss blockchain implementation need for the industry. To make valid arguments, this is supplemented with quantitative analysis results and other collected information presented throughout the thesis.

7.1 Transparency discussion

Timber trader is the actor who is in direct contact with the forest owner and selects operating providers (e.g., logging, transportation). This makes it the actor who has the most knowledge around early stages of the process, and the one who has most upstream visibility. It is moreover here that government imposes most of requirements towards sustainable forestry practices. It is up to timber trader to provide inputs of information that other downstream actors can rely on. Timber traders should have incentive to help support proper working conditions and likewise take responsibility that all guidelines are followed.

Skogdata provides visibility through measurement document. We argue that early information capture is a matter of trust, but the document itself provides necessary visibility as it further collects and shares information about activities involved. The highest average score concerning transparency results from questionnaire is 2,00. This indicated a low collective concern. Looking at Q3 answer, only one of the actors is severely concerned about their lack of routines for collecting, systematizing and sharing information. Even though the answers are somewhat dispersed, the majority don't consider this an alarming issue. As noticed while describing each actor, many of the timber traders provide extensive additional services to ensure all upstream activities are in compliance with laws and regulations. This is a sign indicating that the way industry structure is set up, a timber trader has a lot to gain by being transparent about their activities.

Further on, the measurement document ensures that alterations are not made due to financial settlements. The document has the necessary features to provide trusted visibility to its users. It is perhaps too far of a stretch to state that the document functions as a multi-tier information sharing system but it certainty cover main concerns such as having upstream information visibility and diminishing incentives to alter existing information. Blockchain

can solve transparency issues in a similar way, by capturing and securing information at each step of supply chain. In both cases the solution is to have one common system that can provide available information to all supply chain actors.

7.2 Traceability discussion

As defined in analysis step 1, traceability is about tracking movement of materials and its condition along the supply chain. This should ensure possibility to trace viable information about the materials/products when needed. Through current system analysis we have briefly illustrated that Skogdata's systems ensure information capture at each point of movement up to and including measurement activities. From there on the visibility depends between actors based on their supporting tools. Nevertheless, a transportation load that comes to the downstream industry should be possible to trace back to its origin if requested. As we understand, this is a feature of the system that is not fully utilized by all actors. Perhaps due to regulations (Matlovsforskriften-article-18, 2010), stating that every actor selects the delimitation of devices for tracking itself. Furthermore, this could be due to own willingness to invest in supporting ERP system applications or due to own supply chain circumstances and needs. The later we can say something about based on questionnaire results. With average score of 2,14, very few of the actors think they have a complex downstream supply chain and have worries about information loss. They seem to be satisfied with current system offerings based on question 2 about customer awareness surrounding product authenticity, as this has the lowest average score within traceability element.

Material traceability within the industry is further enhanced by quality measures specified through trading agreements and digitalized through Skogdata's systems. Material specifications are shared backwards towards harvesting activities. We argue that this helps prevent quality issues for actors in downstream part of the supply chain, as their expectations concerning materials are meet. This helps explain why actors are divided when it comes to need for material information in real time, as asked in question 3. Six out of fourteen actors would like to have real-time as a feature, while the rest don't find it necessary. On the other hand, actors do mostly agree that there is not lack of quality parameters in their supply chain based on results from question 4. We speculate that there could be some conditions individual actors would like to be able to fully obtain, such as exact humidity levels throughout the whole process, not only as a one-time measure currently available. Pulp and paper industry is growing due to sustainability investments and governmental support. As

new products are developed, new raw material concerns and requirements are expected to occur.

In the context of traceability, there are some differences between the systems where blockchain is potentially more superior. Blockchain can retrieve information much faster, while through current systems it is less manageable. It seems to require more effort as information is not found at one place. Both ERP- and Skogdata systems need to be used, while individual ERP traceability support varies. Moreover, with current systems we know that whole truck loads or batches can be traced back to its origin. From use cases we have seen that blockchain is used to track and trace individual trees, logs and products. However, blockchain itself don't have these features (Hultgren & Pajala, 2018), it is rather a platform where such information is made available by additional technology. This might depend on actors willingness to use these devices, such as RFID tags. Practically this creates more work as these have to be embedded into standing trees and then into individual logs. There has to be an incentive to engage in such efforts, but benefits are related to real time monitoring, something many of the downstream actors in Norwegian industry would prefer to have.

Current systems make sure that vital information is recorded, which somewhat prevents information loss. We see evidence that capabilities to have better visibility are there. It is perhaps not fully transformed into value adding customer information such as with blockchain. At this point we feel that blockchain as a system is able to utilize information towards end users in a more systematic way. Majority of customers concerning Pulp and paper industry are foreign. As new innovative products are developed, providing ways to experience instant evidence of product authenticity might become more important than currently.

7.3 Sustainability discussion

As found through PEFC description and illustration of certification documentation trading process, it is a complex procedure to ensure that origin of timber material/product are harvested and used in the supply chain according to laws and standards. Current practices help ensure sustainable business operations and preserve forests resources, which should ensure that every stakeholder involved is satisfied. Our findings suggests that industry is dependent on the certification practices and that majority have trust in this system. The formal, visible through Q1, with average score of 3,74, express this is indeed the dominant way to operate sustainably, while the later, visible through Q2, display that nine out of

fourteen actors selected score 1 when asked whether they need to second-guess current practices.

The benefit of current practices is that all trade activities are certified. This provides addition traceability capabilities to Norwegian timber actors, but has a different objective then already discussed traceability capabilities, that is to ensure sustainable practices and strengthen end customer trust. Based on later, actors are divided between eco-labelling needs in their supply chain as Q3 answers depict. However, actors highly agree that it is beneficial to evolve new business models with current practices as support, as analysed through Q4.

Many of the authors argue that current way of achieving sustainability has many weaknesses and reliability issues (Dieckmann, 2020; Düdder & Ross, 2017; Komdeur & Ingenbleek, 2021; Nikolakis et al., 2018). Documentation falsification is point out to be possible due to manual paperwork practices, as 3rd party is responsible for issuing certificates and does the auditing control to verify certification entities standards. This can certainly be a valid issue where weak law system does not support timber industry (Komdeur & Ingenbleek, 2021). As we understand, it is a prolong process to approve compliance control entities, while PEFC system is periodically reviewed both by government, separate entities, organisations and timber supply chain actors. It is difficult to analyse how compliance is performed through current systems, but with all mentioned activities in place, there should be less incentives to engage in forgery practices.

Some suggest that a whole new thinking and system is required (Düdder & Ross, 2017) to deal with current issues from global perspective. Ideally, blockchain would simplify, digitalize, embed, and connect businesses, laws and regulations, customers and other stakeholders into one sustainability compliance system. Some authors think certification bodies would become absent with a blockchain solution (Hultgren & Pajala, 2018), while others suggest blockchain as a way to strengthen certification process (Nikolakis et al., 2018) and help close gaps where forgery and other concerns are forceful (Komdeur & Ingenbleek, 2021). One of the more concrete suggestions is that blockchain can be used to connect forest parcel/land with sustainability certificate to in that way confirm true origin of timber materials/products. In Norway, many of the processes are or can be digitalized, such as forestry management plans that forest owner is responsible to provide in conjunction with being environmentally approved before harvesting can be initiated. Here, both timber traders and forest owner organisations support these activities and provide digital solutions that we believe can be connected together with Skogdata and/or PEFC.

7.4 Trust discussion

Skogdata's systems offer a trading platform for all actors where payment settlement comes at the end when all information is provided, all activities conducted, and raw materials delivered to final user. Agreements are supported by measuring and quality control, which should solve any disputes concerning value of raw materials. This indicates safe and fair structure. Looking at Q2 answers concerning trust, very few actors feel it is uneven power balance which makes them pay higher raw material prices. Actors in timber supply chain can therefore focus on optimizing other aspects of their business, such as strengthen their relationship with other actors. In turn this can result in more information sharing and improved decision making. When asked about trust surrounded information sharing and data received, results show that there is a high degree of trust. Here Q3 answers are at average score of 1,64 and low dispersity of 0,84 as none of the actors picked score 4 or 5. This is promising but if irregular information sharing does occur, it's important to be able to detect that. Here, looking at Q4 answers, only few of the actors feel they don't have systems or tools to do that, but majority feel their systems should be able to capture irregular data.

Some actors might aim to reach or expanding into new or global markets. For that they might need to diversify their raw material input to produce products that can lead to new market opportunities. However, we don't see much evidence this is the case when looking at Q1 answers. With average score of 1,57, only two out of fourteen actors find this being an issue. They seem to be happy with raw material selection currently available.

Blockchain offer capabilities that can create trusty environment where it does not exist. Norwegian timber industry operates as one common entity and has the structure in place to accommodate safe and fair national trading. Blockchain on the other hand opens up for safe and fair global trade, which is a major difference. It can be individually adjusted to each industry with use of specific tokens and control amount of resources as a cap-and-trade system usually used by governments.

7.5 Cost-efficiency discussion

We defined cost-efficiency as a strategic approach, expected achieved as a collaborative effort. Rather than working in silos, business performance is pursued collectively. It is in this was true benefits can be achieved. Norwegian timber industry is a great example of such undertaking as it facilitates towards creating synergies. With 1,86 average score in Q4,

majority of actors are satisfied with cost reducing efforts industry as a whole is capable of providing. With somewhat dispersed answers, it could mean that there is room for improvement. However, few actors have issues with transaction time while doing business with their supply chain members as Q2 answers indicate. This is somewhat expected due to now known industry systems and structures in place. Moreover, it is clear that very few of the actors seems to have a need to engage intermediaries to control supply chain activities that are not visible to them, as depicted through Q3.

Blockchain cost-efficiency capabilities is one of its greatest strengths if applied as one common exchange platform. Potentially this can transform how businesses are conducting transactions with each other. Simply, it reduces complexity, risks and costs of every actor involved. Every aspect of trading can be improved, here mostly concerning financial, logistical and relational challenges. In Norwegian timber industry, material delivery is successful from several perspectives. Digital tools are in place to accommodate the physical flow, its information flow is commonly accessible while the financial outcome is visible. This is highly comparable to blockchain objectives. Blockchain might impose penalties to individual actors to ensure delivery conditions which can have its usage in certain situations. We didn't find evidence of such practices in Norwegian timber industry other than lower value achieved when material quality is not meet. Perhaps its usage area would be towards element of transparency in conjunction with newly initiated (Transparency-Act, 2022).

8.0 Conclusion

In this section we are addressing research questions and giving our opinion around research-limitations, implications, and recommendations. As part of the embedded research method, we are firstly examining sub questions before addressing the main question.

SubQ1: *How can blockchain contribute to improve performance of Norwegian timber supply chain?*

Blockchain capabilities have been closely investigated through literature review and case analysis using five supply chain performance elements as a basis. Findings were discussed in comparison with how current systems support Norwegian timber supply chain. As Skogdata's representatives pointed out, Norway is one of the few countries that have one common integrated logistics system between forest owners and downstream production industry. Available raw material selection and efforts to develop own production gives less incentive to import materials from alternative sources. This currently diminishes the scope of potential use area for blockchain within the industry as there are less issues to resolve.

SubQ2: *What are the most valid supply chain elements of concern that can be considered improved?*

Our findings suggest that industry don't have significant struggles to immediately have to deal with, based on analysis of five elements of supply chain performance. Downstream industry results show consistently low average questionnaire score. Collectively, including all five elements we have calculated an average score below 2. The two highest scores occurred within the sustainability element. A simplified analysis was conducted to better understand issues around certification and circumstances of actors involved to execute this process. It is indeed a complex undertaking to provide proof of origin through ecolabeling/environmental certification to downstream actors and further towards end consumers. Our findings suggest that actors trust the system but are divided between its functionality. We support the possibility to digitally connect forest management plans with raw materials to further enhance validity of sustainability claims towards end user. Another answer splitting the respondents is related to raw material traceability and real-time monitoring. Due to the strength of the system as seen through the analysis, its less demand to apply this feature. This diminishes idea concerning using RFID tags on individual logs as many of authors investigate possibility towards.

Main RQ: *What are the underlying circumstances that might determine blockchain implementation in the Norwegian timber industry?*

As we speculated at early stages, much depends on the industry needs, surrounding the issues with supply chain performance. Solutions are developed to cover a specific need. Users are concerned with functionalities, rather than the technology itself. Blockchain potential can be discovered and requested explored by any actor in relation to Skogdata due to ownership profile. Likewise in relation to any collaborative effort between individual companies and supporting organisations, such as long-term projects. Even though there is currently not enough internal knowledge within Skogdata to implement blockchain technology, it is not dismissed as a possible solution. However, our findings based on sub-research questions suggest diminished possibility towards blockchain implementation. Norwegian timber industry has existing solutions to cover their supply chain performance needs, where Skogdata is concerned with developing and improving existing solutions. However, there could be future needs that can require blockchain as a supplementary solution. These can be related to sustainability deriving from end-user needs and certification entities efforts.

8.1 Limitations

During the research we didn't have system access to Skogdata's product portfolio. This is a limitation from practical perspective. We had to satisfy these needs with publicly available information. Similarly, to include work on the technological feasibility of deploying blockchain within the industry would require system architecture at supply chain level, which would yield more accurate comparison. However, we can confirm that we didn't make any assumptions during system analysis. On the other hand, some of the processes analysed might be simplified due to lack of information. Some factors might be imperfectly presented or arise some technical questions, but all information used surrounding Skogdata's systems is either publicly available or confirmed/explained by Skogdata's representatives during the semi structured interview.

We initially experienced low response rate to the questionnaire, which initiated more measures towards collecting sufficient amount of answers. It turned out to be a prolong process which resulted in time constraints towards other aspects of the thesis. Majority of the respondents were positive towards contributing, proceeding into long conversations and often physical visits requiring long trips.

Our method of conducting literature reviews didn't result in what we consider optimal outcome, giving us limited context in relation to Norwegian timber industry. This might have affected area of focus related to supply chain performance.

8.2 Practical implications

This thesis is not restricted by any agreements, and can therefore to accessed after approval, which provides up to date information for those interested in the topic. It provides useful information surrounding how Skogdata operates, make decisions and other details about their role in the industry. It also contains their thought on blockchain and use of technology in general. Currently there are knowledge and capacity limitations towards blockchain, both as a technology and what it can provide to the industry. Our thesis is somewhat filling this gap and provides some insights about its opportunities and capabilities in Norwegian timber supply chain setting. In general, our work can contribute towards those doing research within topic of timber industry and blockchain. Further it provides useful information towards those doing research on blockchain with implementation prototypes and require detailed practical information to conduct their procedures. Transcribed interview information might interest those working in the industry or academics that are not able to gain direct information from Skogdata concerning the topic.

8.3 Research recommendations

As discovered during the semi structed interview, there are industry collaborative projects dealing with type of concern we are investigating. Ongoing long term project mentioned by the participants turns out to be an initiative to bring Industry 4.0 tech and tools to enhance overall digital information flow in the sector (*SFI: SmartForest*, 2020). This is a confirmation that our research topic is up to date with what industry is dealing with. We recommend further research to be conducted that can help pinpoint exact use area of blockchain in the industry. This thesis can function as a basis for that or help develop perception and generate idea surrounding that aspect. Further, appendix section contains complete questionnaire and available results in the analysis section. These can be used for further analysis or to create a basis for conceptional framework with hypothesis testing.

It could be beneficial to additionally evaluate specific supply chains within the timber industry and their information systems in conjunction with Skogdata's solutions. It would further contribute to evaluate suitability of implementing efforts. As research have unveiled,

Skogdata solutions are built on Microsoft Platform. Research should therefore investigate specific blockchain solutions, compatible with Microsoft solutions and incorporate capabilities of available Industry 4.0 tools.

9.0 References

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10.0 Appendix

Semi structured interview questions and answers (Skogdata AS):

Main topic: Under what circumstances can blockchain be implemented in the Norwegian timber industry?
Q1 - How are supply chain challenges mapped in regards to industry needs?
Q2 - How is it determined what kind of underlying technology its relevant to use/start using?
Q3 - How much influence do the actors in the downstream industry have when it comes to choosing technology and solutions?
Q4 - Do you provide different solutions for the pulp and paper industry and different solution for wood industry?
Q5 - Which factors can have the most influence when it comes to the use or implementation of new technology?

Question#1: How are supply chain challenges mapped in regard to industry needs?

Participants were asking for specific examples for us to provide in order to address this question. We talked about transparency, tracing, and quality issues, referring to those applied in the questionnaire. We ended up asking several sub-questions when providing examples with various perspectives. Some of these were: "What happens when an important actor has a need or a problem they want to address?" "How do you detect issues actors have" and "What happens when an actor wants to prevent a reoccurring issue?".

Answer#1: *"We believe that many of the problems can be captured with the current system. Some problems can be detected through Norsk virkesmåling, such as when addressing quality issues that are specified in the contract between buyer and seller.*

Participants provided another comment related to quality issues by stating that:

"The harvesting machines capture a lot of quality data related to the logs. The potential to use such data when needed is there."

Some problems and topics are known, while others might remain undiscovered. Participants explain that:

"Other issues can be detected through research projects. One of them is an ongoing long-term project that will last for another 7 years, which certainly has the potential to address/discover new upcoming issues as those brough up by you. "

During our discussion it came up that there are some improvements being applied to the system:

"We are currently working on modernizing measurement systems, which we are going to spend couple of years on improving. We suspect that topics and issues we are discussing here might come up during this work, but it's hard to imagine to which extend."

Question#2: How is it determined what kind of underlying technology its relevant to use/start using?

The thinking behind this question is to gain an understanding how company operates and make decision about the underlying technology that sets a premise for their product portfolio. These answers might say something about what it would take to implement or consider implementing blockchain technology.

Answers#2: *"When it comes to underlying technology, today we have four main products but at the same time forty other small systems. Vi are using technology we feel is the most appropriate but at the same time keeping in mind the competence we have here at Skogdata. We have limited number of employees such as technologists and developers. For them to be collaborated and work across multiple areas, it's important that we don't take inn to many variations of technologies. We have standardized platforms we use and develop."*

After some discussion concerning type of application areas, participants confirm that users of Skogdata's products have influence when it comes to potential blockchain use:

"We are owned by the same timber industry actors that use our products. We don't operate completely freely when it comes to this type of decision making."

Later it was added that:
"When it comes to decision making, we have a roadmap for our projects. It follows a sequential order where these are board-level approved, thereby including actors of the timber industry in the decision-making process."

Question#3: How much influence do the actors in the downstream industry have when it comes to choosing technology and solutions?

This question was partly answered when discussing question #2, but participants were still asked to elaborate and provide more thoughts surrounding this question.

Answer#3: *"It depends whether we are talking about platforms or functionalities. They (customers/users) have influence when it comes to solutions, while they are not that concerned about the technology itself. Solutions must cover a specific need. "*
Its further explained that:

"The choice for technology is a principal choice made long time ago, its not something that is considered in a day-to-day operation."

Question#4: Do you provide different solutions for the pulp and paper industry and different solution for wood industry?

We asked this question to understand the present level of system customization which can be critical in determining whether supply chain actors require specialized solutions for their business processes.

Answer#4: *"Mainly we offer standardized products delivered across various solutions. In the example of VSYS Virkeshandel, there is one product but more than 30 different users. It's important that we don't customize too much as then we would lose control. "*

Its further added that:
"Keeping this in mind, the applications might be a 100% fit for some and 95% for others perhaps."

One of the most important aspects concerning demands from the users seems to be that:

"The applications that we deliver to our customers need to be integrate with their systems, which is a demand from their side."

Question#5: Which factors can have the most influence when it comes to the use or implementation of new technology?

Besides own capacity and competence participant point out that they are not dismissing blockchain technology, stating that:

Answer#5: *"If we get a requirement to use it or a need occurs, and this seems reasonable, we will certainly look into blockchain as potential solution"*

When asked if such demand has occurred so far, i.e., if any of the actors has asked about blockchain the answer was that:

"This has not occurred yet, and we don't know much about blockchain or its capabilities. The first thing that comes to mind is verification of transactions (economical). We didn't think it could be applied in a supply chain setting"

After further discussion surrounding blockchain potential and its area of usage, participants pointed out that:

"When it comes to timber industries from a global perspective, Norway and Sweden are the only countries that have one common integrated logistics system between forest owners and downstream production industry."

Questionnaire for downstream timber supply chain actors:

Transparency

We have concerns about transparency in connection with upstream actors. The concerns are related to the suppliers' working conditions, ethical guidelines and social responsibility, as we suspect that malicious conditions are taking place behind the scenes. *

Verdi

We lack an overview of actors, activities and processes that are carried out before the raw materials arrive at our facilities. *

Verdi

We lack routines for collecting, systematizing and sharing information (which includes supply chain activities) with both internal and external actors. This information has a big impact on their decisions to buy, invest or have a relationship with our company. *

Verdi

We are constantly experiencing conflicts with our suppliers or customers who require the intervention of third parties to find a solution (e.g. quality claims, disputes, delivery and payment) *

Verdi

Traceability

We have a complex/obscured downstream supply chain with high fluctuations in demand, which means that important information about our products disappears after they have been sold. *

Verdi

We lack good systems that can effectively ensure that our customers are aware that our products are innovative from an environmentally friendly perspective. *

Verdi

We have a high need for early information about the condition of the raw material in real time in order to be able to streamline our own production and similar activities/processes. *

Verdi

We lack quality parameters (e.g., timber humidity and stored temperature) that upstream actors can use to capture information related to the condition of the raw material/products and share this with us *

Verdi

Sustainability

We only use environmentally certified suppliers of timber/wood products as this is the only way we can ensure that we achieve our sustainability goals. *

Verdi

We need to double-check details about the certification process associated with timber origin as we constantly suspect or become aware that there have been incorrectly documented cases. *

Verdi

We advertise for sustainability using eco-labelling of products we produce ourselves through "eco-labelling/environmental certification" because this is the only way our customers recognize that our products are law-abiding, environmentally and socially sustainable. *

Verdi

It is not advantageous to invest in a circular economy or similar business model as it is difficult to achieve benefits with current practice. *

Verdi

Trust

We cannot acquire timber products that really meet our needs as these are not available through national markets or through credible global markets. *

Verdi

It is uneven trust and distribution of power in the market that makes us pay higher prices for timber raw materials than our competitors. *

Verdi

We do not trust data and information we receive from other actors. *

Verdi

We lack systems that capture and confirm irregular data. *

Verdi

Cost-efficiency

We have high costs due to high risks in the supply chain. *

Verdi

We are dissatisfied with and unable to reduce the transaction time (long payment, coordination and delivery time) with our supply chain actors. *

Verdi

We use intermediary actors on our own initiative (for example, external companies that control upstream activities) to reduce supply risk. *

Verdi

Our industry is poorly coordinated (through common organizations and industry standards), poorly supported by laws/regulations and poorly optimized through partnerships. We are not happy with the availability of cost-cutting initiatives these create. *

Verdi