Blockchain for Interorganizational Collaboration: Findings from the Wind Turbine Industry

PhD dissertation

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Executive Summary

Blockchain has garnered much hype since its invention, but here more than ten years past its invention, there is still a very limited application of it in organizations. One of the primary challenges that are associated with introducing blockchain into business settings is the fact that the technology requires a large part of the ecosystem to take part in it, in order for it to be truly valuable. In other words, interorganizational collaboration has a huge impact on the success of blockchain. Regardless of this, collaboration holds a quite limited space in blockchain literature despite the apparent awareness of the importance for blockchain success as it typically only addressed indirectly when commented on.

This PhD therefore seeks to advance the knowledge and literature on blockchain-based interorganizational collaboration. The research takes its offset in Operations and Supply Chain Management literature as well Technology Innovation Management research, as these are fields that addresses interorganizational collaboration quite commonly even if it is typically only indirect.

Methodically, this paper subscribes to a philosophy in the mix of interpretivism and pragmatism and generally makes use of inductive reasoning throughout the research. The PhD is heavily influenced by an Action Research-driven single case study, which takes its industrial setting in the wind turbine industry. Through qualitative data collection methods such as semi-structured interviews and workshops the author gathers primary data to build up knowledge, that in addition to advancing this research, is also used to help develop the UnWind-project's blockchain-based Fastener-case. In this project, the author actively participates in the development of a blockchain solution based on lifecycle traceability for commodity components in the wind industry, thus contributing not only academically, but also to practically to the advancement of blockchain and interorganizational collaboration.

In this dissertation, three themes and papers researched throughout the PhD-period is included as the main work and findings that contribute to answer the research question: *How does blockchain-enabled information-sharing affect interorganizational collaboration?* The first two themes seeks to understand blockchain's impact on specific types of interorganizational collaboration, respectively vertical and horizontal collaboration. Vertical collaboration is essentially supply chain management where the focal organization collaborates with suppliers and customers to improve the supply chain they are part of. This first theme focus specifically on the role of trust in information-sharing for supply chain management. The second theme focus on horizontal collaboration and more specifically on coopetition, i.e. the simultaneous act of competition and cooperation, where two or more organization at the same tier in the supply chain chooses to work together for a common goal despite normally being in direct competition with each other.

Finally, the third paper focus on one of the business opportunities blockchain and interorganizational collaboration enables through increased information-sharing and closer integration transparent, namely servitization. Servitization, which is the transformation manufacturing companies may go through to become more focused on service activities, is something that is heavily reliant on information-sharing and collaboration across organizational bounds as services cannot be properly provided without engagement with customers and other actors in the ecosystem.

As this PhD is constructed utilizing the paper-based model for a PhD-dissertation, abstract for the content of each of the three included research papers already exist and as such, the next three paragraphs are taken directly from the three papers included in this thesis. The references for the abstract can be found in the beginning of chapter 4-6, where the rest of the three research papers are included in their full length.

Theme 1: Blockchain for vertical collaboration:

The purpose of this paper is to gain an understanding of the practicality in using blockchain to share information across organizational boundaries. Previous research has shown trust plays an essential role in information-sharing, but this is not evident in current blockchain literature, which this paper seeks to change. First, the importance of trust in information-sharing is presented by summarizing current literature´s take on the role of trust in information-sharing activities in the supply chain through which an analytical framework is presented. Following this methods used for acquiring the primary data from the wind industry, the secondary data from blockchain literature and the method used for analyzing said data through thematic analysis are explained. The empirical case of the wind industry is then presented and analyzed by presenting the identified themes of 1) product update handling and master data; 2) transparency and traceability; and 3) collaboration. The trust framework presented in the theoretical background is then used to analyze the contents of the themes and the wind case. This leads to the first set findings for the paper; for supply chain-based blockchain to be successful trust must be a pre-requisite for the involved parties, but in addition blockchain also facilitates trust through information-sharing, thus making trust and outcome of blockchain as well. Finally, the paper discusses how blockchain currently ties to operational interactions and not those related to tactical or strategic interactions.

Theme 2: Blockchain for horizontal collaboration:

The paradoxal nature of competitors collaborating known as coopetition, is a phenomenon of increasing importance in a world that is becoming progressively integrated through digitalization. This paper is among the first to explore the potential opportunities and limitations of blockchain as an enabler of coopetition. The distributed nature and cryptographic capabilities of the blockchain challenges the dichotomous view of coopetition – collaborate or do not collaborate – through its technological flexibility in regards to information-accessibility. The paper focuses on the empirical setting of the wind turbine industry, in which a multilateral instance of coopetition is taking place with five turbine manufacturers and eleven first tier suppliers being involved in developing new standards for the industry. Limiting factors for coopetition and blockchain are found to be based in social contexts such as competence- and integrity-based trust and in legal context with competition laws hindering the extent to which coopetition can occur.

Theme 3: Blockchain-based interorganizational collaboration for servitization:

The qualities of the blockchain technology as a means to enhance the traceability throughout the value chain have implications for manufacturing firms to provide services with higher accuracy for other actors within the same value chain. However, the implications of blockchain technology within a broader set of actors in the value chain remain scarcely researched. From a single case study of a blockchain solution within the wind industry, this paper seeks to contribute to the existing body of literature. It presents theoretical and practical implications of moving beyond the immediate value chain dyads and inclusion of the temporal perspective on blockchain technology. One of the most prominent opportunities blockchain seem to offer relates to information-sharing across organizational bounds in non-compete areas of the larger ecosystem's activities. This is exemplified in the article with thorough empirical evidence on how service may be improved for commodity components by enabling a more open approach to sharing lifecycle events on the commodities in the value chain.

Danish Summary

Blockchain har været genstand for stor opmærksomhed siden sin opfindelse, men her mere end ti år efter er der stadig kun en meget begrænset anvendelse af den i organisationer. En af de primære udfordringer, der er forbundet med at indføre blockchain i forretningsmiljøer, er det faktum, at teknologien kræver, at en stor del af økosystemet tager teknologien til sig, for at den virkelig kan få værdi. Med andre ord har samarbejde mellem organisationer en stor betydning for blockchain-teknologiens succes. På trods af dette har samarbejde en ret begrænset plads i blockchain-litteraturen, selvom der tilsyneladende er en bevidsthed om betydningen af samarbejde mellem virksomheder for at opnå succes med blockchain.

Denne PhD søger derfor at fremme viden og litteratur om blockchain-baseret interorganisatorisk samarbejde. Forskningen tager udgangspunkt i litteraturen om Operations and Supply Chain Management samt forskning i Technology Innovation Management, da det er områder, der ofte omtaler interorganisatorisk samarbejde, omend det typisk kun er indirekte.

Metodisk benytter denne afhandling sig af en filosofisk blanding af interpretivisme og pragmatisme og gør brug af induktive logik gennem forskningen. PhD'en er stærkt præget af ét Action Research-baseret single casestudie, som tager sit industrielle udspring fra vindmølleindustrien. Gennem kvalitative dataindsamlingsmetoder såsom semistrukturerede interviews og workshops indsamles primær data for at opbygge viden, som ud over at fremme forskning også bruges til at hjælpe med at udvikle UnWind-projektets blockchain-baserede Fastener-case. I dette projekt deltager forfatteren aktivt i udviklingen af en blockchain-løsning baseret på livscyklus-sporbarhed for standardkomponenter i vindindustrien, og bidrager dermed ikke kun akademisk, men også praktisk til at fremme viden og brug af blockchain og interorganisatorisk samarbejde.

Afhandlingen består af tre temaer og dertilhørende artikler, der er udarbejdet i løbet af PhD'en, og repræsenterer det mest indflydelsesrige forskning til at besvare forskningsspørgsmålet: *Hvordan påvirker blockchain-baseret informationsdeling interorganisatorisk samarbejde*? De to første temaer søger at opnå forståelse for blockchains indflydelse på specifikke typer af interorganisatorisk samarbejde, henholdsvis vertikalt og horisontalt samarbejde. Vertikalt samarbejde referer hovedsagelig til styring af forsyningskæder, hvor den fokale virksomhed samarbejder med leverandører og kunder for at forbedre deres fælles forsyningskæde. Det første tema fokuserer specifikt på den rolle, som tillid spiller for informationsdeling i forbindelse med forvaltning af forsyningskæden. Det andet tema fokuserer på horisontalt samarbejde og mere specifikt på coopetition, dvs. sideløbende samtidige konkurrence og samarbejde to eller flere organisationer imellem. Mere specifikt når to eller flere virksomheder på samme niveau i forsyningskæden vælger at arbejde sammen om et fælles mål, selv om de normalt er i direkte konkurrence med hinanden.

Den tredje artikel fokuserer på en af de forretningsmuligheder, som blockchain og interorganisatorisk samarbejde muliggøre gennem øget informationsdeling og tættere integration, nemlig servitization. Servitization, som er den transformation, som produktionsvirksomheder kan gennemgå for at blive mere fokuseret på serviceaktiviteter, er noget, der er stærkt afhængig af informationsdeling og samarbejde på tværs af organisatoriske grænser, da service ikke kan identificeres og leveres uden involvering af kunder og andre aktører i økosystemet.

Da denne ph.d.-afhandling er bygget op ad en samling af artikler, findes der allerede et resumé af indholdet af hver af de tre inkluderede forskningsartikler, og de næste tre afsnit er derfor taget direkte fra de tre artikler, der indgår i denne afhandling. Referencerne til resuméet findes i begyndelsen af kapitel 4-6, hvor resten af de tre forskningsartikler er indsat i deres fulde længde.

Tema 1: Blockchain til vertikalt samarbejde:

Formålet med denne artikel er at få en forståelse af det praktiske i at bruge blockchain til at dele information på tværs af organisatoriske grænser. Tidligere forskning har vist, at tillid spiller en væsentlig rolle i informationsdeling, men dette er ikke tydeligt i den nuværende blockchain-litteratur, hvilket dette papir søger at ændre. Først præsenteres betydningen af tillid i informationsdeling ved at opsummere den nuværende litteraturs opfattelse af tillidens rolle i informationsdelingsaktiviteter i forsyningskæden, hvormed der præsenteres en analytisk ramme. Herefter forklares de metoder, der er anvendt til at indhente de primære data fra vindindustrien, de sekundære data fra blockchain-litteraturen og den metode, der er anvendt til at analysere disse data gennem tematisk analyse. Derefter præsenteres og analyseres den empiriske case fra vindindustrien ved at præsentere de identificerede temaer 1) håndtering af produktopdatering og stamdata, 2) gennemsigtighed og sporbarhed og 3) samarbejde. Den tillidsramme, der er præsenteret i den teoretiske baggrund, anvendes derefter til at analysere indholdet af temaerne og vindmøllecasen. Dette fører til det første sæt resultater for artiklen; for at forsyningskædebaseret blockchain kan blive en succes, skal tillid være en forudsætning for de involverede parter, men derudover letter blockchain også tillid gennem informationsdeling, hvilket gør at tillid også er et resultatet af brugen af blockchain. Endelig diskuteres det i artiklen, hvordan blockchain i øjeblikket er knyttet til operationelle interaktioner og ikke til taktiske eller strategiske interaktioner.

Tema 2: Blockchain til horisontalt samarbejde:

Den paradoksale karakter af konkurrenters samarbejde, kendt som coopetition, er et fænomen af stigende betydning i en verden, der bliver mere og mere integreret gennem digitalisering. Denne artikel er blandt de første til at undersøge de potentielle muligheder og begrænsninger ved blockchain som en katalysator for samarbejde. Blockchain's distribuerede karakter og kryptografiske muligheder udfordrer det dikotomiske syn på konkurrence – at samarbejde eller ikke at samarbejde - gennem dens teknologiske fleksibilitet med hensyn til adgang til information. Artiklen fokuserer på den empiriske situation i vindmølleindustrien, hvor der foregår en multilateral konkurrence med fem vindmølleproducenter og elleve first tier leverandører, som er involveret i udviklingen af nye standarder for industrien. Begrænsende faktorer for samarbejde og blockchain ligger i sociale elementer såsom kompetence- og integritetsbaseret tillid og på juridiske sammenhænge med konkurrencelovgivning, der hindrer, at samarbejde kan finde sted i et vist omfang.

Tema 3: Blockchain-baseret interorganisatorisk samarbejde med henblik på servicering:

Blockchain-teknologiens kvaliteter som et middel til at forbedre sporbarheden i hele værdikæden har konsekvenser for produktionsvirksomheder, der kan levere tjenester med større nøjagtighed til andre aktører inden for samme værdikæde. Der er imidlertid kun få undersøgelser af konsekvenserne af blockchain-teknologien inden for et bredere sæt af aktører i værdikæden. Ud fra et single casestudie af en blockchain-løsning inden for vindmølleindustrien søger denne artikel at avancerer den eksisterende litteratur. Artiklen præsenterer de teoretiske og praktiske konsekvenser af at bevæge sig ud over de umiddelbare dyader i værdikæden og inddrage det tidsmæssige perspektiv på blockchain-teknologien. En af de mest iøjnefaldende muligheder blockchain synes at muliggøre, vedrører informationsdeling på tværs af organisatoriske grænser på områder, hvor der ikke konkurreres i økosystemet. Dette eksemplificeres i artiklen med grundig empirisk dokumentation for, hvordan service kan forbedres for råvarekomponenter ved at muliggøre en mere åben tilgang til deling af livscyklusbegivenheder om råvarerne i værdikæden.

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List of Abbreviations

AI:	Artificial Intelligence
B2B:	Business-to-Business
B2C:	Business-to-Consumer
C2B:	Consumer-to-Business
DLT:	Distributed Ledger Technology
DSR:	Design Science Research
EDI:	Electronic Data Interchange
G2C:	Government-to-Consumers
NFT:	Non-Fungible Token
IoT:	Internet of Things
IS:	Information Systems
IT:	Information Technology
OEM:	Original Equipment Manufacturer
OSCM:	Operations and Supply Chain Management
P2P:	Peer-to-Peer
QR:	Quick Response
RFID:	Radio Frequency Identification
RQ:	Research Question
SCM:	Supply Chain Management
SME:	Small Medium Enterprise
TIM:	Technology and Innovation Management
TRL:	Technology Readiness Level

1. Introduction

The purpose of the first chapter is to present the structure of the dissertation and the motivation that guides the PhD research. The introduction consists of three parts. In the first section, the motivation for the PhD and its research focus is described. Subsequently, the second section presents the structure of the PhD by providing an overview of the papers included in the dissertation, an introduction to the themes of the included papers, and an explanation of how the themes and papers are connected as a whole in the PhD. Finally, in the third section, the overall research question (RQ) for the PhD and the research questions associated with each theme of the dissertation are introduced in more detail.

1.1. Motivation for the PhD-research

My initial spark of interest for blockchain technology and the consideration for doing a PhD came from my experience in working with digitalization and lifecycle-perspectives. In that work, the interest to work with digital technology that could help reduce transactional barriers in business processes had been the common denominator for my professional life so far. The possibility for blockchain to enable transparent and easily traceable documentation was therefore interesting to explore further, especially due to a potential opportunity for close industry collaboration. The opportunity to research blockchain and find both theoretical and practical value is part of the motivation for the PhD. The possibility of my research output contributing both practically and academically is considered to be of importance in order to ensure relevance and impact of the research. With a topic like blockchain that is still relatively new, it is especially keen to investigate where the value of the technology truly lies.

Blockchain has been heavily hyped in the past decade, but aside from cryptocurrencies like Bitcoin and a growing popularity in the use of non-fungible tokens (NFTs), use cases of the technology are quite limited (Holm and Goduscheit, 2020a). A common denominator of NFTs and cryptocurrencies is that they are both typically based on *public* blockchain solutions, i.e., solutions that are publicly accessible and therefore possible to be joined by anyone (Beck *et al.*, 2018). However, this PhD's focus is on the other general type of blockchain that is referred to as *private*, due to the need for an invitation to join the blockchain-network, and in extension, read and submit transactions. Use cases in this type of network are often related to supply chain management (SCM) activities and as such, typically have the characteristic of being business-to-business (B2B) rather than being business-to-consumer (B2C) or consumer-to-business (C2B). Mature B2B-blockchain cases are few and far between (Holm and Goduscheit, 2020a) and the lack of empirically-based studies on blockchain is often described as scarce with suggestions for future research often mentioning the need for case studies or other empirical evidence (Cole *et al.*, 2019; van Hoek, 2019; Roeck *et al.*, 2019). Furthermore, since private blockchains are less accessible by definition (being closed networks), and B2B-markets in comparison to B2C-markets typically being less transparent for the public to view, private blockchain use cases are rarely accessible, even in the few cases where the technology is implemented successfully.

1.1.1. Theoretical Positioning and Research Gaps

From a more theoretical perspective, the current blockchain literature can therefore be considered to have an empirical gap (Miles, 2017). Of course, the presence of a gap is not a good justification to conduct research, as there will always be new avenues to explore in the interest of seeking novelty. A gap and an interest is however not enough, as there must also be *importance* for the topic at hand in order to justify the research (Rai, 2017). In his editorial for MIS Quarterly, Rai (2017) provides insights on how to ensure importance for Information Systems (IS) research by addressing how to make the research question matter.

While this PhD does not specifically seek to address the IS field, but rather the fields of Operations and Supply Chain Management (OSCM) and Technology Innovation Management (TIM), IS-research is still closely related to the topic of blockchain and as such, the suggestions by Rai (2017) are adopted here.

Rai (2017) emphasised the need to ask a question that matters in order to ensure the importance of the research, which starts by identifying important problems. For a problem to matter and to be important, Rai (2017) suggests that the answer must matter to science and/or humankind in general and not just the researcher. In order to explain the case of this PhD research, it makes sense to go back to the basics of research and expand the scope before moving forward in time and narrowing the scope to illustrate how the research contributes and is of importance in a larger context.

A fundamental characteristic of humankind is our natural instinct to seek and belong to groups, such as families, communities, and societies. In other words, groups are essential to humanity. Different variations of groups have been researched for centuries within social sciences, and in the past hundred years or so, business research has become a central area of understanding this human characteristic as well. In business research, groups of people are typically referred to by other names, such as organizations where a group of people are working in an organized manner to achieve a common goal (often, but not exclusively to earn money). However, for a long time, the focus in business research was either on optimizing individual organizations or on the competition between individual organizations to identify best practices for organizations. This trend started to change in the past decades as research (and practice for that matter) began to focus on not just competition, but also cooperation when considering interorganizational relations. This trend is perhaps best known by the phrasing that *no business is an island* (Håkansson and Snehota, 1989), referring to the fact that it makes little sense to only consider the cooperation *within* organizations when there is also cooperation *between* them. A distinction of relations and processes *within* an organization (intra-organizational) and *between* organizations (inter-organizational) is therefore present and the scope of analysis for business cooperation was broadened from considering a single organization to including multiple.

The focus of this PhD is on the interorganizational relations studied in business research. Particularly, it is on interorganizational *collaboration*, which is when organizations are working towards a *common* goal as opposed to cooperation where companies work for their own goals. More specifically, the PhD focuses on answering how the information shared in interorganizational collaborations is affected by the introduction of blockchain technology. The overall research question of the PhD is therefore formulated as ”*How does blockchain-enabled information-sharing affect interorganizational collaboration?”* With blockchain being one of the most hyped modern technologies, the importance of understanding the effect this technology has on interorganizational collaboration is therefore considered important (Lacity and van Hoek, 2021). The importance of research on blockchain can also be seen quite transparently by considering the calls for research on the topic in high tier journals (Journal of Operations Management, 2022) and from national funding providers (The Danish Industry Foundation, 2018).

The need for blockchain research on interorganizational collaboration specifically can also be observed in literature. For instance, Lacity & van Hoek (2021) describe how collaboration amongst ecosystems partners is the biggest challenge in making blockchain applications successful, describing business-led collaborations to be much more important than the blockchain technology itself. Existing research on blockchain-based collaboration also calls for further research on the topic, even specifically suggesting researchers address "*How blockchains influence certain organizational and inter-organizational processes, such as learning or knowledge transfer*" (Lumineau *et al*., 2021a). The need for empirical blockchain research is further specified by Wang et al. (2019) who suggests longitudinal case studies would be beneficial to understand the pre-adoption, implementation, and post-implementation phases of blockchain better (Wang *et al.*, 2019).

Going back to Rai's (2017) suggestions on formulating research questions that matter, another important aspect is to differentiate between the types of value the answer to the research question will provide. From a *scholarly* point of view, the value provided by this PhD is primarily to provide empirical evidence of blockchain utilized in interorganizational contexts. The current state of empirical research on blockchain technology is quite scarce (Holm and Goduscheit, 2020a) and literature has called for further empirical evidence on blockchain's effect on business (Cole *et al.*, 2019; van Hoek, 2019; Roeck *et al.*, 2019). This empirical gap (Miles, 2017) is the primary scholarly value and goal this PhD has aimed to provide since the PhD proposal was submitted.

After the PhD began and the empirical data collection was started, another gap was identified in the form of a practical-knowledge gap (Miles, 2017). Essentially, the empirical data collected showed industrial practice differs from what academic literature says about blockchain and its use. For instance, literature generally suggests that full transparency of events is an advantage of blockchain (Chang *et al.*, 2019; Engelhardt, 2017), but the organizations involved in the UnWind-project argue that blockchain transparency should not necessarily mean that all organizations involved have full access from the start. Instead, the technology's encryption/decryption mechanisms should be taken advantage of along with smart contracts to create different variations of data accessibility. For example, initial data access may be limited to the latest block of information entered in a blockchain for product lifecycle tracking when a new organization takes over responsibility for a service contract on a product that is being documented and traced via a blockchain. Further access to the data history would have to be bought through a smart contract if desired or be granted automatically if the product being traced breaks down so that the currently responsible organization has the ability to identify whether something has gone wrong earlier in the lifetime when another company was responsible. Regardless of the trigger for full data access, the point of the respondents is that full data access should be a privilege that is monetized or otherwise earned.

Therefore, there is scholarly value to be had in better aligning what is found in literature and what is done in practice. Due to the nature of this gap, there is also *practical* (*utility*) value in answering the research question (Rai, 2017), as the difference between practice and academia may be there due to practitioners not being aware of certain aspects of blockchain applications. In general, early empirical data showed that there was a desire from industrial players to learn more about blockchain and its utility, thus confirming that there is practical value in answering the research question of the PhD.

1.1.2. The UnWind project: Blockchain in the Wind Turbine Industry

An important aspect of the PhD for the reader to be introduced to early on also happens to be a source of a great deal of the motivation for the PhD. The UnWind project took place from January 2020 to June 2022 and has served as a parallel to the PhD project, and as such, the two are heavily intertwined. The UnWind project can be considered the primary empirical research setting of the PhD. The UnWind project had the purpose of identifying and developing a blockchain-based case in the Danish wind turbine industry with the aim to facilitate innovation in the value chain and increase collaboration between sub-suppliers to secure high quality deliveries to the industry (The Danish Industry Foundation, 2020). The UnWind project was funded by the Danish Industry Foundation in connection with a call for projects seeking to uncover the potential of blockchain in the general Danish industrial setting. The project was led by Aarhus University's Department of Business Development and Technology, with Professor René Goduscheit (who is also the main supervisor of this thesis) as the project manager. Three other official project partners were a part of the project:

- APQP4Wind: A non-profit organization focused on quality management in the wind turbine industry, who served as the main contact to the additional industrial partners of the project.
- Fraunhofer Blockchain Lab: A German knowledge institution specialized in aiding industrial and governmental actors in developing blockchain solutions, who was in charge of developing the technical solution to the project.
- Delendorff Advisory: An advisory company focused on the domains of business development and innovation management, whose main role was to support the data collection and dissemination tasks of the project.

In addition to these partners, Siemens Gamesa Renewable Energy and Vestas Wind Systems, both worldwide leading wind turbine manufacturers, also served as close industrial partners in the project. The organizations' roles were to deliver practical relevance and knowledge to the project, and they served as industrial leads to the specific case that became the main output of the UnWind project, which is referred to as the Fastener case.

The UnWind-project's existence alone speaks to the relevance and motivation of this PhD's scope as it clearly illustrates that a variety of organizations, from the Danish Industrial Foundation to the wind turbine industry, have seen the potential in investigating the opportunities within blockchain technology. As such, both industrial and governmental relevance has been implicitly secured from the start of the project, and by making use of action research and other applied science strategies, the PhD has been secured to stay relevant to society.

1.2. Research Questions

This subsection introduces the research question that makes up the PhD. It should be noted that the formulation of the research questions in the included research papers are based on the specific focus in the article, as opposed to aligning them perfectly with the dissertation's structure. For this reason, the red thread tying the papers together is not as clear as it would be if the questions had been formulated specifically to have a sense of progression in their phrasing. In this subsection, the connection and progression of the research questions is therefore explicitly stated to the reader. The overall research question sought to be answered during the PhD is as follows:

How does blockchain-enabled information-sharing affect interorganizational collaboration?

The main research question seeks to identify opportunities and limitations associated with blockchain technology for interorganizational collaboration. In this context, blockchain should be seen as an innovative tool of which is used to share information between organizations, with the PhD having the goal of identifying where the technology makes sense to use and where it does not. More specifically, the PhD aims to understand the perspectives the technology has for enabling new and valuable ways to improve businesses processes that go beyond the organizational bounds of a single organization. With information sharing having taken place for as long businesses have existed in one form or the other, the PhD's main research question can be considered to focus on a specific instance of novel information sharing between organizations. To address this question, the PhD's sub-themes seek to uncover underlying perspectives to the main research question by answering more specific questions along the way.

In simple terms, the three themes that in unison make up the bulk of the dissertation seek to ultimately answer how blockchain may be of the most value in interorganizational settings. The first two themes look at two types of interorganizational collaboration, namely vertical and horizontal collaborations, while the third paper seeks to evaluate the primary business value of a blockchain case that includes both vertical and horizontal collaboration. The connection between the three themes is illustrated in Figure 1 (see below). The overall RQ can be answered by exploring the gray parts of Figure 1 alone, as these two themes cover the two types of interorganizational collaboration that this paper's definition of interorganizational collaboration draws upon (Barratt, 2004). However, without considering the larger context in which the collaboration has an impact, a proper answer to the overall RQ falls a bit flat. For this reason, Theme 3 is included to explore the context in which the blockchain-based interorganizational collaboration is used, and the theme is based on the empirical data´s context as to where the blockchain-based interorganizational collaboration's value is. The use case explored in Theme 3 therefore goes somewhat beyond the general scope of the PhD by focusing on servitization with the intent of exploring the broader implications of this type of business collaboration.

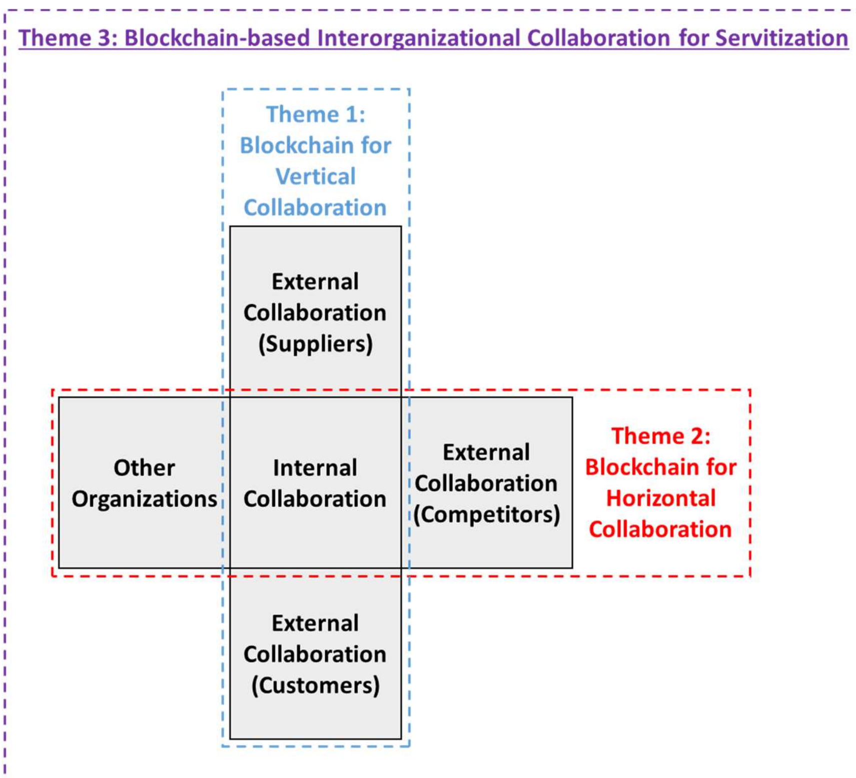

Figure 1: Connection between themes (The figure draws upon the work of Barratt (2004))

Each theme and its associated RQ will be introduced to the reader below.

Theme 1: Blockchain for Vertical Collaboration

The first theme seeks to answer the *RQ1*: *How does blockchain enable trust across organizational boundaries*? Theme 1 focuses on the most researched type of interorganizational collaboration i.e., the supply chain (vertical collaboration). As indicated in RQ1, the focus in this theme's paper is the role of trust in blockchain-based supply chain cases. The paper provides a theoretically based conceptualization of how blockchain-enabled trust works in the supply chain, and then analyzes an empirical case using said conceptualization. The paper is partially based on a literature study presented in another paper by the author of this dissertation along with qualitative data from semi-structured interviews connected to the UnWind project.

Theme 2: Blockchain for Horizontal Collaboration

The second theme addresses horizontal collaboration by *RQ2*: *How does the introduction of blockchain technology facilitate coopetition*? Coopetition is the concept of competitors cooperating and is therefore an interorganizational relation with a somewhat paradoxial nature. This unique balance in competition and cooperation is what this theme will address by examining how blockchain affects the interorganizational relations between the involved organizations.

Theme 3: Blockchain-based Interorganizational Collaboration for Servitization

The third and final theme changes from having a focus on the interorganizational relationship itself and instead shifts to present how organizations may use blockchain-based interorganizational collaboration to advance their service business. The theme seeks to answer RQ3: *How does blockchain enable service transformation of manufacturing companies?* More specifically, the theme addresses servitization, i.e., how manufacturing companies are transformed into being more service-oriented. The primary blockchain-feature in focus here is traceability and transparency of documentation across organizational bounds. The case utilized to assess the potential of blockchain for servitization includes both horizontal and vertical collaboration (i.e., both supply chain buyer-supplier relationships and coopetitive relationships).

1.3. Dissertation structure

In this sub-section, the structure of the dissertation is presented to the viewer with the purpose of providing the author a chance to directly explain the thoughts behind the structuring of the PhD. The PhD is primarily centered on three themes based on the presented research questions and papers from sub-section 1.2. Preceding the three themes in chapters 4-6 are three chapters: 1) Introduction, 2) Theoretical Foundations, and 3) Methodology. Combined chapters 1-3 provide the general background of the PhD, while chapters 4-6 include the main analysis and results of the PhD and its contributions. Finally, Chapter 7 concludes the dissertation by providing a general discussion of the research conducted during the PhD including a conclusion to the overall research question of the PhD.

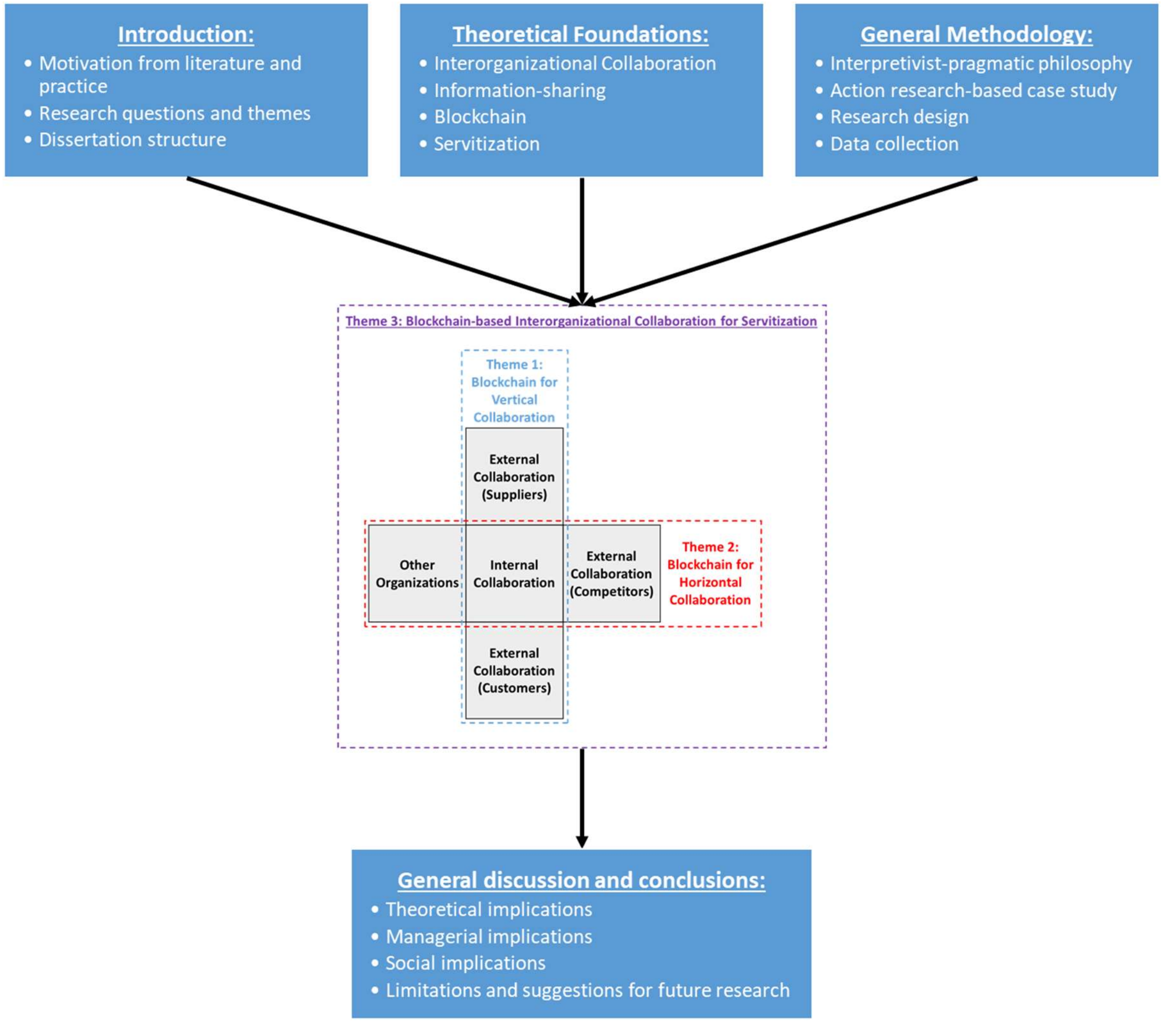

Figure 2: Dissertation Structure

Below is a brief summary of the contents of each chapter:

- **Chapter 1: Introduction** includes the current explanation of the dissertation structure as well as the motivation for the PhD research.
- **Chapter 2: Theoretical Foundations** introduces the key terms and fields relevant to the PhD as a whole.
- **Chapter 3: Methodology** describes the general approach used to conduct research throughout the PhD including a thorough summary of the empirical setting of the PhD's main case.
- **Chapter 4: Blockchain for Vertical Collaboration** presents the role of trust in blockchain-based information-sharing for supply chains.
- **Chapter 5: Blockchain for Horizontal Collaboration** analyzes blockchain's influence in coopetition where competitors choose to collaborate.
- **Chapter 6: Blockchain-based Interorganizational Collaboration for Servitization** concerns the potential of blockchain for service activities by evaluating the case study conducted over the two and half years duration the PhD.

- **Chapter 7: General Discussion and Conclusions** summarizes the PhD project as a whole by discussing cross-theme findings and implications for both theory and practice.

Table 1 summarizes the papers published (or submitted) that are directly included in the PhD dissertation in Chapters 4-6.

Table 1: Overview of Papers Directly included in the Dissertation

Theme Number and Paper Title	Research Question	Authors	Year	Outlet
Theme 1: Dissolving Organizational Bounds - Does Blockchain Digitalize Trust?	RQ1: How does blockchain enable trust across organizational boundaries?	Kristoffer Holm; John Bang Mathiasen; René Chester Goduscheit; Henning de Haas	2022	Academy of Management Proceedings (Published)
Theme 2: Exploring the Opportunities of Blockchain-enabled Coopetition: Learnings From the Wind Turbine Industry	RQ2: How does the introduction of blockchain technology facilitate coopetition?	Kristoffer Holm; René Chester Goduscheit	2023	International Journal of Technology Management (Accepted, waiting for publication)
Theme 3: Blockchain-enabled Servitization	RQ3: How does blockchain enable service transformation of manufacturing companies?	Kristoffer Holm; René Chester Goduscheit	2022	Proceedings of the 23rd International CINet Conference. (Accepted)

2. Theoretical Foundations

The PhD research is characterized by being interdisciplinary and empirically driven rather than being strongly theory bound. Due to an inductively based approach to research, the theoretical foundations cross into several academic fields, namely the OSCM field and the TIM field. In the OSCM field, topics within the supply chain management (SCM) part of the field are mainly utilized as a foundation. Here the blockchain functions as a phenomenon used to elaborate on existing theory, as blockchain presents new angles as an information sharing technology that works across organizational bounds. The PhD research also crosses into the TIM field, in particular service innovation and servitization theory is utilized for the later parts of the PhD. Furthermore, as blockchain is an example of an information system, there are some aspects of IS research that are relevant to the topic, in particular in regard to picking appropriate strategies to research digital technology in a management setting. The overlap of the (O)SCM and TIM fields is within the general scope of interorganizational collaboration and mostly in the context of information-sharing. For this reason, it is interorganizational collaboration and information sharing that will be elaborated further as they function as the general theoretical background for the PhD.

2.1. Interorganizational Collaboration

In the last decades, both research and practice have been characterized by a recognition that business practice should be seen in a larger context rather than that of a single firm (Håkansson and Snehota, 1989), and with the rise of digital technologies, this trend has only grown (Fatorachian and Kazemi, 2021). The trend of looking beyond the organizational bounds of the firm is referred to by Håkansson and Snehota (1989) in the phrasing that *no business is an island*. This phrasing illustrates the context of the project quite well, as it does not make sense to simply consider one organization, but rather the full ecosystem of organizations that in unison make up the *island* that is the interorganizational blockchain-case.

The term interorganizational collaboration is perhaps best explained by breaking down the meaning of each word. Interorganizational consists of two parts: *inter* and *organizational*. Inter is a prefix used when talking about something that happens between groups – in this case organizations. Organization refers to a group of people that work in unison and includes companies, with the key difference being that an organization does not necessarily aim for making money whereas companies do. The term interorganizational should therefore be understood as the interaction of groups of people (typically, but not always companies). Collaboration should be understood as something different from cooperation. When cooperating, you work with other people to achieve *your own* goals, but when collaborating you work to achieve *common* goals. So the full term *interorganizational collaboration* should be understood as the act of organizations working together to achieve common goals.

As such, interorganizational collaboration is a broad term utilized to describe collaboration between two or more organizations. The number of collaborating organizations will be referred to by different means throughout the PhD. When two organizations collaborate, or perhaps rather when only two organizations' role in collaboration is taking into account for analysis, it is referred to as a *dyadic* collaboration or relationship (Pathak *et al.*, 2014). Similarly, when three organizations are considered it is referred to as a *triadic* collaboration or relationship (Wu *et al.*, 2010). Finally, the *network* level of collaboration is where more than three organizations are considered (Zerbini and Castaldo, 2007). In the case of network level relations, it is often full ecosystems, industries or supply chains being considered for analysis. This PhD primarily refers to the network level relations as blockchain technology tends to go beyond three involved organizations.

Another important aspect to define is the different types of interorganizational collaborations that exist which can be seen illustrated in Figure 3. The interorganizational collaborations types listed in Figure 3 takes inspiration from Barratt's definitions for supply chain collaboration (Barratt, 2004).

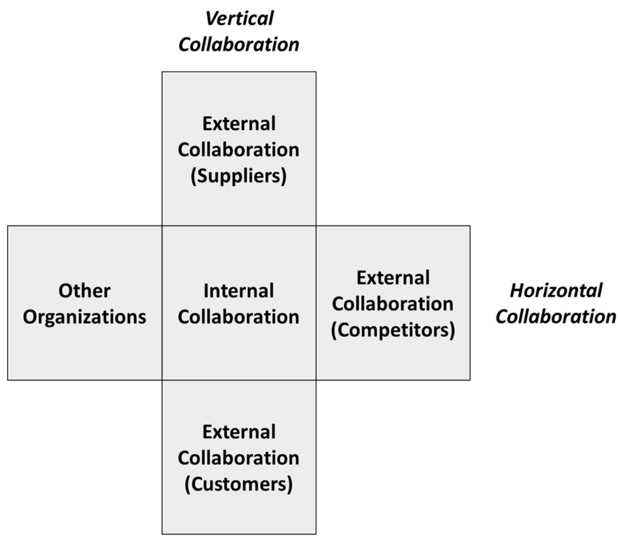

Figure 3: Types of Interorganizational Collaboration (taken from Barratt (2004))

In SCM literature, topics regarding interorganizational collaboration are typically concerning vertical collaboration between a customer/buyer and a supplier (Cao and Zhang, 2011; Fawcett *et al.*, 2012). For instance, the classic theories regarding whether to pick an arm's length principle or more close collaboration depending on the type of product that is being traded. In horizontal collaboration, two organizations on the same vertical "level" collaborate, for instance two manufacturers producing the same type of products such as wind turbines. The unique thing about horizontal collaboration is that the collaborating partners may compete with each other, even if they also cooperate. The simultaneous instance of competition and cooperation is referred to as coopetition (i.e., the combination of the two words) (Bengtsson and Kock, 2000). In this dissertation, the terms coopetition and coopetitive relations are used to refer to horizontal collaboration.

2.1.1. Information-sharing across Organizational Bounds

Information sharing is one of the most common ways for organizations to engage in their relationship as information sharing at its core is communication. The way two or more organizations communicate and share information is therefore already heavily researched and the dissertation does not intend to specifically challenge or test any theories within the topic. Instead it is sought to expand upon the topic within a blockchain-specific context, which is still relatively untouched although some papers have started to appear on the topic (Longo *et al.*, 2019; Lumineau *et al.*, 2021b). Specifically, the focus of the dissertation is to better understand whether information sharing should be considered a prerequisite or an outcome of an interorganizational relationship. For that reason, a big share of the focus of the PhD is on trust as well.

Trust plays an important role in information sharing and this is well documented in literature (Dyer and Chu, 2003; Uzzi, 1997). Uzzi (1997) describes trust as a major aspect of a relationship, and while he focuses a lot on trust being between people, he also ties it to relationships between organizations and their information sharing activities. Dyer and Chu (2003) describe trust as having a mutually causal relationship with information sharing as the two create value for each other and goes on describe how the two are both antecedents and outcome of one another, which falls in line with what the dissertation seeks to understand better for interorganizational relationships and information sharing via blockchain. The relationship between trust and information sharing in a blockchain context is elaborated extensively in Theme 1 and as such, further details on the matter should be found in Chapter 4 of the dissertation.

2.2. Blockchain in Interorganizational Collaboration

As blockchain will be defined and elaborated upon multiple times in chapters 4-6, the purpose of this section is two-fold: first it will provide an overall definition and description of the technology, and secondly, it will briefly describe the importance current blockchain literature puts on interorganizational collaboration for the success of blockchain.

Blockchain is a an example of an information sharing technology (Nandi *et al.*, 2020) that is based on a shared software application for the purpose of which is to create and validate immutable transactional records (Lacity and van Hoek, 2021). The blockchain works as a distributed ledger and uses consensus-based mechanisms to create tamperproof records (Schmidt and Wagner, 2019) that are assigned in blocks of information for specific events. Each block is tied together into a blockchain to create a history of transactions. The immutable and append-only nature of the blockchain (Carvalho *et al.*, 2021) means that no information can be altered once entered – only expanded upon in new blocks – which means that the technology provides a novel way of enabling what is sometimes referred to as a system of trust (Cole *et al.*, 2019).

There are several types of blockchain technology and as such, varied terminology is used to differentiate between them. Two of the most important distinctions is between public and private and between permissionless and permissioned blockchains (Beck *et al.*, 2018). Public blockchains are probably the most well-known type of blockchain technology, as it is what the original blockchain was, an open software that anyone could access and join and be able to read and submit transactions. Private blockchains on the other hand, can only be accessed by people or organizations who are part of/invited into the blockchain network. Permissioned blockchains differentiate from permissionless blockchain in the sense that permissionless blockchains allow anyone in the network to validate transactions, while only authorized notes can validate transactions in permissioned blockchains. This dissertation focuses only on private, permissioned blockchains and as such, blockchain in the context of this dissertation should not be seen as something anyone can access or join. Instead it is only invited parties, specifically organizations in this dissertation, that are in focus and not all organizations are intended to be able to validate transactions.

In other words, when blockchain is discussed in this PhD, it is referring to a closed network of organizations sharing information. Blockchain's characteristics of being immutable and append-only is still a highly relevant feature in this context, and so is the transparency of the technology in the sense that the organizations that have access to the blockchain are able to share information openly between each other.

In regard to how blockchain literature addresses interorganizational collaboration, the topic is rarely touched upon directly, but is nevertheless present in most blockchain literature within supply chain management, as supply chain management involves multiple organizations. There are also a few studies that directly addresses the topic, such as Lumineau et al. who explore whether blockchain could be a new way of organizing collaboration by taking advantage of the governance mechanisms in play in the technology (Lumineau *et al.* 2021b). Dubey et al. (2020) also addresses the topic in their paper where they look at how blockchain may enhance swift trust and in extension, collaboration amongst the actors that engage in the network (Dubey *et al.*, 2020). Finally Wang et al. (2021) address how blockchain may bring a new paradigm to supply chain integration and collaboration through the blockchains' features like traceability and automation (Wang, Wu, *et al.*, 2021). In addition to these papers, Lacity and van Hoek (2021) empathize the importance of ecosystem collaboration for the success of business blockchain applications (Lacity and van Hoek, 2021).

2.2.1. Servitization and blockchain

The final topic that will be briefly introduced here is the concept of servitization, which is the focus of Theme 3 (Chapter 6). Servitization is a term used to describe the transformation manufacturing companies can go through to become more service-oriented as opposed to only selling products (Kohtamäki *et al.*, 2019). While servitization does not directly have a relation with blockchain or interorganizational collaboration, it does have an indirect relation because blockchain enables more connectivity and traceability across organizational bounds which in turn enables manufacturing companies with new ways and opportunities to stay in contact with their products past the point of sell. The information flow for the lifecycle of products can therefore be used to enable servitization ventures by providing the manufacturers data on their products, which gives them insights on how to offer service, maintenance, and replacement offers to their customers in a more integrated way.

2.2.2. Blockchain and trust

Trust is commonly addressed in the context of supply chain management (Treiblmaier, 2018) and interorganizational collaboration (Latusek and Vlaar, 2018) in particular when the focus is on information-sharing processes (Dyer and Chu, 2003). As such, it is only natural that it is also a commonly discussed topic in blockchain research (Engelhardt, 2017; Ferrer-Gomila *et al.*, 2019; Pedersen *et al.*, 2019; Seidel, 2018). When discussing trust in a blockchain context the conversation often goes towards transparency (Scott *et al.*, 2023; Wang *et al.*, 2022), which is natural as the blockchain is based on de-centralized technology and has an immutable nature do to the way information is stored in the blockchain technology. It has been suggested that blockchain can be used bridge trust as well as transparency and traceability in the context of supply chain management and sustainability (Centobelli *et al.*, 2022). Similarly blockchain has been found capable of facilitating interorganizational trust in strategic alliances (Chen *et al.*, 2023). Several trust management models have been suggested to be based on blockchain technology for areas such energy and power grid management (Dehalwar *et al.*, 2022; Masmoudi *et al.*, 2021).

While current research explores many technical angles and conceptual frameworks for uncovering the angles in which blockchain may prove useful, two overall gaps are identified. 1) There is a lack of empirical evidence regarding the statements made about blockchain's impact in trust, transparency and information-sharing in current literature. 2) While there are many interpretations as to whether trust is a prerequisite or outcome of blockchain, there is little to no research addressing whether both may be true and how the nature of said trust transforms over time. In order to address these themes Paper 1 in chapter 4 will utilize an empirical case study to provide such empirical evidence and utilize the findings to analyze how trust is discussed amongst respondents as either a pre-requisite or outcome of implementing blockchain technology.

3. General Methodology

The purpose of this chapter is to introduce the reader to the general methodology of the PhD including the utilized research philosophy and strategies, a case description of the Fastener-case, as well as a summary of the data collection carried out throughout the PhD. The intention of this section is *not* to account for the specific methods utilized to answer the RQs of each theme, as these considerations are presented in the individual papers' respective methodology sections already. As such, this chapter should be read as an introduction to the overall considerations and actions that have been taken during the PhD period. The intention is for the reader to understand the overall consideration of the PhD while the details are kept to the papers presented in chapters 4-6.

3.1. Research Philosophy

The PhD project has distinct characteristics that are important to understand when discussing the research philosophy. Perhaps most essential is the general logic used in the thesis, which mostly comes down to be inductive approach that takes direction from empirical input as much if not more than theory. Furthermore, the research is interdisciplinary in nature, taking on views from both engineering disciplines and business and social sciences. Considering these characteristics, it should not come as a surprise that the philosophical stance of the PhD project is characterized by somewhat mixed views. The PhD takes its philosophical standing in interpretivism, meaning that there is no objective reality, but rather reality must be experienced and interpreted to understand the underlying meaning of a set of events (Walsham, 1995). In simpler, more project-specific terms, the blockchain phenomena must be considered in the context in which it is to be utilized for it to be truly understood. The collaborative potential of the technology must therefore be explored in the "reality" of the setting it is to be used in. For this PhD, the specific reality explored empirically is the wind turbine industry supply chain and broader ecosystem. In a broader more theoretical context, it is blockchain-based interorganizational collaborations.

The PhD also has traits of a pragmatist's philosophical view. Specifically, the PhD subscribes to the pragmatist's idea of research needing to solve problems, and that reality must be interpreted in the context of the new situations that arise as the research progresses (Elder-Vass, 2022). As will be elaborated in section 0, the PhD also follows an action research strategy. The philosophical duality with elements of both pragmatism and interpretivism is not uncommon in research on digital technologies (Goldkuhl, 2012) and can take various forms. For instance, Goldkuhl (2012) states "*An action researcher would not only aim for local change but also for knowledge aimed for change in general practice*", which is essentially the stance that is taken in this dissertation. The PhD does not only aim for creating change in a setting of the wind turbine industry in practice, but for B2B-settings in general. The PhD does not only aim to suggest how blockchain changes one field's view on information-sharing, but rather looks to understand it in a broader context. Lastly, the PhD does not only look to understand how blockchain specifically effects certain theories such as coopetition or servitization, but rather how increased transparency and connectivity affect the theories in a larger-than-blockchain perspective.

Due to the practical approach in the PhD project where not only theoretical contributions have been in focus, but empirical data have also played as big a part as theory. The PhD has been contributing to the UnWind project and the Fastener case within said project where the identification of a case for blockchain in the Danish wind turbine industry was first sought after and subsequently developed to fit the industry's needs (UnWind, 2020). In the process of doing so, parts of the PhD is perhaps best described as having an abductive logic (Dubois and Gadde, 2014), where juxtaposing use of theory and empirical insight have characterized the development of the practical blockchain solution and its business case, as well as the research conducted before, during, and after the UnWind project period.

Overall, the PhD and its papers fall mostly under the inductive logic, as the general approach to research has been to continuously gather and interpret data in order to define and give direction to the research. Essentially it can be summarized to the fact that the research (for the most part) has known the *what* and the intended *results* in terms of the research, while trying to uncover the *how* (Dorst, 2011). The thing that sets the research apart from most inductive research is that the *what* and the *result* switch around at times because both blockchain and interorganizational collaboration can be seen as the *result* and the *what* individually:

$$\boldsymbol{WHAT + HOW\ leads\ to \rightarrow RESULT}$$

$$Blockchain + HOW\ leads\ to \rightarrow Interorganizational\ Collaboration$$

OR

$$Interorganizational\ Collaboration + HOW\ leads\ to \rightarrow \text{Blockchain}$$

In other words, there is a "hen and egg" situation in play in terms of whether blockchain enables interorganizational collaboration or if interorganizational collaboration enables blockchain, something that in and on its own can be considered a part of the findings of the research. Regardless of which comes first, the approach to researching the connection is the same throughout the majority of the PhD, with the unknown being the *how*, thus leading to research questions starting with how in the papers included in this dissertation (see p. 22 for an overview of the dissertation's RQs).

3.2. Research Strategies

Two research strategies have helped guide and form the PhD. The case study approach is the primary research strategy utilized in the academic articles and in extension the dissertation, as the strategy has been to use the novel insights from an empirical context to address how existing theoretical views within research on interorganizational information sharing are affected. In addition, action research has been used as a guiding principle to ensure that not only knowledge, but also action could be generated from the PhD-project. This is due to the author's ambition of creating research that is directly applicable for the industrial use of blockchain-based traceability. The research strategies share the common denominator that they are practitioner-oriented (McNiff, 2013).

3.2.1. Case Study

The case study (Eisenhardt, 1989) approach is utilized from start to end in the PhD in the context of the UnWind case, and for the papers included in this dissertation, it focus on the Fastener case specifically. The case study approach is chosen due to the current lack of empirical cases on B2B-blockchain in literature (Holm and Goduscheit, 2020b). There are of course other methods to present empirical research, but the case study approach was deemed appropriate due to the method providing the opportunity for in-depth analysis of qualitative data and the opportunity to present a practice-oriented view. Eisenhardt (1989) presented case studies to be a way understanding the *dynamics present within single settings* and argues that case studies are effective in tying actual data to theory crafting. As mentioned in the introduction, the PhD is heavily based on the empirical evidence collected in the UnWind project and the related Fastener case and the case study approach is highly appropriate for the empirical situation. To be clear, the primary empirical data of the PhD comes from a single case study based on the UnWind project and the challenges of conducting a single case study is present. Several papers have however, argued that single case studies can provide significant value if they present strong and ideally unique (in the sense of literature novelty) insights based on empirical evidence (Dubois and Gadde, 2014; Flyvbjerg, 2006; Voss *et al.*, 2002).

Voss et al. (2002) argue that the fewer cases that are included in case study research allow for deeper levels of observations and in extension analysis, and argues that single case studies for this reason makes particular sense to use when conducting longitudinal research. As this PhD has followed and aided in the development of a blockchain case over the span of three years and has seen it evolve from the beginning to operational testing, it can be argued to be a longitudinal study. Since the PhD project has had the opportunity to collect data on the design, construction, and testing of the blockchain case throughout the project span, it has not relied on archival data or retrospective data from respondents, thus minimizing the chance of post-rationalizations from respondents in regards to the choices made (Voss et al., 2002).

Of course, the big disadvantage of single case studies comes from the extent to which the findings can be generalized. However, as argued by Flyvbjerg (2006) amongst others, it *is* possible to generalize through single cases as long as they are properly picked. For one, a single case is enough to unveil inconsistencies with what literature suggests being true, such as the practical-knowledge gap (Miles, 2017) described in subsection 1.1.1. Another argument that can be made about the challenge of generalizability for single case studies is of course whether or not it is actually important or not as some believe it is overrated as a source for scientific progress (Flyvbjerg, 2006). Novelty and value of the insights from a single case study can help advance the knowledge pool of academic or practical interest regardless of whether it can be generalized. As for the Fastener case, its characteristics and findings can probably not be generalized to fit B2C-settings too well, but it does not mean that there is no knowledge to be taken from the Fastener case that can be of value for a B2C-blockchain researcher to learn from.

Case selection is the final thing that will be addressed in this general section for the case study strategy. In the pursuit of academic transparency it should be stated that the case choice comes partially from convenience. As have been presented earlier, there is a severe lack of empirical blockchain cases to learn from, so a researcher interested in learning about blockchain-based interorganizational collaboration cannot be too picky as there is simply not that many cases to pick among. This gap in empirical evidence is however already a good argument as to why the case or perhaps rather research strategy is chosen, as the relative novelty of simply having a case to present will help advance the field.

With the Danish Industry Foundation recognizing the value of understanding the potential of blockchain technology in the context of a particular industry, there is also some argument as to why it is not simply the author of this PhD that finds it a relevant case to focus upon. However, this argument on its own would still make for a rather weak reasoning as to why the case setting makes sense from an academic point of view. Lacity and van Hoek (2021) argue that the biggest challenge for blockchain applications for business lies in successfully collaborating with partners, and the wind turbine industry is characterized by a long history of interorganizational collaboration and systematic innovation (Andersen and Drejer, 2008). In other words, there is a good argument to be made that the specific industry setting has ideal conditions for implementing a successful blockchain application. Further argumentation comes from the conditions of the industry, such as the fact that traceability and documentation become increasingly important and complex to handle as the lifetime increases, and since wind turbines have expected lifecycles of 20+ years (Jensen, 2019), it means the need and value in using technology that aid in storing and recording documentation increases. While this latter argument does not directly tie to theoretical importance, it does fall in line with the philosophical stance that research should aim to solve real problems. In other words, it makes better sense to look at the wind industry where documentation will have value over decades as supposed to another industry where the product lifecycle is shorter.

Finally, an argument on the case selection comes from the fact that conditions in the UnWind case, while ideal in several ways, is not necessarily unique to the sector. A different way to describe the case research setting is simply to say that it is about lifecycle traceability of commodity items (in this case, fasteners in the wind turbine) that for the most part could have been focused on microchips for cars. Ultimately, the case is much more about the value of immutable, transparent documentation across organizational bounds than it is about wind turbines or fasteners. This argument of course ties back to the ideas of Flyvbjerg (2006) in terms of how a single case study may be used to generalize results.

3.2.2. Action Research

Action Research (AR) is utilized throughout the PhD as a research strategy due to the intention of creating not only scholarly value, but also practical value (Mcniff and Whitehead, 2010). Specifically, the project aims to help develop a functioning, valuable blockchain solution with the industrial partners of the wind industry, and in order to accomplish this, the researcher will provide knowledge to the industrial partners from which they can take actions. In other words, the intention is to generate both knowledge and action and therefore the PhD can be considered research in action as much as it is research about action (Coughlan and Coghlan, 2002). The AR practice follows the "general rules" of interpretivism in the sense that data collection is accepted to be influenced by both the respondents and the researcher, as they will alter each other's perception through their communication (Walsham, 1995).

AR has been utilized in research similar to that of this PhD, such as for designing blockchain-based supply chains (Wang, Chen, *et al.*, 2021) and for identifying key factors in the startup phase of interorganizational collaboration based on knowledge sharing (Gattringer and Wiener, 2020). Furthermore, AR has been suggested as a promising approach to achieve a richer understanding on organizational blockchain adoption (Cole *et al.*, 2019). All in all, the AR strategy is therefore considered to be a good fit for the PhD research and its goals.

3.3. Case Description: The Fastener case

At this point, many references have been made to the Fastener case, but there has yet to be a proper introduction as to what the case is actually about. The purpose of this section is to provide the reader with this insight. First, the general setting of the case is explained in further detail.

3.3.1. Industry Conditions

The wind industry is on the surface relatively simple to understand and can generally be tied to two products: the turbine and the wind energy produced by the turbine. The two products obviously have intertwined life cycles and supply chains tied to them, and due to the nature of the project, these are important to understand. It is within the lifecycle and supply chain of the turbine that the most complexity is to be found and it is in this context the Fastener project primarily will have an impact.

The lifecycle of a turbine is a complex case even if only the operational period is taken into consideration. Turbines are manufactured to operate for 20-25 years under environmental conditions that vary for each turbine, and unlike other energy producing technologies, several parts are moving almost constantly under operation, in particular the blades and generator. Furthermore, it is necessary that turbine are active close to 100% of their lifetime for the sake of the levelized cost of energy to be competitive with other energy producing technologies. Any downtime during periods where energy could otherwise have been produced is therefore a large concern and ultimately why service and maintenance of turbines are considered equally, if not more important than the manufacturing of turbines.

The operational period in which the turbine needs service and maintenance is typically not limited to one organization. Several organizations may be involved in the service and maintenance of the turbine at any given point in its lifetime due to the various parts of the turbine requiring different skills, tools, and certificates to handle. Furthermore, the overall responsibility for handling service and maintenance of turbines may change over time. Often the OEM delivering the turbine to its operational location will be responsible for service and maintenance, but at times, the turbine owners and/or investors may also be responsible. In both situations, the responsibility of maintenance may be outsourced to third party providers. Complicating the situation further is the fact that responsibility for service and maintenance may change during the turbine's operational lifecycle. For instance, the beginning years (typically 7–10-year periods) may have the OEM in charge, after which the service contract is taken over by the wind park (a wind park is a location where multiple turbines are located) owner or even a competing OEM. As such, the lifecycle of the turbine is complicated and can vary even between turbines located in the same wind park.

A turbine consists of thousands of components supplied by hundreds of suppliers that in turn have their own suppliers, ultimately making both the turbine as a product and its associated supply chain(s) quite complex. As turbines are constantly being innovated, both in terms of size and design, and because their lifetime is decades long, orders of turbines come in numbers where mass production of turbines is not economically viable, causing turbine manufacturing to be based on serial production. This has the consequence that components used for the turbines (such as the load-carrying bolts and fasteners) also come in relatively small numbers, meaning manufacturing of these components is typically done using a serial production setup, meaning suppliers must adjust their production lines to when orders are being made.

3.3.2. The Blockchain Solution for the Fastener-case

The blockchain solution that has been designed for the Fastener case must function under the conditions described in the above subsection. Furthermore, each commodity component must be individually identifiable, i.e., it must be possible to look up a specific bolt located in a specific turbine via the blockchain solution. Finally, each commodity component must be traceable throughout its lifecycle. The lifecycle in the Fastener case is determined to start at the point where a fastener (or another commodity component) is sent from the supplier and ends once the component is broken down or decommissioned along with the turbine it was in.

Figure 4 is taken from a conference paper that the author of this PhD coauthored and shows the different events and data points that would be registered in the blockchain solution of the Fastener case (Singh *et al.*, 2022). Further details on Figure 4 and the lifecycle a commodity component goes through, can be found in the article (Singh *et al.*, 2022).

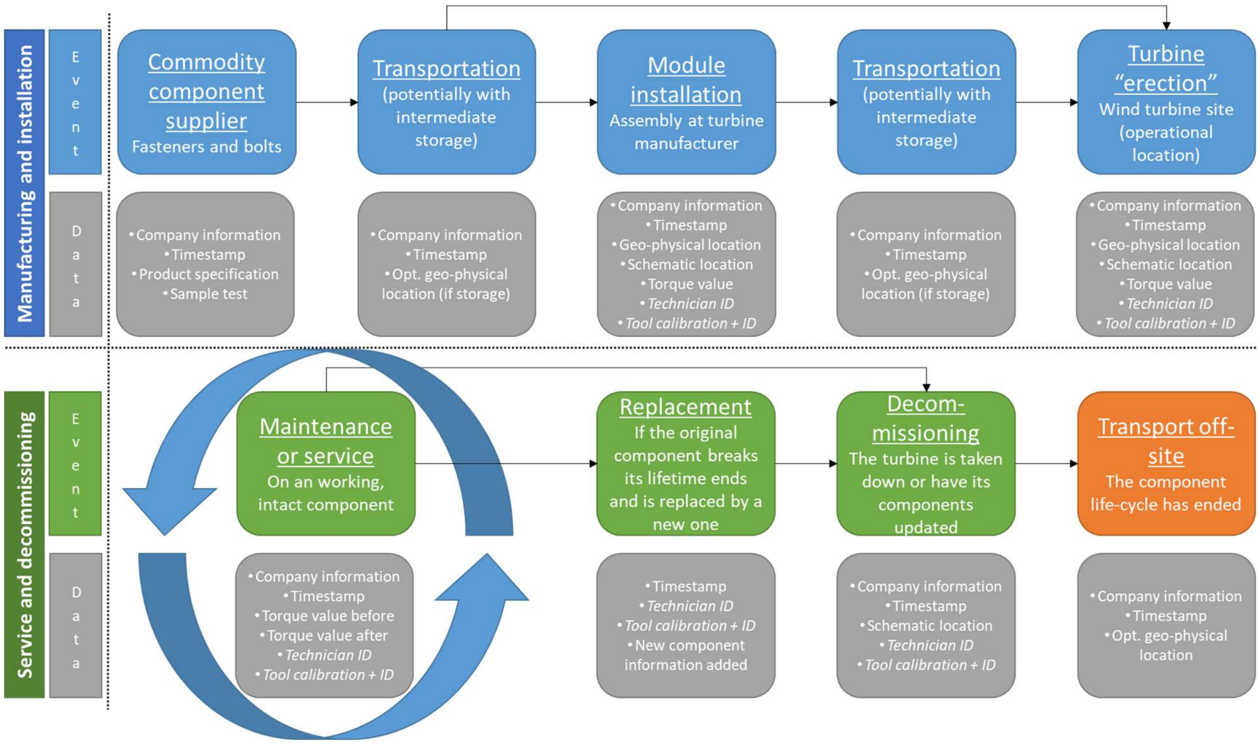

Figure 4: Events and Data-points in the Lifecycle of Commodity Components in the Wind Turbine Industry (Figure taken from Singh et al. (2022))

Further explanation of the events occurring in the case can be found in the last paper where the service perspectives of the case is addressed more thoroughly (see section 6.4, p. 80).

3.4. Data Collection

The empirical data of the PhD is of qualitative nature and has come in the form of various means, and as such the PhD makes use of a qualitative multi-method approach regarding data collection. In addition to the primary empirical data collected through various qualitative methods, the PhD has made use of literature studies and searches. All in all, approximately 100 hours of raw qualitative data was collected for the PhD project. Below is a summarized overview of the primary data collected in the PhD.

3.4.1. Interviews

12 semi-structured interviews were conducted with respondents from or supporting the wind industry. The respondents all shared a background within either supply chain management or digitalization and were all white-collar workers working as specialists or middle managers. Interviews were conducted in person, when possible, but due to a large part of the PhD taking place under the COVID-19 pandemic, many interviews were conducted online via Teams or Zoom. Notes were taken at all interviews and nine of the 12 semi-structured interviews were permitted to be recorded. The length of the interviews varied between 45 and 90 minutes. An interview guide was used during the interviews, with the guide being adjusted to fit the specific respondents' background and position. An overview of the semi-structured interviews can be seen in Table 2.

Table 2: Overview of semi-structured interviews

Description of respondents and their organization	Recorded	Length (minutes)
Supply chain specialist working in procurement at an OEM	No	45
2 respondents working within supply chain digitalization in an OEM (1 middle manager, 1 specialist)	No	60
Middle manager of procurement unit in OEM	No	90
Specialist in digitalization business (supplier of digital solutions)	Yes	60
Digitalization middle manager from OEM	Yes	90
2 respondents, 1 middle manager, 1 specialist focused on digitalization (supplier of digital solutions)	Yes	60
Supply chain management specialist at an OEM	Yes	90
Supply chain specialist at an OEM	Yes	60
Middle manager working within R&D at an OEM	Yes	50
Digitalization specialist working at an OEM	Yes	60
2 respondents both digitalization specialists working at an OEM	Yes	90
Supply chain management middle manager working at a supplier to the OEMs	Yes	60

In addition to the semi-structured interviews, nine unstructured interviews were conducted with respondents from or associated with the wind turbine industry. The interviews were not recorded and were for the most part unplanned, but nevertheless provided important insights to the project. The interviews were documented through notes, and the statements used based on these interviews were confirmed by the respondents before being included to counteract the unplanned nature of the interviews. The interviews lasted 30-90 minutes.

3.4.2. Workshops

21 workshops were conducted with a variety of people from the wind turbine industry. The positions of the participants in the workshop varied to a larger degree than the interviews, but for the most part participants had a background in either supply chain management or digitalization. Workshops lasted between 60-180 minutes and notes were taken as documentation for all of them. Only five of the 21 workshops were

recorded due to the workshops containing confidential data. Most workshops occurred online both due to the COVID-19 pandemic and the fact that many of the participants were located in different countries, making physical meetings highly impractical. For online meetings, Zoom or Teams were used as platforms for the meetings.

Seven of the 21 workshops focused on an industry procurement standard for commodity components. These workshops have been documented by field notes by one the authors of this paper and partially in the developed standardization document. There were roughly 20 participants at each workshop with representatives from both OEMs and suppliers of commodity components.

Four of the 21 workshops directly concerned the development of a blockchain prototype and were all recorded. The participants of the workshops were members of the UnWind project team and 2-4 industry representatives from the OEMs.

Six of the 21 workshops focused on the business case tied to the Fastener case and are documented through a combination of field notes, summaries of meetings shared and developed by the participants, and in some cases photos (when illustrative modelling had been appropriate). The participants of the workshops were members of the UnWind project team and 2-4 industry representatives from the OEMs.

The last four of the 21 workshops concerned traceability and the development of the QR code based solution that serves as a gateway technology between the blockchain in the digital world and commodity components in the physical world. These workshops are documented by field notes and are summarized in e-mail exchanges between the participants. The participating parties in these workshops were 2-4 industry representatives from the OEM.

4. Blockchain for Vertical Collaboration

The content of this chapter is taken and copied directly from the following research paper produced during the PhD:

Holm, K., Mathiasen, J., Goduscheit, R.C., and De Haas, H. (2022) '**Dissolving Organizational Bounds - Does Blockchain Digitalize Trust?**' *Academy of Management Proceedings 2022* (1), 11934

The paper was presented at the 82nd annual meeting of the Academy of Management.

4.1. Introduction

Blockchain, an information-sharing technology is bringing organizations and their networks into a new digital age and as such, the implication of the technology is being explored in topics such as operations and supply chain management (Cole et al., 2019). As supply chains and other interorganizational relations are digitized, new empirical insights naturally affect our theoretical understanding and in the case of blockchain, few things are addressed more than trust (Koh *et al.*, 2020; Pedersen *et al.*, 2019; Seidel, 2018). The importance of trust in information-sharing is well-established (Dyer and Chu, 2003; Laeequddin *et al.*, 2010; Uzzi, 1997). Dyer and Chu (2003, p.66) describes how "*trust and information sharing are both an antecedent and an outcome of the other*", which is an aspect this paper seeks to elaborate on.

One of the biggest issues the authors find in the current literature on blockchain-related trust is that the relation between these concepts are widely differently described and understood. Arguments are made that blockchain eliminates the need for trust (Pedersen *et al.*, 2019), distributes trust (Seidel, 2018), facilitates digital-based trust (Wang, Han, *et al.*, 2019) or even builds trust (Koh *et al.*, 2020). While the varying descriptions fit with Dyer and Chu's (2003) statements on information-sharing and trust being both antecedents and outcomes of each other, there is a lack of synthesizing in current literature when it comes to the relation between trust and blockchain. Since trust is still so inconsistently addressed in literature, despite being a key factor for both information-sharing and collaboration in a larger context (Connelly *et al.*, 2018), it makes the road to success for blockchain rockier than it needs to be. In fact, a paper found that successful applications of blockchain are business-lead collaborations and not technological phenomenon, the lack of a reliable understanding of trust could therefore be considered detrimental for blockchain applications to advance and mature (Lacity and van Hoek, 2021b).

The purpose of this paper is first and foremost to demystify the relation between trust and blockchain by addressing not just the nature of blockchain-based trust, but also the pre-requisites and outcome of the blockchain-based trust. The research question the paper seeks to answer is: "*How does blockchain enable trust across organizational boundaries?*" There are two challenges that makes answering this research question difficult; (1) blockchain technology remains in its infancy (Wang, Han, *et al.*, 2019); (2) empirically driven research of blockchain in supply chains is limited (Roeck *et al.*, 2019). In order to overcome the first challenge, this paper strives for theory elaboration (Charmaz and Thornberg, 2020; Ketokivi and Choi, 2014), by bridging nascent theory on blockchain with the well-established theoretical foundation of trust. The second challenge is addressed by analyzing primary data from a single case study. The case study focus on a developing blockchain use case from the wind turbine industry in which five large turbine manufacturers, eleven first tier suppliers and non-profit organization are collaborating to establish a blockchain used for tracing commodity components throughout their lifecycle.

Before blockchain can enable trust across organizational bounds, pre-existing trust and willingness to collaborate must exist amongst the involved organizations. Once the blockchain is introduced into the interorganizational setting, the nature of trust between partners are seemingly transformed, becoming partially digitalized through the blockchain's features. For instance, the blockchain's immutability make competence-based trust in humans partially redundant by converting it to a digital-based trust. As events (such as proof of provenance, proof of certifications etc.) are stored in the blockchain history in an append-only fashion, organizations can trust in blockchain as a technology (across organizational bounds) rather than in people to maintain correct transactional histories (within organizational bounds). Blockchain also partially transform integrity-based trust, in particular in situations where new players get involved in the blockchain network. Under normal conditions trust is considered to be built over time and therefore a new supplier, customer etc. entering in relations with an organization will have a low degree of trustworthiness. With the blockchain's cryptographically encrypted, immutable nature however, the focal organization can trust in the blockchain's integrity instead, meaning they will not have to worry that a new partner organization changes details in their business contracts etc. without informing the focal company.

4.2. Theoretical foundations

This section is divided in two sub-sections. First, the traditional view on trust in supply chain management is presented and then the blockchain technology is introduced and evaluated in terms of maturity and current blockchain-literature's take on trust is presented.

4.2.1. The Role of Trust in Operations and Supply Chain Management

Trust has been studied extensively; for instance, in the fields of relationship marketing (Morgan and Hunt, 1994), buyer-supplier relationships (Dyer and Chu, 2003), inter-organizational relationships (Connelly *et al.*, 2018) and supply chain management (Parast, 2020). These researchers conceptualize trust to be embedded in relationships (Uzzi, 1997) and sees it as a multifaceted construct (Blomqvist, 1997; Connelly *et al.*, 2018).

Organizations' are unable to trust one another, but practitioners in the interacting companies have the abilities to perceive trust (Dyer and Chu, 2003) and thereby capture the benefits of interacting in trust-based relationships (Parast, 2020). Trust is embodied and thus individualized, but the processes of capture the benefits of and trust building activities are "*more a property of collective units than of isolated individuals*" (Blomqvist, 1997, p. 283). In other words, trust is individualized, but the processes capture the benefits and trust-building activities across organizational boundaries do also involve social interaction among practitioners, who are working in separated domains and might have different backgrounds and mental faculties. Thus, in line with trust researchers (Blomqvist, 1997; Uzzi, 1997; Dyer and Chu, 2003) this paper considers trust to have both interpersonal and organizational dimensions.

Trust, the social lubricant for practitioners' interaction (Ireland and Webb, 2007) influences the opportunity for sharing information across organizational boundaries. Trust evolves and is the result of repeated cycles of interaction (Blomqvist, 1997) in which practitioners evaluate whether their expectations are fulfilled. Yet, an old saying highlights that "*it takes years to build trust and seconds to destroy it*". Thus, trust is mutable (Özer and Zheng, 2017) and situational (Mayer *et al.*, 1995). In the following, the paper conceptualizes three types of nature, which trust may have; digital-, competence-, and integrity-based trust.

The Nature of Trust

Digital trust is a relational construct (Buechner, 2020) in which the practitioners involved have sufficient willingness to be vulnerable to a technology (Lippert, 2007). For instance, the driver of a car trust the digital adaptive cruise control systems when driving at the highway. It means that digital trust depends on the practitioners' disposition to trust a technology and their perception of the reliability of the technology. Mayer *et al.* (1995) says that the need for trust only arises in risky situations. In other words, if the practitioners' perceptions of the credibility and reliability of the technology exceed their willingness to be vulnerable, digital trust is sufficient to share information across boundaries. In other situations, trust will not be a prerequisite for information-sharing across organizational boundaries (Dyer and Chu, 2003); if a practitioner(s) has complete access to needed information, it will make trust superfluous to the information-sharing process (Blomqvist, 1997; Uzzi and Lancaster, 2003). Thus, digital trust is sufficient for information-sharing across boundaries if trust is not a prerequisite or if practitioners have sufficient willingness to be vulnerable to technology.

In other situations, trust will be a prerequisite if the information to be shared is sticky (Szulanski, 1996), semantic and/or pragmatic (Carlile, 2004), and thus domain specific (Connelly *et al.*, 2018). Focusing on this asymmetric prerequisite seems central to gain an understanding of the extent to which different kinds of trust enables information-sharing across organizational boundaries. A widespread conceptualization across relationship marketing, buyer-supplier relationships, interorganizational relationships, and supply chain management literature includes the interpersonal and organizational dimensions of trust and distinguishes between competence-based and integrity-based trust (Connelly *et al.*, 2018). Despite minor variations in the applied terminologies especially between *integrity trust* and *goodwill trust*, the notion of competence-based and integrity-based trust has gradually grown out of the stream of trust literature (Dyer and Chu, 2003; Mayer *et al.*, 1995; Newell *et al.*, 2019). The distinction between the two types of trust is whether it is related to handle a specific task thus domain specific or related to partner/organization thus across domains (Connelly *et al.*, 2018).

Competence-based trust is domain specific (Connelly *et al.* 2018) and refers to the extent to which the other organization is perceived to possess sufficient resources (Newell *et al.*, 2019), technical and managerial skills (Sako, 1992), and knowledge (Becerra *et al.*, 2008) to perform something (Blomqvist, 1997). Competence-based trust provides practitioners sufficient assurance that the other organization is capable of performing a given task in compliance with handed over information and/or guidelines. According to Connelly *et al.* (2018), the focal point for competence-based trust is instrumental motives, which means the repeated cycles of interaction are mainly driven by expectation to handle specific problems. Thus, competence-based trust is related to the expectation of whether the other organization has sufficient resources, skills, experience, and reliability to fulfil specific obligations.

While the above competence-based trust revolves around instrumental motives, the integrity-based trust is mainly rooted in a perception of a partner/organization's social and attitudinal motives across domains (Connelly *et al.*, 2018). This type of trust includes perceived openness and good intentions to resolve one's differences (Blomqvist 1997) and norms of reciprocity (Ireland *et al.*, 2007), which includes willingness to adapt to the other party (Uzzi, 1997) and thereby jointly exploit new opportunities (Sako, 1992). Integrity-based trust revolves around alignment of values and the extent to which the interacting practitioners adhere to a set of principles that both consider acceptable (Mayer *et al.*, 1995). In other words, integrity-base trust is rooted in a willingness to adaptations, both in tangible and intangible asset. Based on the above, the nature of trust can be digital-based, competence-based, and integrity-based. In the following, the prerequisite of trust-based interaction is presented.

Pre-requisites of Trust-based Interactions

Trust embedded in an arm's length relationship functions as the social glue for sharing information (Laeequddin *et al.*, 2010), but in itself an arm's length relationship cannot trigger the process of sharing information. Given that trust is embedded (Uzzi, 1997) and situational (Dyer and Chu, 2003), the prerequisite of trust unfolds when practitioners have the intention to or are involved in a cycle of interaction in which one or both of the interacting partner(s) lack information (Blomqvist, 1997). Daily exchanges of information in areas such as strategy, products, services etc. make up complex patterns of interaction across organizational boundaries (Araujo *et al.*, 1999). To gain an understanding of the prerequisites of trust-based interaction it seems necessary to categorize the patterns of interaction into manageable types.

To study the nexus between different types of trust related to sharing easily-codified information in buyer-supplier relationships Newell *et al.* (2019) draw on a distinction between strategic, tactical, and operational information. This distinction is prevalent in supply chain management literature (Handfield et al., 2011, p. 216; Slack and Brandon-jones, 2019, p. 321). For instance, Slack and Brandon-Jones (2019) focus on the level of details in strategic, tactical and operational information. Handfield et al. (2011) draws on a portfolio approach to shed light on differences in relation to the function of interaction cycles, clearly illustrating how interacting organizations are involved in many interactions. This paper does not only focus on easily-codified information as Newell *et al.* (2019), but include more or less codified information (like Becerra (2008)) and utilize the strategic, tactical, and operational taxonomy.

Strategic information is long-termed and focuses on acquiring a sufficient base level of different types of capacities and/or capabilities downstream, intra-organizationally and upstream. Strategic information lacks details and the cycles of interaction often involve intense negotiations before achieving common ground (Whittington *et al.*, 2020).

Tactical information is medium-termed and is more limited in scope compared with strategic information. Development of products/services or business processes at the tactical level normally involve across disciplinary interaction (Handfield et al., 2011), which however have to comply with the strategies of the interacting companies (Whittington *et al.*, 2020). Tactical information-sharing across disciplinary domain is characterized by some negotiations (Dyer and Chu, 2003). Compared with strategic information tactical information is more detailed (Newell *et al.*, 2019), but not as detailed as operational information.

Operational information is short-termed and deals with handling day-to-day business decisions in order to optimize activities across organizational boundaries; it involves interventions to resources to absorb deviations from plans (Slack and Brandon-Jones, 2019). Operational information is mainly used to execute orders, to correct plans, and to implement workarounds. Standardization, routines and effectivity are central (Slack and Brandon-Jones, 2019), which entails that operational information is detailed and precise.

Outcome of Trust

Trust embedded in a relationship enables information-sharing. Shared information differs in substance (Carlile, 2004; Becerra *et al.*, 2008). While researchers agree on a nexus between different nature of trust and different substance of the shared information (Newell *et al.*, 2019), the conceptualization of the information substance varies; public versus private information (Uzzi and Lancaster, 2003), codified versus uncodified information (Becerra *et al.*, 2008) or syntactic, semantic versus pragmatic information (Carlile, 2004). The latter is a frequently used distinction to study information-sharing across disciplinary boundaries. Thus, this study subscribes to the syntactic, semantic and pragmatic categorization.

Carlile (2004) combines the Shannon–Weaver model of transmitting information (Shannon and Weaver, 1964) with classical pragmatism to suggest three approaches to information-sharing; the transfer of syntactic information, the translation of semantic information and the transformation of pragmatic information. The distinction between the three types of information depends on the differences and dependences across the interacting organizations (Carlile, 2004). Differences and dependences are inherent in doing business because "*no business is an island*" (Håkansson and Snehota, 2006). While differences arise as consequences across disciplinary collaboration, the dependencies occur due to technical and coordinative issues (Carlile, 2004). Sharing syntactic information means no differences or dependencies, sharing semantic information involves some differences and dependencies, and sharing pragmatic information entails high differences and dependences (Kellogg *et al.*, 2006).

Whether a syntactic, semantic or pragmatic information is workable or not depends entirely on the practitioners' opportunities to gain a common understanding of the transmitted information (Bechky, 2003). The focal point for making information understandable is the extent to which the practitioners/organizations are capable of levelling out the differences and dependences (Le Dain and Merminod, 2014). It might involve the use of legal requirements, standards, rules, and software-codes embedded in IT-systems, or development specifications, the use of common language by the interacting practitioners and negotiations (Carlile, 2004).

Syntactic information is directly workable (Nonaka, 1994) as it can be codified in standards, rules, regulations, and thus embedded in various software applications. The involved organizations are familiar with the syntax being used; a shared and sufficient syntax has been established. Carlile (2004) denotes this kind of information-sharing as a transfer process; it is efficient because differences and dependences have been specified and resolved in advance.

To make semantic information workable requires interpretations. Increasing differences and dependences result in standards, rules, and procedures can impede the information-sharing. This means that the criterion for making semantic information useful across disciplinary boundaries is the achievement of a common understanding, which often requires mutual interpretation and in some situations negotiation (Kellogg *et al.*, 2006). According to Carlile (2004) if facing semantic information, a translation approach is required.

Pragmatic information is localized, invested in, and domain specific (Bechky, 2003), thus rooted in the habitual way of working (Kellogg *et al.*, 2006) and inseparable from the practitioners' interests (Le Dain and Merminod, 2014). Because of this investment in the way of working and very likely divergent interests, something is at stake when sharing pragmatic information. In other words, intense negotiations are pivotal for making pragmatic information workable, which requires a transformation approach (Carlile, 2004).

Analytical Framework for Trust

Trust is individualized, but the processes of forming trust involve social interaction among practitioners and interactions with technologies; illustrated in the grey ellipse in Figure 5. Trust influences information-sharing and is simultaneously influenced by the information being shared. As trust is multidimensional, the analytical framework operates with prerequisite for trust listed in the left part of Figure 5, nature of trust depicted in the middle part of the Figure, and outcome of trust presented in the right part of the Figure. The dotted lines from Prerequisite to Nature and to Outcome illustrates a nexus between the three different levels.

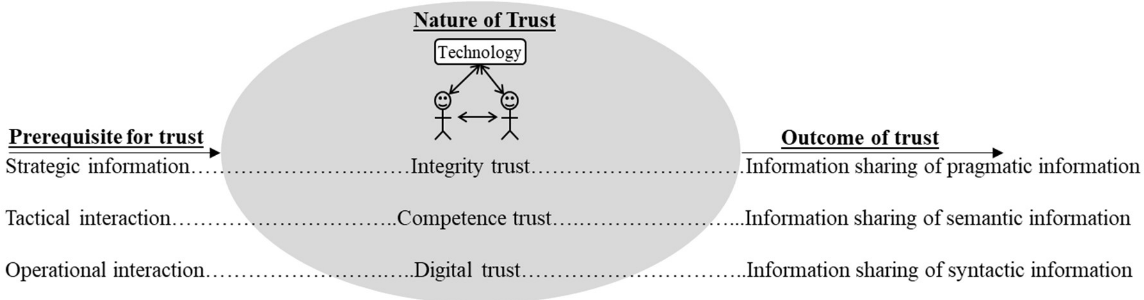

Figure 5: The Analytical Framework on Trust

4.2.2. Blockchain Technology

Blockchain's connection to information-sharing may not be apparent to everyone, but put in simple terms blockchain can be said to be a particular kind of information-sharing that is made possible through digital technology (Longo *et al.*, 2019; Nandi *et al.*, 2020). According to Hastig and Sodhi (2020) blockchain technology has two notable characteristics that should be understood (Hastig and Sodhi, 2020). First is its distributed nature, that practically means that all members of the blockchain network has a copy of the history of transactions that have occurred amongst the peers in the network (Wang, Han, *et al.*, 2019). Second is what is referred to as a "system of trust" which refers the blockchain´s users having to validate and agree on any change made in the blockchain network through consensus mechanisms (Cole et al., 2019).

Because of the distributed nature and consensus mechanism, a distinctive trait of blockchain is that the data stored is immutable; i.e. unchangeable once recorded in a block of information. For that reason it is also append-only; i.e. while former data points (blocks) cannot be changed, a new data point (block) can still be added to "update" the (block)chain of information (Carvalho *et al.*, 2021). These characteristics make blockchain appropriate for keeping accurate histories, traceability (Hastig and Sodhi, 2020) and transparency (Saberi *et al.*, 2019a). These characteristics makes blockchain an intriguing way to improve information security and transparency (Swan, 2019) and the technology enables a unique medium for recording information from value production to value actualization (Pazaitis *et al.*, 2017).

Blockchain Use Cases and Technology Maturity

The application of blockchain is at a nascent stage (Martinez *et al.*, 2019). The focal point for studying blockchain forefronts technological matters rather than the practical application in supply chains (Angelis and da Silva, 2019). Yet, some researchers have explored the potential impact on supply chains (Cole *et al.*, 2019), while the number of practical applications remain limited (Roeck *et al.*, 2019). It indicates a low Technology Readiness Level (TRL) of blockchain. TRL is a taxonomy system to evaluate the maturity level of a particular technology (Moni *et al.*, 2019); from 1 (low maturity) to 9 (high maturity). These nine TRL levels are grouped into three stages; 1-3 indicates conceptual stage, 4-6 implies development stage and 7-9 demonstrates deployment in operational contexts. With the purpose of gaining an understanding of the current maturity level, the authors of this paper evaluated the papers in a pre-existing systematic literature review of blockchain use-cases in supply chains (Holm and Goduscheit, 2020a). Table I draws on these findings and presents use-case examples, maturity level and the original source of the use-cases.

Table 3: Use-cases addressing supply chain management

Application of blockchain – user case	Maturity level	Original source
Tracing the provenance of products in supply chains	Concept	Montecchi et al., 2019
Concept for a platform intended to reduce container (air) space	Concept	Tan et al., 2018
Concept for handling cyber-physical supply chains	Concept	Dolgui *et al.*, 2019
Concept for Cannabis tracking in Canada	Concept	Abelseth, 2018
Smart contract-based tracking process	Concept	Chang et al., 2019
Supply chain traceability using the "Unified Theory of Acceptance and Use of Technology" framework	Concept	Francisco and Swanson, 2018
Maritime Labs case: Online auditing and processing of dangerous goods	Concept	Yang, 2019
Concept for improving data quality in emerging markets (fashion industry)	Concept	Choi and Luo, 2019
Blockchain's impact on additive manufacturing	Concept	Kurpjuweit *et al.*, 2019
Concept for ubiquitous manufacturing platform	Concept	Barenji *et al.*, 2019
General impact in operations and supply chain management Concept for air logistics	Concept	Cole et al., 2019
Certification of origin, authenticity and integrity	Concept	Longo et al., 2019
Pharmaceuticals industry consortium seeking to trace pharmaceuticals	Development	Lacity, 2018
Concept for open innovation in product design and innovation more feasible	Development	Rahmanzadeh et al., 2019
Mixed Integer Non-Linear Programming model for supply chains sustainability	Development	Manupati *et al.*, 2019
Prototype for customer management processes	Development	Martinez *et al.*, 2019
Open Music Initiative case	Development	Arcos, 2018
Tracking environmental impact from suppliers (food and beverage company) Tracking products on the retail shelf back to the producer(s) International shipping to enhance documentation of the flow of goods	Deployment	van Hoek, 2019
Food Trust (IBM): Tracking the provenance of food items Food-product provenance	Deployment	Scuderi et al. 2019
Moog: Traditional manufacturing decentralizing their manufacturing set-ups.	Deployment	Lacity, 2018
Tradelens (IBM): Sharing documents in real time, improving transparency	Deployment	Yang, 2019
Everledger diamond time-lapse case: Provenance tracking for ethical purposes	Deployment	Choi, 2019

As it appears from Table 3, the majority of use-cases are at the conceptual stage. The conceptual use-cases suggest blockchain-solutions for various purposes, such as customer order management (Martinez et al., 2019), product design (Rahmanzadeh *et al*, 2019) and reducing information asymmetry (Longo et al., 2019). The common denominator for the conceptual use-cases is blurred, but it seems they are more innovative suggesting fundamental new information-sharing approaches compared to the more mature blockchain use-cases.

Only few of the use-cases are at the deployment stage. These use-cases address issues related to enhancing the accessibility of operational information, such as IBM's TradeLens (Yang, 2019) seeking to automate the sharing of shipping documentation in the logistics industry. In the same line of thought, both the Everledger use-cases (Choi, 2019) and IBM's Food Trust (Scuderi *et al.*, 2019) shed light on the origin of diamonds and food items respectively. Another article presents two tracking-related use-cases, of operational information; one focus on environmental impacts of food and beverage products, while the other deal with backward traceability; from retail to the original supplier (van Hoek, 2019).

In general, use-cases at the development stage are prototypes, which still are in the early testing phases; for instance, the Open Music Initiative (Arcos, 2018) share operational information, which recently has moved from "*lab to pilot platform*". Other examples are the application of blockchain prototype to simulate customer order management (Martinez *et al.*, 2019) and a MATLAB-based testing of a mixed integer non-linear programming model for supply chain sustainability (Manupati *et al.*, 2019).

The above use-cases contribute valuable insight in opportunities for sharing information across organizational boundaries. Conceptual use-cases suggest new applications of blockchain to enable different types of information-sharing. Deployment use-cases forefront traceability of operational information. Development use-cases address both traceability of and improved transparency of operational information; these are more innovative than deployment use-cases, but still not as innovative as the conceptual use-cases. Despite the substance of the information being shared in conceptual, development, and deployment use-cases differs, the conceptualization of trust across the use-cases listed in Table 3 seems be at random. Some researchers neglect trust completely (Choi, 2019) while others mention trust as a black box phenomenon (Martinez *et al.*, 2019). Only three use-cases, all at the conceptual stage, open up the black box of trust (Cole *et al.*, 2019a; Francisco and Swanson, 2018; Longo *et al.*, 2019).

Francisco and Swanson (2018) consider trust to be the focal point of blockchain. Their viewpoint is that trust is not between the participants involved in the interaction, but related to the distributed character of and the credibility of the information inscribed in the chain of blocks: in other words, trust is embedded in the consensus-based updates of blocks. These consensus-based updates facilitate practitioners with no pre-established relationship to share information across boundaries. Another stream of research focus on the underlying consensus-based mechanics and forefronts digital matters as data encryption and coding in blockchains (Cole *et al.*, 2019), cryptography (Rahmadika and Rhee, 2018), keying and hashing (Hald and Kinra, 2019), writing in and reading of immutable blocks (Pedersen *et al.*, 2019).

The consensus-based mechanisms embedded in blockchain are portrayed to replace third parties involved in governing the legitimacy of transactions (Engelhardt, 2017), to replace personal trust (Schmidt and Wagner, 2019), are substituted for trust rather than forming trust (Ferrer-Gomila *et al.*, 2019), to form a trust-free (Pedersen *et al.*, 2019) or trustless environment for the interactions (Cole *et al.*, 2019). Seidel (2018) goes a step further stating that the distributed consensus-based mechanism has a positive influence on handling coordination issues and thus renders current supply chain theory outdated.

However, a group of researchers challenges the above one-dimensional conceptualization of trust and suggest a more varied picture of the extent to which blockchain has an influencing role of forming trust (Connelly *et al.*, 2018; Hald and Kinra, 2019). As this study echoes this viewpoint, the following sections conceptualize the analytical framework to gain a more fine-grain understanding of the practical usefulness of blockchains to govern supply chains.

4.3. Methodical Considerations and Methods

As there are only a few deployed (highly mature) supply chain-based blockchain use-cases, the use of inductive logic to generate theory from an empirical setting is inappropriate (Ketokivi and Choi, 2014), as is the use of deductive logic due to the lack of general theories for blockchain (Yin, 2003). An abduction-based logic (Dubois and Gadde, 2002), is therefore chosen as it allows elaboration of theory by bridging (Kovács and Spens, 2005), the nascent blockchain topic with the well-established theory on trust. This logic has been used in past research to elaborate on blockchain's impact on established theory, such as Transaction Cost Economics (Roeck *et al.*, 2019), Customer Order Management (Martinez et al., 2019) and the Resource-Based View (Nandi *et al.*, 2020).

4.3.1. Research Design and Setting

The applied research design is illustrated on Figure 6 in which the iterative focuses on theoretical and empirical evidence is shown in terms of their development during the research. This paper is preceded by a systematic literature review of blockchain use-cases and unstructured interviews with two OEMs, a system supplier and a non-profit organization. The empirical findings and theoretical foundations of this paper is however, focused on other things and as such, it is these aspects that will be addressed further. The empirical evidence of the paper initiated with a focus group, where senior supply chain actors provided insights on their view on the applicability of blockchain in the wind industry supply chain.

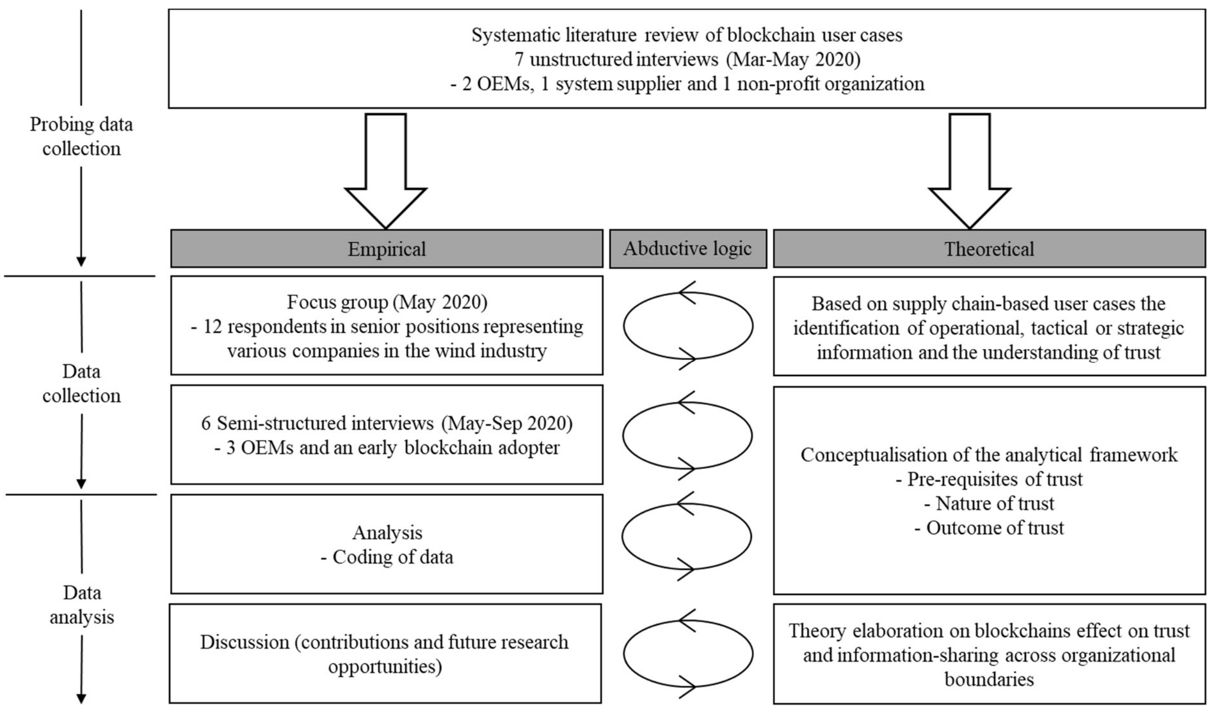

Figure 6: Research Design of the Paper around here

For this paper the empirical setting is the wind industry, due to its innovative initiatives being characterized by taking place across organizational boundaries over 30 years (Andersen and Drejer, 2008), as well as its challenges with production bottlenecks and maintenance of turbines being cost-heavy (Sovacool and Enevoldsen, 2015). These characteristics are all fitting for the supply chain-based blockchain technology as it seeks to cross organizational boundaries and potentially being capable of reducing bottlenecks and complexity in maintenance through information-sharing.

4.3.2. Data Collection

A focus group consisting of 12 participants representing major turbine manufacturers, turbine owners, system suppliers, component suppliers and supply chain service suppliers across 14 different companies. Two themes were in focus; (1) data transparency and sharing of data between supply chain partners and (2) on the trust between supply chain partners. The five semi-structured interviews were conducted with three globally leading OEMs and the only known blockchain solution provider within the wind industry.

The initiating focus group interview lasted two hours and had three of the four authors facilitate the focus group, while the fourth observed and took notes. The semi-structured interviews were recorded and transcribed and lasted 1-2 hours with additional notes being taken during the interviews. Interviews conducted in Danish were translated to English following the interviews. All four authors took an active role in the semi-structured interviews, ultimately aiding in reducing interviewer biases (Kallio *et al.*, 2016). To guide the semi-structured interviews a questionnaire was developed, which in alignment with Dubois & Gadde (2002) was continuously modified as the research developed theoretically and empirically. As a consequence of COVID-19 all data collection was conducted online.

4.3.3. Data Analysis: Qualitative Coding

In order to create a coherent story from the semi-structured interviews (Miles *et al*., 2013), a well-defined coding process is needed to ensure scientific rigor (Linneberg and Korsgaard, 2019). The coding process follows an inductive logic in which the authors of this paper, create themes of findings based on the qualitative data (Gioia *et al.*, 2013) obtained through the semi-structured interviews.

4.4. Empirical Findings and analysis

This section presents the primary data in themes based on the contents of the interviews conducted during the data collection process. Three general themes have been inductively identified during the qualitative coding of the collected data from the wind turbine industry blockchain use case.

4.4.1. Handling product updates and master data

Across all interviews the process of handling product updates and changes to product documentation, was mentioned as a process were the wind supply chain interviewees seems to find a need for alignment of data, and reflects on the potential of using blockchain technology. The change process covers changes to the product documentation, the bill of material, work instructions etc. In nature, it is a cross-functional and cross-organizational process, and involves both strategical, tactical and operational interactions. All interviewees points at the importance of having an integrated process for handling changes to products and at the same time realizing that in reality it is not happening. An example of the operational interaction from Interview D: *"If a designer he is done with his task, well then send directly to the supplier automatically who then gives his input and reviews these specifications"* shows a wish to automate the exchange of data, an operational interaction. On a tactical/strategical level Interview A explains how they have created a "Digital Twin" of a product, i.e. a digital duplication of the product specification and attribute information, *"We have digital twins of ships….. We monitor and verify that what is being said, that is being produced, fits with the requirements."*. In this example the digital twin is used on more levels, tactical to monitor and apply changes to the product (ships) and operational, to audit and verify that specifications are met during production and service of the product.

Listening to the interviewees they point at competence trust (semantic information) and digital trust (syntactic information) as the foundation for the process of handling product changes. There seems to be a need to control the work on the process, Interviewee D: *"There are also some who need to check and so on or the other flows in the process*". Also, the digital trust is visible when Interviewee D points at the need for standardization *"I guess that. Engineering Change Management must operate almost in the same way more or less in most industrial or large industrial enterprises"*. The interviewees point at the outcome of the trust, is sharing of information based on the blockchain technology, Interviewee D: *"So if the data it's first generated- then it should in the form of a blockchain in the form of a single or other flow being trigged* *by a blockchain Then maybe it should just land at the customer strait away instead of us going to collect everything"* - a semantic- or syntactic information-sharing.

Another theme raised by the interviewees are the handling of supply chain master data. This covers many different data types depending on the business process where the data is used. Applying a block chain in supply chain for master data handling, requires a thorough mapping of master data. Interviewee A represents a company offering to help customers through the mapping and preparation, Interviewee A: *"We are helping the customers who need a blockchain by mapping the relevant data collection points, and define a process for data collection, that is safe and robust, because this is where the weakness is in a blockchain – if you enter poor data the blockchain will share poor data."* In this case a 3. party is helping the customer perform the mapping of the master data to make sure the quality of the data is in place for operating a blockchain.

The scope of the data mapping is operational interactions, digital trust and syntactic information. Interviewee A is also offering to validate the master data *"we also go in and assess whether the data complies with the requirements, that is, in relation to the inspection of valves. To just be the example not. And then you have a digital twin".* The validation is tactical and also connected to auditing processes and data against specifications, competence trust and semantic information. Interviewee A points at the blockchain as a trust creator (digital trust), having the blockchain as the backbone of the supply chain, Interviewee A: *"Blockchain is the technology that will allow us to guarantee the validity of the data in the future world/economy driven on data…Blockchain will become the backbone of future supply chains in the industry"*. The current information-sharing as outcome of the master data management is syntactic information as indicated by Interviewee B: *"So we're not focusing on orders and all these separate things. So we're not tracking, for instance, these data at the moment."* also interviewee D points at the syntactic level (digital trust) of the information-sharing, Interviewee D: *"Well, it's static documentation …. But it's important in terms of quality".* Even though interviewee A offers the opportunity to map and validate data (semantic information), the other interviewees seems to be reluctant to involve a 3. party in the master data management.

4.4.2. Transparency and traceability

The ability to create transparency and visibility of where parts are in a supply chain is of high importance. The need for traceability is expressed by interviewee B: *"It's something as simple as why don't we throw GPS's on all our transport equipment and our transports. So instead of trying to get registrations onto the scanner and so on, so you can get an overview of where your goods are at…. So not only do you know exactly where the thing is, we are not yet, although everyone thinks it is a good idea. But it also needs to be implemented".* The need for visibility is clear and it is also evident that the quest for traceability can be a long way.

The traceability often becomes an operational interaction, and sometimes a 3. party is involved to verify that what have been produced is adhering to specifications, resulting in digital trust and semantic information. The potential of having a blockchain for sharing operational traceability information (semantic information) is evident by interviewee B: *"It may be that a blade has been standing in a port where there is an incredible amount of salted air or something. And then something starts to rust. Eight years later, our department asks if it has stood down at Chennai harbor or something like that. It would be really cool to* *be able to track it in the digital thread"*. Here the interviewee sees a blockchain as a digital tread, a system for tracking and storing syntactic information (data) about a product.

Another application area for a blockchain in the wind supply chain is aftersales service. Interviewee D points at the benefit of having the historic events from running a wind turbine in a blockchain logbook. This would give the service technicians an opportunity to better correct errors at the turbine, interviewee D: *"Change a component on a turbine out at sea also if an entire park needs to be shut down because you don't know if it's a fault on one component or whether it's a genetic flaw on all the wind turbines in the park for example if you quickly go back to see that it was a mistake in work situations. You can see if we have an error on a single component. This means if you shut down an entire park or if you shut down the individual turbine".* The prerequisite for trust is in this case the tactical interaction in the supply chain. The nature of the trust in this case is digital as it is concerned with the data collection, storage and flow in a blockchain as basis for supporting wind turbine technicians in servicing the turbines. The outcome of the trust is information-sharing of syntactic information.

4.4.3. Collaboration

Having relationships to customers and suppliers on different organizational levels is a foundation for operating a supply chain. Implementing a blockchain in a supply chain influences the relationship and the prerequisites for trust between the parties. The empirical findings on supply chain collaboration points at operational interaction being the focal point in the understanding of which business processes the blockchain technology can support, and at the same time interviewees have a focus on blockchain being a universal trust enabler between parties in a wind supply chain, Interviewee A: *"BC based on algorithm creates this trust - where no middleman is needed. This works well for scenarios where data is born and stays digital"* this is further elaborated by Interviewee B: *"Yes, in fact, because if we have a subcontractor to produce the blades, it happens in many cases, we also wants to know that the blade is exactly as it should be according to process and rules, so that must be complied with. And if it can just be documented in such a blockchain, then we know."* It is operational interaction, digital trust and syntactic information being addressed by the interviewees.

Another area of potential for application of blockchain technology in a wind supply chain is the collaboration and integration of planning decisions across entities in the supply chain.

From interview B we learn that it is a complex process to align across planning levels – strategic to operational to secure the ability to deliver to the customer and prerequisites for the process is interaction across all organizational levels, and across company boundaries. Interviewee B: *"It really takes a lot of discipline, and it also requires that we be much more explicit about our business rules that we have that we really want to optimize based on. So we already know that a year-long journey to get there. Everyone thinks it's a good idea, but it takes a while."* The complexity both in terms of data handling and collaboration seems to make it difficult to practise the involvement of all stakeholders.

The interaction becomes operational based on digital or competence trust and the outcome are syntactic information, i.e. purchase orders, confirmations and invoices etc. The type of trust found at the interviewees shows a challenge in trusting the collaboration stakeholders in the supply chain, from interview A this becomes clear *"I honestly believe that there is a long, long way to get to the point where we dare to put a little transparency forward … So if you think that because new technology is coming, suddenly you dare to put your cards on the table. I don't believe that. Everybody's so scared and so pressured in this business"*.

The quote points out that implementing a new technology like Blockchain, creating transparency on data is not going to facilitate a higher level of trust – competence or integrity trust, between the supply chain partners in a wind supply chain.

The nature of trust practised is limited to digital trust, ie. believing in the data, not the competencies or the integrity of the supply chain partners, which is also stressed by interviewee A: *"I do not think we should come up with a vision that in the future we can act together in a way where everyone trusts each other."*. The outcome is that the information shared are operational, Interviewee D: *"As I said in relation to such dates, I don't see what should be secret as such. The only thing I could see might be, and it must apply to any wind company- perhaps how long it takes for one to produce a turbine."*

Part of the supply chain collaboration is the after-sales service processes. This is characterized by long contracts and highly skilled service technicians making sure the wind turbine is producing. In case the service contract is shifted to another company the acquired experience and knowledge operating the specific wind turbine is not exchanged with the new service provider. This would be tactical and/or strategical information and require competence and integrity trust to exchange. Interviewee C comments on this *"Now there is something about our service contracts running for a certain number of years. Maybe for ten years, maybe for 15 years, maybe even 20 years. But it could actually happen that it was another OEM who was taking over service at our turbines. We may not be so interested in that, they can just read all the data from our supplier. From start to now and I think it's going to be a major road block."* As it is today in wind supply chain, the trust level in the supply chain collaboration does not support having a blockchain as the backbone for the service-related data. Listening to the interviewees the current system integration is on an operational level, EDI based exchange of orders, confirmation, invoices and payments etc. According to interviewee A blockchain will be the future basis for trusting the information exchange in the supply chain *"BC is a technology to make sure data can be trusted. BC is a digital asset BC will be the back bone of future supply chain"* This calls for a focus on not just operational interaction but also tactical and strategical interaction.

Another example of the operational information focus and digital trust level, is presented by interviewee B, describing the collaboration with a transport supplier in a case of traceability for transport of turbine parts Interviewee B: *"It is our freight forwarder, they are connected to it, when they register on their devices, then we get the information, which events simply. Then you don't have to call them and ask Where is it? You can see this in the system that tells you that the system you. And it also tells if something should have happened that hasn't happened yet and then it becomes more exceptional action."*. This quote shows that focus is on the digital trust and operational interaction. Interviewee C describes the level of trust in wind supply chain collaboration like this *"I think that's what you have to do. You have to make some agreements between two companies. There is so little (Trust) today that you protect yourself and make a patent. Then you hide a little and set up some shields, because no one is going to steal this data from me… One must have some data exchange agreements in place"* This quote clearly says that the trust level in supply chain collaboration in wind is on a digital level, contracts is needed to regulate any cooperation.

4.5. Discussion

This paper was guided by a research question on the potential of blockchain to enable trust across organizational boundaries. This section presents the theoretical contribution of the paper, the managerial implications that can be derived from the analysis, the limitations of the paper and indications of future research within the field.

This paper claims that the line of inquiring in the prevalent blockchain literature: i) Draws on a one-dimensional conceptualization of trust, which contrasts other research that suggests that trust is multidimensional (Ireland and Webb, 2007). ii) Explicates trust as being enabled by purely digital matters, which conflicts with the viewpoint that trust is a micro-level phenomenon (Dyer and Chu, 2003) and influenced by social matters (Uzzi, 1997). iii) Presents a static view of trust, which is diametrically opposed to trust researchers highlighting trust as being situational (Blomqvist, 1997) and malleable (Özer and Zheng, 2017). iiii) Based on a systematic literature review (Holm and Goduscheit, 2020) it seems that only use-cases at the conceptual stage address trust, meaning we lack a practice-based understanding of how blockchain technologies can influence the trust dimension in complex supply chains.

4.5.1. Theoretical Implications

Prior literature has claimed that the blockchain technology facilitates a situation where 'system trust replaces personal trust with a wide range of implications' and that 'transactions can be conducted without personal trust between the parties, as blockchain provides consensus mechanisms to establish a valid state of truth' (Schmidt and Wagner, 2019). This paper paints a somewhat more complex picture of the qualities of the blockchain technology as a substitute for trust within the supply chain.

Our first observation is aimed at the gap between the conceptual potential and the actual implementation of the blockchain technology. Blockchain use-cases contribute valuable insight in opportunities for sharing information across organizational boundaries. Conceptual use-cases suggest new applications of blockchain to enable different types of information-sharing, such as customer order management (Martinez et al., 2019), product design (Rahmanzadeh et al., 2019), and reducing information asymmetry (Longo et al., 2019). The common denominator for the conceptual use-cases is blurred, but it seems these are more innovative and suggests fundamental new information-sharing approaches compared to the more mature blockchain use-cases. Deployment use-cases forefront traceability of operational information. Development use-cases address both traceability of and improved transparency of operational information; these are more innovative than deployment use-cases, but still not as innovative as the conceptual use-cases.

Our second contribution considers the character of the information-sharing within the blockchain. In order to describe our perception of trust in the context of the blockchain, Figure 7 outlines the various prerequisites, natures and outcomes of trust.

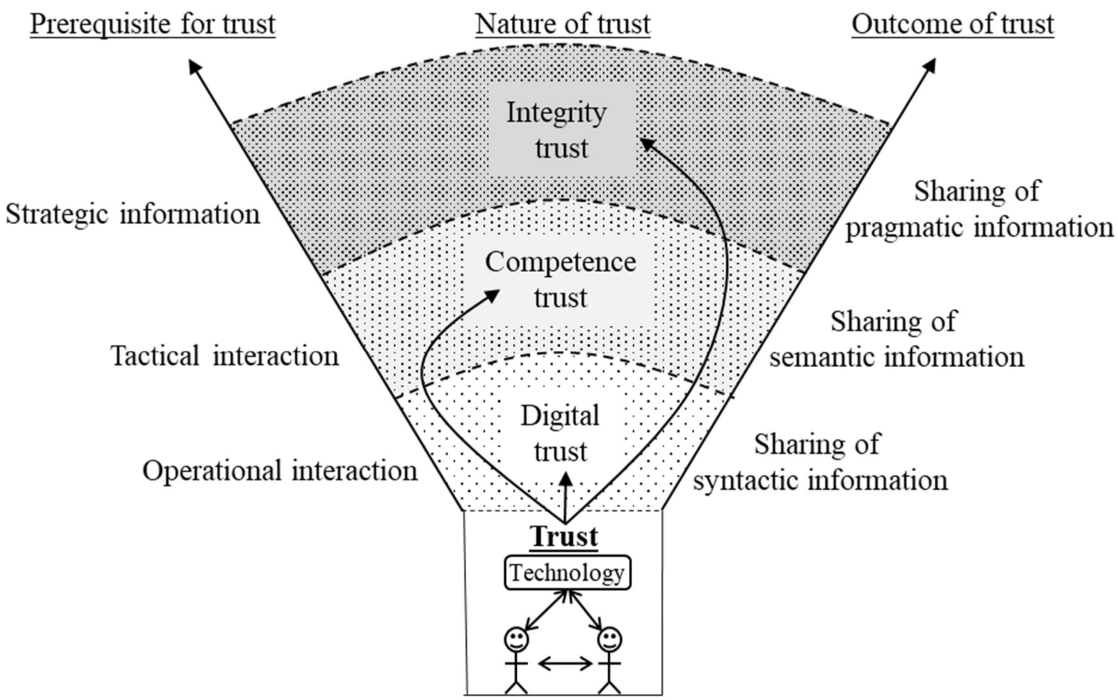

Figure 7: Prerequisite, nature and outcome of trust

Researchers advocating that blockchain is a trustless or trust-building machine (Biggs *et al.*, 2017) only address the outcome of trust and implicitly they subscribe to technological determinism; the viewpoint is that blockchain determines the information-sharing across boundaries. This paper has focused attention on the process of forming trust and thus to open up the black box of the "trustless or trust-building mechanisms" embedded in the blockchain technology. Pedersen *et al.* (2019) among others argue that the consensus-based mechanisms of writing in and reading of immutable blocks are the enabler of "peer-2-peer" information-sharing via the internet. However, our findings demonstrate that peer-2-peer information-sharing is not just technologically enabled, as it also involves social matters among practitioners (Uzzi, 1997) as these are often working in various organisational trust domains (Connelly *et al.*, 2018). Likewise, practitioners have different experiences and faculties for trusting the information being shared across boundaries. In other words, when practitioners digitally share information across organisational boundaries, they trust that the blockchain technology functions as expected. Blockchain neither creates trust nor is it a trustless technology. As a process, trust unfolds when practitioners are using a technology to share situational information across organisational boundaries. The theoretical potential of blockchain technology is encompassing all three rings of trust in Figure 7. A recent publication on blockchain-empowered sustainable manufacturing and product lifecycle management (Leng *et al.*, 2020) illustrates how blockchain enables sharing of operational information about transactions, time-stamps throughout the value chain, RFID codes as a means to tracking tools and positioning components etc. These kinds of trust manifestations, which can be located in the first ring of the 'onion' in the Figure 7, are, according to Leng *et al.* (2020) expanded with competence trust: The blockchain is a means to ensure that all parts of the value chain is compliant with respect to accommodation of the (changing) customer and regulatory requirements. The introduction of smart contracts is a way to handle the varying formal and informal expectations is a manifestation of the competence-based trust of blockchains.

Through their description of blockchain in the context of sustainability and product lifecycle, Leng *et al.* (2020) do not limit their perception of the blockchain as a part of competence trust. The authors describe how '*…blockchain can provide a tool for the product lifecycle management community (including designers, manufacturers, assemblers, and manufacturing service providers) to establish a unified database to share product information and make deals, enabling untrusted manufacturers to exchange capabilities and requirements freely*' (Leng *et al.,* 2020, p. 4). Their ideas of the blockchain as a way to ensure that actors that are new to the value chain not only comply with the predefined standards, but also the good intentions and reciprocal line of actions of these new actors, are examples of integrity-based trust in Figure 7.

Our analysis of the application potential of the blockchain technology in the context of the wind industry, however, illustrates that the practitioners are rather far from perceiving the technology as a lever of such deeply rooted trust. The blockchain technology is perceived as a repository of operational interaction. The interview persons stress the blockchain as a way to ensure transparency and traceability in terms of contractual, transactional agreements and the outcome of trust is sharing of syntactic information. The exchange of information is not a part of a collaborative relationship between the different actors within the value chain and a deliberate effort to create dependencies throughout the other companies in the chain. It is merely a tool to reactively identify, for instance, breaches in the value chain if the final product does not comply with the promised performance. Several of the interviewees mention qualities of the blockchain that could potentially be seen as an expression of deeper levels of trust and collaboration. For instance, in Interview A the informant describes the potential of a digital twin to be included into the blockchain. However, in the interviewees' subsequent description it becomes clear that this digital twin is a means to document the specifications of the final product rather than an arena for collaborative development such as suggested by Leng et al. (2020).

Prior literature has been somewhat ambiguous on the role of trust as an object or as a subject in blockchain. Pedersen et al. (2019) go as far as stating that if a relationship between two organizations is marked by trust, there is no need for using blockchain technology. On the other end of the continuum, Newell et al. (2019) emphasize that the lack of established trust, or earlier trust breaches, little to no information-sharing occurs. In other words, the question is whether the blockchain technology is an enabler of trust – or whether a certain level of trust is needed in order to establish a blockchain.

Our analysis of the wind industry identifies the essence of prior trust as a precondition for establishing a blockchain solution. The interviewees stress the concern about the shadow of the future (Dhanaraj and Parkhe, 2006) when for instance sharing data with one supplier in a blockchain. Despite the fact that the OEM has extensive trust towards this supplier, the risk of providing critical information for this supplier and hence losing future control of the data (if the supplier for example chooses to engage with another OEM), represents a barrier. The assumption that there is a substitution effect between (lack of) trust and a blockchain solution does not gain much empirical support from our analysis.

4.5.2. Managerial Implications

From a managerial perspective, embracing the blockchain technology does not appear to be a trivial task. The interviews with the OEM's and other actors within the wind industry identified an immediate interest in blockchain technology and an acknowledgement of the promises of the technology. The informants, however, not only voiced challenges in the ability to grasp the technological and practical implications of blockchain solutions. The willingness to share business critical, delicate and/or proprietary information with other actors in the supply chain was limited. While the theoretical potential in the blockchain technology in an industry like the wind industry is substantial, the practical applicability tends to be scarce.

An implication of this research could be to approach the blockchain technology incrementally. Commencing with a limited blockchain solution with relative few data entries, few actors (only two companies) and a transparent process when changes in the blockchain solution is needed will probably make most sense. Hopefully, this first proof of concept can then spur an interest in expanding the solution to other activities and a larger number of organization and by this harvest a larger portion of the theoretical potential.

4.5.3. Limitations and Suggestions for Future Research

The limited number of actual cases of blockchain solutions within the wind industry sets natural boundaries for the analysis presented in this paper. The collection of data has been aimed at the potentials of the blockchain technology rather than the actual implementation of blockchain solutions. With the growing interest in enhanced quality and transparency within supply chains in general and a surge in the utilization of digitalization specifically, future research could be able to scrutinize real-life examples of blockchain solutions. These future studies can expediently analyze the entire process of the 'blockchain journey'. First, the drivers and barriers will be relevant to map. This will be an analysis that emphasize the role of trust, which this paper has started. Secondly, the analyses can seek to understand the decisions during the actual implementation of the blockchain solution – including the decisions on the platform, the number of actors on the solution, the data fields etc. Thirdly and finally, it would be interesting to be able to assess the impact of the implementation of the blockchain solution. Hence, not only the development of interorganizational relationships (like trust), but also the potential efficiency gains, the quality of the outcomes, the financial performance of the market offerings etc. would be interesting avenues of research.

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4.7. Clarifying the Qualitative Coding Process

For the sake of clarity, this section is not a part of the published article. This section is included to provide additional insights into the qualitative coding process utilized in the paper for the sake of transparency to readers of the dissertation. As mentioned in the paper, the coding is inspired by the Gioia method, which focus on creating order concepts for 1st order coding, themes for 2nd order coding and aggregate dimensions as a final step (Gioia *et al.*, 2013). The paper presented in chapter 4 does not follow the Gioia method strictly, but rather combines the idea of 2nd order themes with aggregating dimensions, thus only using two layers of coding.

As a first step for the analysis work, all interview data was transcribed by one of the authors and keywords and topics were highlighted based on inductive reasoning. In simpler terms, topics that were heavily based around topics such as trust, collaboration and information-sharing were noted down for each interview. The keywords and topics were then given headlines typically based around an actual phrasing of the respondent in order to secure the empirical evidence maintained a low level of interpretation at this stage. Based on this process the 1st order concepts were established.

The 2nd order coding was then initiated by taking the different concepts of the various interviews and trying to identify common themes. This was done by looking to the theoretical foundations established in section 4.2 and looking for commonly utilized blockchain and/or information sharing keywords. Both theme 2 and 3 were made using this method creating the themes of "transparency and traceability" and "collaboration". The first theme presented in the analysis, however, deviated slightly from this as the authors decided that it would be more appropriate to let the first theme be based around the perhaps most commonly addressed topic in the interviews; "Handling product updates and master data". In other words, the first theme is based upon a theoretical framing to a lesser degree than the other two themes.

5. Blockchain for Horizontal Collaboration

The content of this chapter is taken and copied directly from the following research paper produced during the PhD:

Holm, K. and Goduscheit, R.C. (2022) '**Exploring the Opportunities of Blockchain-Enabled Coopetition: Learnings From the Wind Turbine Industry**'. *International Journal of Technology Management*

This paper is accepted for publication, but is at the time of writing not available yet.

5.1. Introduction

The management of technological solutions has grown more complicated in recent years as digital integration has advanced and organisations have become more integrated (Rai *et al.*, 2006). In order to be successful in managing business activities in the modern world, one needs not only to consider the intra-organisational activities of a company, but also the inter-organisational activities (Littler *et al.*, 1998). Naturally, value chain partners, such as suppliers upstream and customers downstream, are amongst the first to be included in one's business activities (Cao and Zhang, 2011), for instance, as seen in entire academic fields on topics such as supply chain management and marketing management (Parente *et al.*, 2008). Therefore digital technologies such as the Internet of Things (IoT) (Manavalan and Jayakrishna, 2019), blockchain (Kumar *et al.*, 2020) etc. have been researched thoroughly in the context of how digital integration may benefit more than just the focal company but also its closest partners. A less-explored phenomenon, however, is when organisations collaborate with their competitors, a venture commonly referred to as coopetition (Bengtsson and Kock, 2000b). This type of inter-organisational collaboration is the focus of this paper. Specifically, this paper will focus on a particular digital technology, the blockchain, due to its characteristic of being a distributed ledger (Reddy *et al.*, 2021) thus being an example of a collaborative-based technology per definition.

Coopetition is not a new term for technology and innovation management, and entire special issues have been dedicated to it (Ritala *et al.*, 2016). Existing coopetition literature emphasizes the potential plus-sum game of competitors that choose to cooperate as opposed to merely competing (Gnyawali and Park, 2011). Much of the prior literature, however, has scrutinized coopetition in relatively abstract terms by stipulating that competitors can indeed gain from more cooperation, while the concrete manifestations of the cooperation have often been neglected. This dearth of thorough analysis appears somewhat surprising since the potential disagreements and conflicts regarding the separation of cooperative from competitive activities have been highlighted in the most seminal articles (Bengtsson and Kock, 2000b).

Recent coopetition research has begun to investigate the role of digitalization and digital platforms as a means for facilitating coopetition. For instance, Cozzolino et al. (2021) discuss how incumbents adapt to the growing presence of digital platforms and find they go through three sequential phases: selective cooperation, allied competition, and selective coopetition. By taking the perspective of incumbents, the study by Cozzolino et al. (2021) presents a unilateral approach on digitalization and coopetition. There is a lack of research which adheres to a more multi-lateral perception of the role of digital technology in coopetition and as such, this paper will focus on the network-based perspective of coopetition (Wilhelm, 2011). In continuation of this, Cozzolino et al. (2021) call upon research that seeks to understand the role of Industry 4.0 technologies like blockchain, IoT etc. This paper aims to fill this gap in existing literature by analysing a cooperation between a long list of both competitors and non-competitors within an emerging network with blockchain as one of the key components.

Specifically, this paper will use the context of a developing blockchain case from the wind turbine industry, which seeks to increase traceability for commodity items. The wind turbine case involves five turbine manufacturers and eleven first tier suppliers of fasteners and bolts, and as such, consists of multiple levels of coopetitive relations. The objective of this paper is to clarify the extent to which blockchain technology has potential for separating the various activities on which two or more competitors can cooperate. Furthermore, the potential limitations of blockchain as a tool for enhancing cooperation between competitors is explored for the sake of presenting a nuanced analysis of blockchain's impact on coopetition. Consequently, this paper aims to answer the research question: *How does the introduction of blockchain technology facilitate coopetition?*

5.2. Theoretical Foundations

This section provides a background of the fundamental terms and theories discussed in the paper. It takes its offset in general coopetition literature and proceeds to introduce blockchain technology including arguments as to why the technology has particularly interesting characteristics for coopetition research.

5.2.1. Coopetition

In their seminal paper, Bengtsson and Kock (2000) define competitors as actors that produce and market the same products, and they describe cooperation as the collective action of individuals to achieve a common goal. While the relationship between competitors is, per definition, associated with competition, it can also be marked by actions of a more cooperation-based nature (Ritala and Hurmelinna-Laukkanen, 2009). Instances of coopetition are characterized both by the complexity in the paradoxical nature of the relationship between the involved parties, as well as the unique opportunities in which these parties may endeavour (Bengtsson and Kock, 2000b).

The underlying premise of coopetition is that the collaboration between competitors can increase 'the business pie', which can be shared by the actors (Peng *et al.*, 2018). As such, the cooperation can be a plus-sum game for the actors as an alternative to arms-length competition (Gnyawali and Park, 2011, 2009). This means that temporary coopetition-based innovation creates more value than individual companies would be able to make on their own, thus leaving more value to later be competed for by the actors (Ritala and Huizingh, 2014). Put in simple terms, coopetition occurs when organizations are able to put on the shoes of the competitor, thus being able to predict and understand their reactions. This is key for the joint venture between competitors to be successful, as the organizations need a strong understanding of the 'game' they are in with their competitors in order to play it well (Nalebuff and Brandenburger, 1996). An example of the outcome is that the degree of innovation for companies participating in coopetition has been shown to increase when it comes to developing technological capabilities (Ribeiro-Soriano *et al.*, 2016).

5.2.2. Coopetition from a multilateral perspective

Coopetition has been explored from more than one point of view including dyadic perspective, triadic perspective, and network perspectives. The dyadic perspective, in which two organisations' perspectives are taken, is the most commonly explored take on coopetition (Pathak *et al.*, 2014), while triadic (with three involved parties) relations are also explored to a lesser extent (Wu *et al.*, 2010). The network perspective in which full ecosystems are explored is rare and complicated as many organizations are involved and even indirect competitors must be taken into account (Zerbini and Castaldo, 2007). Finally, the connection between how dyadic and network levels can be linked together has also been explored (Wilhelm, 2011).

Research on the influence of digital integration on coopetition is scarce and mostly addresses how digital platforms causes disruption in industries and ecosystems (Cozzolino *et al.*, 2021). Prior studies have not focused on how digital integration is utilized as a way to enhance or simplify coopetitive relations between organizations by incorporating digital technology.

5.2.3. Coopetition as a dichotomous variable

Currently research on coopetition sees the phenomenon as a dichotomous variable, i.e., competitors either cooperate or they do not (Gnyawali *et al.*, 2016). As a consequence, there is little nuance in the current literature which scrutinizes when competitors will gain value from cooperating and as such, the conditions and antecedents of coopetition remains relatively unknown (Ritala *et al.*, 2016). Case studies on Business-to-Business (B2B) relationships hint to the tendency that supply chain management and marketing activities are more prone to cooperation between competitors than other business areas (Golgeci *et al.*, 2019). Nevertheless, an extensive analysis of the 'coopetition potential' of various business areas has not been presented. In continuation of this observed gap in coopetition literature, the practical implications involved in the decision-making processes on where the limits of cooperation between competitors occur remain to be properly addressed.

5.2.4. Coopetition and Blockchain

The role of digital integration on one hand and delimitation of cooperative vs. competitive areas of business on the other have not, to the authors' knowledge, been systematically addressed in prior studies. The use of blockchain technology could exemplify an approach to digital integration that would enable a meaningful tool for disentangling these business areas. Several arguments can be made for this viewpoint.

Argument 1: Since blockchain is defined as a distributed database that records transactional data or other information (Cole *et al.*, 2019b), the technology is in itself reliant on cooperation between multiple parties. These cooperative pre-requisites are described as some of the most substantial challenges to overcome for blockchain to be successful (Lacity and van Hoek, 2021a).

Argument 2: In continuation of the first argument, the blockchain technology is a decentralized structure where all actors with an access to the blockchain principally have the same rights and obligations. Studies on digital platforms tend to focus on the role of one dominant (large) actor and its possibilities to orchestrate a long list of (smaller) other actors. This has for instance been analysed in the context of Amazon and its customers and other actors within the value chain (Aversa *et al.*, 2020; Ritala *et al.*, 2014). Similarly, research has sought to understand the role of digital integration within cooperation between competitor giants like Samsung Electronics and Sony Corporation (Gnyawali and Park, 2011). The decentralized structure of the blockchain technology does not imply an implicit power structure and, hence, seem more suitable as an empirical setting for the study of coopetition. Further research into SMEs specifically have been addressed as desirable in order to better understand the context and environment in which coopetition may occur (Ritala *et al.*, 2016).

Argument 3: Finally, a common denominator between blockchain and coopetition research is the focus on social aspects like trust (Czakon and Czernek, 2016; Pedersen *et al.*, 2019) and governance (Mariani, 2016; Zachariadis *et al.*, 2019). This characteristic of a need to focus on social interactions in order to be successful is not exclusive to blockchain in a technological perspective, just as social aspects are not just important for coopetition, but all relations. This, however, only means that it is more imperative to uncover the connections between interorganizational-founded collaborative relations and technological solutions that are heavily reliant on them for their successful application.

Existing studies have acknowledged the coopetitive paradox of simultaneous collaboration and competition as an issue to be solved for blockchain to grow in scale (Carson *et al.*, 2018), while other studies simulate the benefit of cloud computing providers forming temporary coopetitive relation (Taghavi *et al.*, 2018). While the connection between blockchain and coopetition is mostly unexplored, one paper does explore how tokenization (i.e., tying a product to a digital currency, representing its value in the virtual world) could be used for creating a coopetitive environment for the benefit of new opportunities in circular economy (Narayan and Tidström, 2020). Tokenization is, however, just one general use case of blockchain and this paper will address another common blockchain use, i.e., provenance-tracking of an asset throughout its lifetime (Montecchi *et al.*, 2019).

5.2.5. Coopetition from a technology management perspective

This sub-section seeks to uncover existing coopetition research within the general field of technology management in order to provide the reader with an understanding of the current state of coopetition within the field. In an article serving as the introduction to a special issue in the International Journal of Technology Management on coopetition and innovation, the current state of coopetition is summarized into four major discourses (Ritala *et al.*, 2016): *Cause-and-effect,* referring to coopetition's effect and consequences on innovation outcomes. *Processes and practices,* referring to the effects of the paradoxical, simultaneous cooperation, and competition and the tensions, dynamics, and interactions it causes. *Strategy,* referring to how value is appropriated and created in coopetition. *Embeddedness,* referring to coopetitive innovation based in networks and ecosystems.

Empathizing the importance of coopetition in technology management, a study on the importance of knowledge-sharing for high-tech companies shows how coopetition contributes positively to the a holistic knowledge-sharing framework (Shih *et al.*, 2006). Coopetition's positive impact on technology management is further elaborated in a paper where the role of proximity in coopetitive alliances is explored, and where it is found that technological proximity (similar technological understanding) between organizations was key to successful coopetitive innovation (Jakobsen and Steinmo, 2016). Furthermore, the study showed that cognitive proximity (common understanding and effective communication) had high importance for innovation development, while social proximity (social relationships) helps build trust and lessen tension between competitors.

Organisations involved in coopetition networks is found to achieve a higher degree of corporate innovation when they put themselves into the centre of coopetitive network as opposed to the periphery, and that the increased innovativeness achieved results in improved financial outcomes as well (Baierl *et al.*, 2016).

Some papers focus specifically on how SMEs may benefit from coopetition by being able to better resist environmental forces and reduce risks by collaborating (Granata *et al.*, 2016). SMEs may also benefit from coopetitive relationships by joining bands and taking advantage of the market leader's innovations (Lim *et al.*, 2010).

5.3. Methodology

This paper will make use of a case study approach (Eisenhardt, 1989) due to the topic of blockchain being relatively new and the context to coopetition being relatively unexplored thus benefitting from qualitative, empirical data. This paper focuses on a project from the wind industry, in which qualitative data is collected from stakeholders involved in said project. The following sub-sections will first explain the choice of using a case study strategy, then present the wind industry blockchain case and then proceed to present the techniques used for data acquisition and analysis.

5.3.1. Case Study

The paper's offset in coopetition research shows how blockchain shares topical interests with coopetition as the information-sharing technology requires cooperation between partners to be successful due to its distributed nature (Lacity and van Hoek, 2021a). In order to better understand this aspect of both coopetition and blockchain, the logical approach is therefore to understand the collaboration between the actors in such situations. As such, a qualitative approach seems most appropriate and as the purpose of this paper is neither to test or generate new theories, but rather elaborate on existing ones, the case study provides an ideal strategy for this paper (Ketokivi and Choi, 2014).

While a singular case study is often associated with being difficult to generalize from, it has also been argued that the right case study may in fact be optimal to generalize from if it is strategically chosen to be representable of a phenomenon (Flyvbjerg, 2006). Flyvbjerg (2006) argues that a strategy for selection of a single case can be either random or information-oriented, the latter of which is the case for this paper. This paper's case is chosen due to three factors: First, the case is chosen because it is an ongoing case in which deep detail on both coopetition and blockchain can be acquired. Secondly, the case is chosen because of its unique aspects that offers insights into coopetition that deviates from existing theoretical assumptions, such as how it presents a more nuanced view on when coopetitive relations can occur. Third and finally, the case displays a multilateral coopetitive relationship, where several levels of coopetition occur concurrently.

The case study will be utilized to examine what the requirements are for participating in coopetitive relations from a multiple-actor view, and through these insights provide a more nuanced understanding of the current dichotomous way of thinking about coopetition, ultimately seeking to unveil where the line in the sand of coopetitive relations lie.

5.3.2. Empirical setting: Blockchain use case from the wind industry

The empirical setting used to explore the connection between coopetition and digital integration (in particular blockchain technology) is the wind turbine industry. Former research on the industry has found that innovation often occurs in inter-organizational contexts (Andersen and Drejer, 2008b). Due to the long life-time (20+ years) of the wind turbine and in extension their components (Jensen, 2019) as well as the aforementioned history of interorganizational collaboration, the wind industry makes for an ideal setting for exploring both blockchain and coopetition. In other words, the case was chosen due to the industry's unique history of collaboration and more importantly coopetition.

Eisenhardt and Graebner (2007) argue that cases should be "*chosen for the likelihood that they will offer theoretical insight*" and that they should aid in the "*revelation of an unusual phenomenon*". As the case comes from an industry known for dealing with the phenomenon of coopetition it is therefore deemed likely to provide theoretical insights (Eisenhardt and Graebner, 2007). As this paper seeks to understand what the introduction of blockchain does to facilitate coopetition, it is therefore ideal to pick a case where the involved partners are already in a coopetitive relationship.

This paper follows an ongoing industry project based on developing a blockchain-solution that can improve the physical (and informational) value chain for operationally-critical, standard components for wind turbines (such as bolts and fasteners). The primary purpose of the blockchain is to create a technological platform through which it is possible (and profitable) to document the lifecycle-events of standardized components by creating a more transparent provenance-history utilizing the distributed and immutable nature of the blockchain to ensure reliable product history.

The industry project includes various stakeholders with the initial prototype being based on the collaboration between five original equipment manufacturers (OEM) and eleven first tier suppliers (See Table 4 for details). In addition to this, a university (where the authors of this paper belong), a non-profit organization that guides quality-standards in the wind industry, a technical partner that is the main architect of the IT-aspects of the blockchain-solution, and an advisory company all aid as partners in the development of the blockchain solution. These partners are funded through a research-project to help conceptualize, develop, test, and evaluate the initial blockchain use case in the wind industry.

Table 4: The Competitive and Collaborative Relations of the Stakeholders

Stakeholder	First-tier suppliers	Turbine manufacturer
Number of participants	11 suppliers of the specific components in focus for the initial blockchain case.	5 turbine manufacturers involved in creating a component standardization for procurement and traceability.
Competitive relation within stakeholder group	The suppliers compete on delivering commodity components to the wind turbine manufacturers. While commodities providers mainly compete on price, quality also plays a big role and is described by both suppliers and turbine manufacturers. Quality matters enough that manufacturers often keep to trusted suppliers even if cheaper alternatives are available.	The turbine manufactures compete on tenders for manufacturing wind turbines as well as on the tenders for performing service on the turbines. In extension, there is competition on key components such as blades and control systems. The manufacturing and processing of such components therefore are kept secret and the knowledge related to them is considered a key competitive advantage.
Collaborative relation within stakeholder group	Suppliers agree that standardization of components can be accomplished if the wind turbine manufacturers are willing to collaborate themselves. Suppliers have little concern about sharing information on component design with each other to standardize components. Interviewed suppliers state that there is more trust between	The turbine manufactures collaborate on common challenges such as transporting towers and ensuring quality of suppliers. In addition, there is a common agreement that most of the components utilized in the wind turbine are not worth competing, as they are too simple in nature to differentiate. For this reason,

[redacted]	them and their closest competitors (in terms of price and quality) than between them and suppliers who sell cheaper products at lower quality. Suppliers with high-quality products acknowledge that demand is high enough for all (quality) suppliers to have a share of the market.	standardization of these components are currently progressing. Manufacturers also show willingness to share information on the events in the commodity components' lifecycle in order to improve the service aspects of the industry

5.3.3. Data Collection

The case study draws upon qualitative data collected in the period of January 2020 to July 2021. Most of the data collected is characterized by an action research-driven approach and can be considered research in action as much as research about action (Coughlan and Coghlan, 2002). Therefore, the authors of this paper can be considered actively participating stakeholders in the development of the blockchain-project in the wind industry and have had an unknown degree of influence on the development of the project. Three data acquisition methods have been used: (1) unstructured, informal interviews, (2) semi-structured, formal interviews, (3) workshops with multiple participants.

Unstructured interviews are characterized by the lack of an interview guide and only having a few pre-determined topics planned to guide the direction of the conversation. 13 unstructured interviews have been conducted continuously throughout the data collection period. These interviews occur either when new potential stakeholders consider joining the project or when informal discussions on sub-aspects of the larger project is at an early, more innovative stage. Ten interviews were conducted with OEMs while the remaining three were with suppliers. All respondents were tied to either supply chain or digitalization initiatives.

Nine semi-structured interviews are conducted, six with OEMs, and three with suppliers based on exploring the value, costs, barriers, opportunities, and limits of using blockchain in a supply chain setting. The semi-structured interviews are utilized when further clarification has been needed concerning topics unveiled in the unstructured interviews. The general themes of the semi-structured interviews are based on: (1) blockchain technology, (2) supply chain-related business activities, and (3) collaboration amongst ecosystem partners ((3A) OEM and OEM, (3B) supplier and supplier, (3C) supplier and OEM, (3D) other B2B-relations). All semi-structured interviews have followed an interview guideline, of which the main content has remained focused on the three aforementioned topics.

Finally, the main source of empirical data comes from the 21 workshops that have been conducted during the development of the blockchain use case. Seven of the 21 workshops have been based on the development of an industry standardization for the procurement process of standard components. As such, these workshops only indirectly relate to the blockchain case, but nonetheless relate to the coopetition of the same partners that are part of the blockchain solution. Both suppliers and OEMs participated in these workshops with all the involved participants sharing a connection to quality management. These workshops have been documented by field notes by one the authors of this paper and partially in the developed standardization document.

Four additional workshops have been based on the development of a blockchain prototype with mostly OEMs-informants participating. All four of these workshops have been recorded. Six workshops have been focused on the general business case and are documented through a combination of field notes, summaries of meetings, and in some cases photos (when illustrative modelling has been appropriate). The business case workshops have primarily involved OEMs with input from suppliers at two of the workshops. The remaining four workshops were based on the development of a QR-code-based solution intended to tie the physical components to the digitally based blockchain. The QR-based workshops have been documented by field notes and are summarized in e-mail exchanges in which the next developing goals and tests results are of primary focus. Only OEMs have participated in these meetings. Suppliers were consulted prior to the workshops and informed after the workshops. Furthermore, it should be noted that the suppliers were welcomed to participate but chose to have the OEMs develop the wanted solution with the argument that it was the OEMs who wanted the QRs included and that the suppliers simply would consider it a deliverable and not an opportunity as such.

5.3.4. Data analysis

The qualitative data is analysed using a multi-phased coding process (Gioia *et al.*, 2013). The qualitative data acquired through the data collection phase is first analysed, and through an inductive logic, themes are presented in order to present the main points from the interviews and workshops. Then, as a second step in the analysis, the presented themes will be related to the theoretical foundations of coopetition presented in section 2 of this paper. Specifically the themes will challenge the current theories tied to the multilateral perspective and the idea of coopetitive dichotomy before the role of digital integration in the context of the blockchain technology is analysed.

Practically, the approach to transforming raw data from the data collection process was handled in steps as suggested by Gioia et al. (2013). First, interview transcriptions and notes were reviewed, and any mentioning of collaboration, competition, or information-sharing was underlined as the first step in the multi-phased coding. The sections of raw data identified after this process were then put into themes based on inductive reasoning with the theme headlines being inspired by the statements made by the respondents.

5.4. Findings: Thematic Analysis

This section presents the findings of the case study through the four themes inductively created based on the data collected from interview and workshop participants. Figure 8 provides an overview of the four themes identified through the thematic coding, followed by key points made for each of the themes, and further specifications for each of the points below that. The content of Figure 8 is further elaborated in the following sub-sections where statements made by respondents are presented and an exemplification of blockchain's role is provided for each of the themes of the analysis.

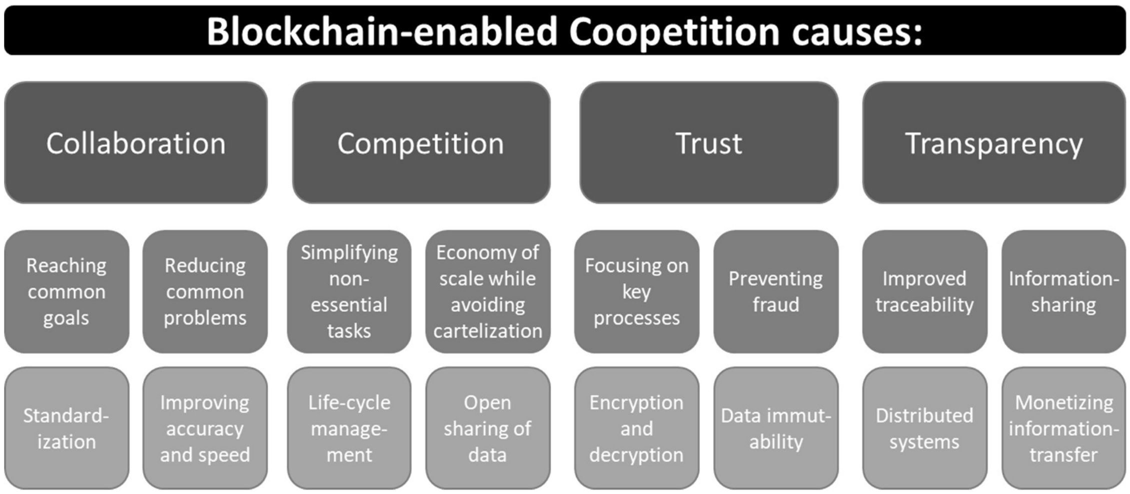

Figure 8: Overview of the themes identified and their key-points

The top row in Figure 8 includes the main themes identified throughout the analysis of the empirical data. The second row illustrates causes and advantages for coopetition falling under each category. The bottom row specifies features that are enabled by blockchain which that help improve the business conditions of the involved parties in the blockchain-coopetition.

5.4.1. Collaboration: Reaching Common goals and reducing common problems

Collaboration is a central theme for both coopetition and blockchain and is apparent throughout the entire case study. In essentially all interactions between authors, interviewees and workshop participants, a holistic goal of improving the competitiveness of wind energy has been addressed. As one of the OEMs stated: "*Increasing the size of the cake, rather than fighting over the share of it we have, will give all of us more to eat.*" Various respondents empathize that the competitors they mostly focus on is other energy providers, such as coal and solar, and to a much lesser extent, other wind industry players. In a sense, they see "*common enemies*" to be more important to outcompete.

From the OEMs' point of view, a recurring comment has been that a large amount of the parts used in wind turbines consists of commodity components, i.e., components that have no associated industry secrets tied to them. As one of the respondents stated: "*A lot of the parts in the wind turbine are really just dumb pieces of metal or plastic*". Here, "dumb" should be understood in the sense that the components are neither digitally enabled nor providing data and that their associated manufacturing processes are relatively simple. For this reason, the OEMs and suppliers alike see a benefit in standardizing the procurement process relating to the non-compete components. Despite the OEMs' need to adjust their current business processes and sharing a degree of design data with their direct competitors, they see the collaborative approach in making their suppliers more efficient worthwhile as it will ultimately make the industry stronger.

The blockchain's role in reaching common goals is in the standardization that comes beyond the component designs, particularly in the documentation perspective, where the blockchain will function as a common, yet de-centralized platform for storing and sharing relevant information on components over the wind turbines' operational period. The blockchain aids in reducing a common problem that may arise when a component needs to be back-traced, which is currently a slow and often partially manual process. With information being digitally stored on component events throughout the lifetime of each individual component, the blockchain will significantly lessen the time spent on identifying provenance of issues with components. Furthermore, should a company in the supply chain go out of business today, the information they have would perish with the company, potentially harming the larger supply chain. With blockchain, this does not happen, as a copy of the relevant data is stored amongst all peers in the blockchain.

5.5. Competitiveness: Limitations from both business and legal perspectives

In addition to collaboration, the other aspect of coopetition is that of competitiveness and this is another theme that presents itself throughout the data collection. Naturally, there are limits of coopetition and for the wind industry blockchain case, this is true as well. While non-compete items are perfectly fine to standardize, it is a little different when it comes to a few key components of the turbine, such as the wings. Interestingly enough, the OEMs are not necessarily against the idea of having traceability connected to these critical components on which much effort is put towards secrecy, but the transparency is a no-go. In other words, the OEMs are not against using blockchain as a platform for saving transactional events tied to critical components, but they wish to make use of the variable reading access for which permissioned blockchains provide the opportunity.

As previously mentioned, demand and forecasting from the suppliers point of view opens another prospective on the use of blockchain". In an ideal world the suppliers would be able to see further into the future so that they would be in a better position to mass produce components for the OEMs. As one supplier puts it: "*We feel as a manufacturer, that this industry is way behind with regards to planning and forecasting.*" The limiting factor here is not actually the OEMs as much as it is fair competition laws. For instance, European competition law prevents OEMs from openly sharing market expectations with their suppliers and as such, there are legal boundaries to how useful the blockchain as a transparent collaborative tool would be for the sake of forecasting.

This means the blockchain will generally be limited to sharing events of the past openly, for instance which supplier provided the components or the quality of service during the last maintenance event. Events of the present, such as how many components that are in a batch provided by a supplier to an OEM, will not be shared openly as this would be problematic due to the competition laws. The data may, however, still potentially be allowed to be stored in the blockchain if it is in an encrypted fashion, i.e., only the supplier and buyer will be able to read how many components were in a batch. This is however somewhat unclear due to the novelty of blockchain-based solutions.

5.5.1. Trust as a limiting and enabling factor

Trust has been a common topic brought up in the discussion surrounding information sharing and collaboration alike. One interesting example from one of the suppliers as to when and with whom they are ready to collaborate is focused on the trust aspect. "*We have respect for some of our competitors… We don't have respect for others*". Elaborating on the statement, the respondent made it clear that; "*collaboration with our core competitors, we have no issue with*". The respondent goes on to elaborate that it is both because they respect their competitors competences in making good product and their integrity in the sense that they are not trying to undercut the market prices or quality – which is an experience the respondent often has had with less direct competitors trying to enter the market.

The trust between suppliers and OEMs is also touched upon, with the suppliers having unfortunate experiences with the OEMs developing new processes or solutions, but not always sticking with them – and as such, time becomes an important factor for the degree of trust collaborators show.

The blockchain can be considered to enable trust amongst participants due to the fact that any data recorded in it will be immutable and as such, no one will be able to tamper with data in the blockchain at a later time (intentionally or not) without the tampering being detected. The blockchain is, however, somewhat limited by trust amongst the participants who use it. For instance, there might still be certain aspects of the component manufacturing process that supplier will not agree to share on the platform due to the transparency in the blockchain.

5.5.2. Transparency, traceability and information-sharing

Transparency and traceability in information sharing has already been touched upon slightly and this is not by accident as this is yet another common theme brought up during the data collection. The OEMs face a demand for having higher traceability of their components than they did previously. This demand derives from various sources such as social, environmental and economic reasons. Explaining the process at which ownership of components, turbines, and data change over time will make it apparent why traceability is important to consider. Due to the long lifetime of wind turbines, components often end up being replaced and at the very least, components will be maintained on a regular basis. To do this efficiently, transparently sharing the events that components have been through in the past becomes increasingly valuable over time, as it will improve predictability of future events. This documentation in turn will ultimately lead to better service and thus operational performance of the wind turbines over time.

The blockchain technology's role in this process is to facilitate the transparency, for instance, by allowing a new service provider to gain access to the former service providers handling of the component maintenance. Through the cryptographic nature of the blockchain, it will be even be possible to monetize this transition to a new service provider by selling the decryption key to the new provider, thus giving them insight to specific events.

5.6. Discussion

Existing research on the connection between blockchain and coopetition is limited. To the knowledge of the authors of this paper, the only paper going into detail on the connection between the two phenomena takes the focus on how tokenization can be used for new opportunities in circular economy (Narayan and Tidström, 2020). As such, the primary contribution of this paper is to embark further research on this topic. Since Narayan and Tidström's (2020) paper focuses on tokenization, the underlying blockchain can reasonably be considered to be of public nature, rather than private (Beck *et al.*, 2018). The wind turbine case study of this paper on the other hand is characterized by being based on a private, permissioned blockchain solution. The private, permissioned blockchain comes with different considerations than public blockchain solutions, namely that only invited individuals (or companies in this case) can join the blockchain. This more classic way of maintaining business processes within industrial bounds, therefore in and on itself is unexplored terrain in the perspective of coopetition research. Furthermore, this paper challenges various theoretical views of the coopetition literature stream such as the dichotomous view and expands on the ideas of multilateral coopetition.

5.6.1. Theoretical implications on coopetition

The primary contribution of this paper is found in the empirical blockchain case study, as it is the first of its kind to discuss the relation between coopetition and private, permissioned blockchain technology. In the current state of coopetition literature, digital integration in general is scarcely explored (Cozzolino *et al.*, 2021) and as such, this paper's first contribution comes from the exemplification of an empirical case that is based on digitally-enabled coopetition. The second overall contribution of this paper lies in clarifying the specific blockchain mechanics that enable coopetition, which is summarized in Table 5.

Table 5: The Relation between Coopetition Theory and Mechanics of Blockhain

Coopetition Theory	Blockchain Mechanics	Empirical Context
Multilateral coopetition (Zerbini and Castaldo, 2007)	Peer to peer network Distributed network	5 OEMs and 11 supplier collaborating
Coopetition happens close to the customer (Bengtsson & Kock 2000)	Provenance and transparency of data	Blockchain-coopetition based upstream in manufacturing and supply
Dichotomous view on coopetition (Gnyawali et al., 2016)	Cryptographic encryption	Monetizing the handover of information on service events to competitors
Trust in competitors (Czakon and Czernek, 2016)	Immutability and append-only nature	No alterations can be made to service documentation

In the theoretical foundations, two gaps in the current literature on coopetition was presented. The first of these relates to the lack of research on digital technologies' influence on coopetition (Cozzolino et al., 2021). This study's focus on blockchain provides an explanation and exemplification of one such technology and as such, expands on current literature on digital platforms for coopetition. The second gap refers to a lack of research in coopetition-based business activities outside of marketing and supply chain management activities (Golgeci et al., 2019) and while this paper does focus on the supply chain activities, its particular focus on service and lifecycle-oriented activities remains novel.

In addition to filling out the abovementioned gaps, this paper advances the current understanding and considerations on digital technologies' impact on trust-related activities in the era of industry 4.0 (Lumineau et al., 2022). Lumineau et al. (2022) suggests that industry 4.0 is moving trust to be based upon systems rather than organizations, which falls in line with the case findings in which it is suggested that organizations will trust the blockchain to be trustworthy as opposed to the competing organization(s).

In the following sub-sections this paper seeks to elaborate on the theoretical contributions by discussing the contents of Table 5, where the relationship between coopetition theory and blockchain mechanics are presented.

Blockchain-enabled multilateral coopetition

In order for a blockchain solution to make sense in a supply chain context, it should include various companies (peers) in the peer-to-peer network in which the blockchain in built (Reddy *et al.*, 2021). The wind turbine case study in itself is therefore an example of multilateral coopetitive relations as it seeks to unite competitors in two layers (suppliers and OEMs) on one platform for the benefit of improving the service conditions for the wind turbines.

Competitors on OEM-level seek to align business processes to standardize and optimize costs of upstream activities. The blockchain specifically enables competitors to collaborate by sharing data on service events in a way where they do not necessarily need to share the specifics of what they are doing unless they are paid for sharing their data. This is due to the cryptographic nature of the blockchain allowing competitors to control how much of the information put into the blockchain can be read by others. Furthermore, the blockchain indirectly enables the OEM-competitors to collaborate on achieving general cost reductions through economy of scale. This is due to the standardization process taking place for commodity components as a step towards fully digitalizing the documentation process of components for the wind turbine.

OEM and supplier collaborations ensure more effective handling in the procurement process, and the increased information-sharing capabilities by the blockchain enable quicker and more reliant back tracing concerning component-errors.

Supplier-supplier relations are managed by having the suppliers come together to ensure new procurement and traceability aspects leave them all in a stronger, more predictable position as opposed to before. While the blockchain does not directly encourage collaboration between suppliers as they still manufacturer components on their own, the platform which the technology provides does enable the supplier more transparency in what happens with their products after the point of sale. By gaining more information on their products, it is assumed by respondents of both OEMs and suppliers that the suppliers will be better equipped to innovate better processing and documentation techniques for their products.

Wind turbine service technicians will benefit from each other during their maintenance work by being able to get quicker feedback on potentially faulty batch components in their competitors' turbines through the information-sharing enabled by the blockchain. Former literature (Carayannis and Campbell, 2009) has suggested that multilateral coopetition is affected by and sometimes directly created by technological diffusion of new technologies. The case of this study is a good example of this, as the introduction of blockchain has created new ways for the industry to facilitate collaboration.

Concluding, this paper contributes to literature by illustrating and explaining how the use of blockchain technology is an instance of coopetition. Furthermore, the paper illustrates how blockchain may enable further coopetitive relations amongst its users through its characteristics of enabling transparency and traceability across the supply chain and wider ecosystem. As the introduction of blockchain requires coopetitive relations in the environment in which it is introduced, the technology helps facilitate coopetition by providing a means to safely share and store information across organizational bounds.

Blockchain-enabled Coopetition moving downstream

Traditionally coopetition literature suggests that activities close to the customers (downstream) of an organization as opposed to those further away (upstream) should be handled in different manners (Bengtsson & Kock 2000). However, as the wind turbine case shows, blockchain-based coopetition may challenge this view as the real value of a transparent transaction history only grows over time in the product life cycle and as such is closer to the customers. Specifically, the wind turbine owners and third-party service technicians will benefit from coopetitive relations between competitors on both supplier and wind turbine manufacturer levels. This is because it will enable more efficient service and thus improve the wind turbine as a product as a whole as it will be able to produce more energy (and thereby revenue) by being better maintained. Thus, the blockchain's characteristics of enabling transparency and data provenance provides more incentive for coopetition to take place not only upstream, but also downstream. This is due to the benefits of traceability for the lifecycle of a product being larger further into its lifecycle (and thereby downstream in the supply chain) as the product's journey is increasingly longer and more complex the further it is into its lifecycle.

Of course, it can be argued that this is still upstream activities from the perspective of the wind turbine owners as their customers are consumers of power and electricity, but it would be a mistake to see it solely from this angle. An interesting perspective to take away from the wind turbine case is that it is the turbine manufacturers that are pushing for increased traceability (through blockchain) and cooperation between competitors. This is in order for the turbine manufacturers to be more attractive towards their customers- the turbine owners.

While the wind turbine case of course differentiates from what would be relevant in other industries such as those focused on consumer goods, there is no reason to think that the value in better lifecycle traceability and transparency cannot be generalized to other industries dealing with products of long lifetimes. For instance, the automotive, aviation, and construction industries all face similar conditions including having increasing emphasis on sustainable practices, which blockchain an coopetition may enable new opportunities through more transparent interorganizational information-sharing.

Nuancing the dichotomous view on coopetition

The blockchain case has illustrated that coopetitive relations is not as simple as "either we collaborate or we do not" (Gnyawali *et al.*, 2016). The blockchain technology enables flexibility in terms of how much data is shared between each member of the network through its cryptographic features. The competitors' collaboration in itself is however, also displays a bigger nuance than compete or collaborate, for instance the considerations as to which components that should be included in the standardization work shows this as well. The immutable nature of blockchain that prevents former blocks of information recorded in the blockchain is also interesting in regards to trust between competitors. While the cryptographic setup in the blockchain can enable the sale of information, by decrypting certain parts of the blockchain's content, it is not like it actually changes anything in the history. Therefore, a competitor buying access to otherwise encrypted information on the blockchain can trust that the seller has not altered any information before giving the buyer access.

This paper and blockchain as technology therefore challenge the dichotomous view as the opportunity for more complexity in the handling of data is different in a blockchain system, where encryption and decryption of data may be used to shift between a state of competition and collaboration.

Trust in competitors

One of the key aspects blockchain facilitates is trust and the technology is particularly interesting when trust-relationship is between competitors. Czakon and Czernek (2016) suggests that third party legitimization and industry (network) reputation are major decision factors for entering into coopetitive relationships. This paper illustrates how blockchain may replace the need for third party legitimization as the blockchain technology can function as an alternative to classic third party mediation. Furthermore, network reputation may be boosted by the blockchain technology in the sense that the technology's transparent nature allows for better assessment opportunities of other industry players' reputation. Furthermore, the immutable nature of the blockchain may to some extent make reputation an obsolete factor, as organizations can choose to trust in the integrity of the technology rather than that of competing organizations actions when disputes of former agreements occurs.

5.6.2. Limitations and suggestions for future research

The analysis of the case study data has shown the importance trust from both a integrity-based view and a competence-based view (Connelly *et al.*, 2018), which is a factor empathized in current coopetition literature (Czakon and Czernek, 2016). The view on coopetition as a dichotomous variable (Gnyawali *et al.*, 2016) has been challenged, but could still be explored much further in order to understand the limiting factors of coopetition.

One big challenge of this paper and for blockchain research in general is that the understanding of the technology and its application is still often difficult for respondents to comprehend due to its complexity. As such, a major limitation of this study is the lack of in-depth industry understanding of the technology's potential. Further research into the approach and methods of conducting research on blockchain technology is therefore advised. One potential route to go based on the authors experience is to explore less about blockchain and more about the enabled value it provides – for instance transparency, data immutability, or of course coopetition.

The long standing interorganizational collaboration of the wind industry has been observed both in literature (Andersen and Drejer, 2008b) and through the empirical data collection and has provided some opportunity for understanding the importance of pre-existing trust and collaboration before endeavouring into a coopetitive-based venture, such as the implementation of blockchain. However, the importance of having pre-existing coopetitive relations could be explored much further and more rigorously. Understanding pre-existing coopetitive relations could provide important knowledge for the successful implementation of not just blockchain technology, but coopetitive relationships of any variety.

As this paper takes a single case study approach, there is opportunity for exploring what other industries and cases might bring to the knowledge pool in blockchain-enabled coopetition alone. In particular, it could be insightful to understand the differences between a case like the one presented in this paper – where coopetitive relations preceded the case – and compare it to a case where blockchain initiated the coopetition. Generalization of single case studies is of course another issue and for that reason, further studies examining different cases would be ideal to see in future research to test and elaborate on the findings of this study.

As previously addressed, current research on coopetition is limited in the context of digital integrations in general and as such, the authors call for further exploration on digital technologies' influence on coopetitive opportunities and limitations as the current literature is almost exclusively focused on digital platforms (Cozzolino et al., 2021).

In sub-section 5.1.3, the authors suggest that the traditional idea of coopetition belonging in upstream activities of the value chain and not in downstream activities may need to be challenged. As such, the authors of this paper call for action in terms of obtaining a better understanding on the value of coopetition for downstream activities such as product service and lifecycle traceability.

The authors encourage future research to explore the difference between private and public blockchain-cases, permissioned, and permission-less cases etc. to better understand how the specific impact of the variations of the blockchain technology. This paper has focused on a case that explores a private, permission-less blockchain, and as such it would be insightful to learn the similarities and differences between such a case and public-based blockchain – permissioned or permission-less (Beck et al., 2018). Furthermore, blockchain technology is based on various consensus mechanisms, each of which has varying incentives for being used and the choice of consensus mechanism is therefore decisive for the specific benefits of the technology. Finally, one of the most prominent features of blockchain technology is the enabling of smart contracts – automated contracts carrying of tasks based on whether certain conditions are met. Due to the vast potential for digitalization in these contracts, there is potential to better understand this particular sub-case of the blockchain technology as it may be able to significantly optimize the use of blockchain and coopetition in a wider context.

5.7. Conclusion

This paper sought to answer the research question: *How does the introduction of blockchain technology enable coopetition?* In the theoretical foundation, three arguments were made as to why blockchain is an intriguing technological phenomenon to consider in a coopetition context. These arguments are re-addressed to answer the research question by incorporating points made in the findings and discussion sections.

Argument 1: As blockchain is a distributed database utilized to maintain tamperproof records of transactional data at each participants' location, the technology in its very nature facilitates coopetition through its information-sharing characteristics. As the wind turbine case study shows, however, this does not necessarily account for all information being openly accessible to all participants in the blockchain. The blockchain's cryptographic nature allows the involved organisations to set rules and possibly even automate changes in said rules through a combination of the governance mechanism involved and the use of smart contracts. Thus, the blockchain's characteristics enable coopetition to be more than a dichotomous variable, in actuality allowing more fluency than simply "cooperate or do not" (Gnyawali *et al.*, 2016).

Argument 2: As we have already begun to address above, the participants principally having equal rights and obligations, but not data access. This also means that there is no principle difference in regards to company size or type, meaning the suppliers of bolts and fasteners from the wind turbine case, who are all categorised as SMEs, have equal rights and obligations as the big corporate turbine manufacturers. Of course, the blockchain also enables coopetition between suppliers as the suppliers can share their data in the encrypted blockchain platform without fearing their competitors gaining access to their business secrets.

Argument 3: The social aspects, such as trust, become enabled through the blockchain's technological setup. Through its cryptographic nature, competence-based trust (Connelly *et al.*, 2018) is enabled through the technology rather than through normally people-born trust. This trust and the relationship it helps build is one of the more essential outcomes of coopetition according to former studies (Jakobsen and Steinmo, 2016) in coopetition and as such, the blockchain's technological features becomes an extension of the social implications of coopetition.

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5.9. Relationship between OEMs and suppliers

It should be made clear to the reader that this section is not a part of Paper 2, but rather a section supporting the dissertation and the reader’s understanding of the OEM and supplier relations. While there in an ideal world would be a section describing the relationship between each OEM and supplier mentioned in this case study, practically the data does not exist for providing such a description. As such, this section will only provide insights into the power dynamics and other general relational characteristics between OEMs and suppliers.

The first thing that is important to understand regarding the OEMs’s and suppliers’ relationship is that the OEMs naturally have more power in the relationship. This is due to the vast difference in size of the companies with OEMs employing thousands of people and generating billions of euro in revenue annually, while suppliers are SMEs with employees in the double digits typically (there are few larger suppliers with over 100 employees) and revenues far under a billion euro even for the biggest suppliers. Specific numbers are not available to the PhD-candidate and the numbers given in this section are based on the information provided by a representative of the Fastener-case from the OEMs who have vast experience with all involved cases study parties.

Another aspect that is important to understand, which is also addressed somewhat in both paper 2 and 3, is that suppliers have little to no interest in the traceability aspects that the blockchain enable. This should not be understood as them having an issue with increased transparency in the supply chain, but rather be understood as them typically seeing their business ending past the point of sale and delivery to the OEMs. The suppliers are all observed to be open to share further information with the OEMs and potentially other members of the supply chain further downstream (such as the OEMs customers, who owns the wind farms) as long as they are properly paid for the additional time they have to put into providing the documentation necessary for the blockchain’s records.

A final aspect that is quite important to understand in the relationship of the OEMs and suppliers is that they are all either European or US-based, which is indirectly important in the industry due to certain non-European/US players on both OEM and supplier level is considered to be different to do business with. Part of this difference is perceived to be because of cultural differences, while others are more directly tied to strategy of the companies. In general the wind turbine industry and their suppliers for various mechanical components tend to be more focused on quality than price in the EU/US than the counterparts outside who tends to be the other way around. Because all respondents of the case study is European/US-based there is therefore an inherent trust and understanding between the different companies that quality comes first, even if price and cost-out strategies are still in focus as well.

6. Blockchain-based Interorganizational Collaboration for Servitization

The content of this chapter is taken and copied directly from the following research paper produced during the PhD:

Holm, K. and Goduscheit, R.C. (2022) '**Blockchain-Enabled Servitization**'. *Proceedings of the 23rd International CINet Conference*.

This paper was presented at the Continuous Innovation Network conference.

An earlier version of this paper (Paper H, see section 8.1, p. 103) was presented at the *6th World Conference on Production and Operations Management* and was invited for a special issue in the *International Journal of Operations and Production Management*. At the time of writing this, the expansion of this paper for the journal is still underway.

6.1. Introduction

Connectivity-based technologies have been described as a means for manufacturing companies to combine product sales with profit from service sales – a transition often conceptualized as servitization (Kohtamäki et al., 2019a). These technologies enable the manufacturer to remotely survey the installations with their customers and, hence, provide more informed, timely and accurate service offerings (Huikkola et al., 2020). One of the prominent technologies that provide both historical and real-time insight into the installed base is blockchain technology. Some of the fundamental qualities of blockchain are transparency and efficient sharing of information within the value chain. Both value chain transparency and information sharing potentially facilitate product-oriented firms to leverage their ability to provide qualified services for their customers. Nevertheless, empirical analyses of the role and value of the blockchain technology within servitization remains scarce. The few pieces that address the potential role of blockchain and servitization focus on a relatively operational level of application of the technology as an enabler of performance contracts as a substitute (or a supplement) for traditional arms-length contractual relationships (Hunhevicz et al., 2022).

This paper seeks to explore this gap in existing literature by presenting a case study from the Danish wind industry where four OEMs and twelve sub-suppliers collaborate on the development of a blockchain solution that would enable them to track components and modules within the installed wind turbines and hence inform the provided service. Hence, the paper will seek to answer the following research question:

How does blockchain enable service transformation of manufacturing companies?

6.2. Theoretical foundations

The theoretical foundation of the paper consists of a presentation to the concept of servitization and a discussion of servitization in the context of blockchain technology.

6.2.1. Servitization

The rich and growing body of literature on servitization builds on the premise that customer interactions and understanding are essential in order to succeed in the effort to servitize. Close and continuous customer contact and having a finger on the pulse within the customer base is perceived as pivotal. The ultimate goal of this customer proximity is to increase both loyalty among the customers, business growth and, in turn, more stable revenue streams (Kowalkowski et al., 2015). Servitization can be perceived as a way to avoid the commodity trap where the manufacturer is overly reliant on providing the product and nothing else and hence is vulnerable to price pressure (Chesbrough, 2011). In the effort to describe the importance of customer proximity, Calabrese et al. (2020) use the term customer sensing. The manufacturer, who holds the ability to sense the requirement of the individual customer even at a very early stage (and perhaps even prior to the customer's own registration of the need) holds a substantial competitive advantage.

Conceptually, the ability to sense the customer requirements should be distinguished from the ability to respond effectively to the requirements. The most expedient response of the manufacturer opens up for a trade-off between potential strategies in order to meet the requirements of the customers. Kohtamäki et al. (2020) describe how a number of case companies experience conflicts between customization of the solutions provided for the market and the achievement of scale-related efficiencies in production and delivery of the goods. Especially servitized offerings that are marked by a high degree of complexity tend to be highly customized but relatively inefficient, while even fewer complex offerings suffer from the same underlying optimization challenge between customization and efficiency.

As a natural consequence of the emphasis of prior literature on the essence of customer interaction and proximity, a presumption would be that the relational, inter-organizational and ecosystem level analysis would be prominent within the previous studies on servitization. Companies in general, and SMEs in particular, are often not selling directly to the end-customers and are, hence, highly depending on the ability to collaborate with other parts of the value chain in order to get access to the customers' preferences, requirements and needs Kohtamäki et al. (2019a). From this perspective, it appears surprising that Kohtamäki et al. (2019b) in a recent study identified the relational, network and ecosystem level of analysis as a research gap in existing literature. Recent studies tend to have addressed this gap. For instance, in their paper on digitally enabled process innovation, Kamalaldin et al. (2021) have stressed the importance of ecosystems and collaborative approaches within the process industry. Indeed the importance of understanding the influence and importance of digital technologies in servitization have been addressed as a better understanding on how digital technology may be leveraged is currently lacking in the literature (Coreynen *et al.*, 2017).

6.2.2. Blockchain in a servitization perspective

While the seminal articles on servitization have stressed the importance of having information on the installed base of products with the customer (Oliva and Kallenberg, 2003), the insights generated from the customer side tend to be "hand-held" by the employees engaged in the customer-directed activities (for instance service and maintenance). These employees provided (and still provide) first-hand knowledge about potential issues with the installed base of products, need for adjustments and maintenance and, ultimately, additional sales. The emphasis from this perspective is the level of proximity to the customer through the service organization and the ability to make the customer aware of the point of contact within the service organization (Kucza and Gebauer, 2011).

Blockchain is a distributed ledger technology that helps ensure aspects such as traceability and transparency in supply chain management (Martinez et al. 2019). Practically the technology records and stores the transactional information from a series of events in an immutable fashion, i.e. data can be added, but not changed (Schmidt and Wagner 2019). In other words, blockchain creates the opportunity store and share data across organizations as opposed to the classic way of doing it, where information is stored in "silos" in each company. Blockchain's characteristics have been argued to enable opportunities for service innovation perspectives (De Keyser et al. 2019) as it allows for manufacturing organizations to stay connected with their products after they enter the larger ecosystem (Culot et al. 2020, Salwin et al. 2020). For instance, Culot et al. (2020) argues that blockchain can function as a network technology enabling online functionalities and states how the technology has an impact of automating middleman-activities. Salwin et al. (2020) argues that blockchain provides new possibilities for printing machine services, such as eliminating the need for intermediaries and reducing information asymmetry between manufacturer and customer. Within shared manufacturing blockchain has been found to provide opportunities for solving copyright issues within service-oriented additive manufacturing (Yu et al. 2020). In addition, other articles indirectly present servitization opportunities that may be taken advantage of by using blockchain. For instance, blockchain may be used for proof of sustainable practices (Saberi et al. 2019) or for various traceability purposes (Hastig and Sodhi 2020). In an article analyzing 30 years of servitization literature, the implementation of advanced lifecycle service is suggested as one path manufacturing companies may take to transform their business (Rabetino *et al.*, 2021). This type of service fits perfectly with the characteristics of blockchain and has been argued to be one way to use blockchain for sustainable supply chain management (Saberi *et al.*, 2019b).

6.3. Design/methodology/approach

As this paper seeks to add empirical insights on the theoretical topic of servitization by analyzing the blockchain phenomenon, a qualitative approach is deemed appropriate. This approach has been used by other researchers seeking to understand the implication of blockchain in various areas such as value systems in the sharing economy (Pazaitis, De Filippi, and Kostakis 2017) and the resource-based view in supply chain management (Nandi et al. 2020). This paper will specifically focus on a single case study where blockchain is used to create product traceability throughout the supply chain and lifecycle of commodity components in the wind turbine industry.

An important aspect to understand regarding the case and the associated data collection is that the authors of this paper actively have been a part of the development of the blockchain case. In other words the authors' motives have not solely been knowledge generation, but also to take action in creating the best conditions for a practical solution benefitting the industrial partners. Due to these circumstances, it could be argued this paper is based on an action research approach (Coughlan and Coghlan 2002). This type of engaged approach has been suggested to be of value in studying blockchain as it creates the opportunity for acquiring a richer understanding on how organization may adopt the technology (Cole, Stevenson, and Aitken 2019).

6.3.1. Data Collection

Primary data is collected through unstructured and semi-structured interviews as well as workshops with participants from the wind turbine industry. In total 12 semi-structured interviews of 45-90 minutes duration, 10 unstructured interviews of 20-60 minutes duration and 19 workshops of 60-180 minutes of duration make up the empirical findings presented in this paper.

The data is collected between January 2020 and April 2022 and is characterized by the fact that no blockchain solution existed in the beginning of the data collection. That is because the case study of this paper, has been followed by the authors since before blockchain was chosen as a solution. The beginning point of the case can be summarized to an industrial need for better traceability of critical commodity components in the wind turbine. Components are considered critical in the sense that the wind turbine may not be in operation if the components are broken. On the other hand, the components in question are considered commodities because they are relatively simple to make and substitute. For components with these two traits there are therefore both, little reason to have business secrets and a value in better understanding and documenting the conditions the components go through in their lifetime.

6.3.2. Research Setting

The research is set in the wind turbine industry, which have a couple of notable characteristics that are particularly important to understand. First, the industry is known for having a long history of systematic innovation based on collaboration (Andersen and Drejer 2008). Second, wind turbines are products of significant size and costs and are built to operate for 20-30 years (Jensen 2019), which means documentation of events and traceability in general place an important role in securing success over time. In addition to these characteristics, it is important to remember that the wind turbine industry ultimately is centered on the generation of renewable energy and as such has an explicit focus on sustainable practices.

In this particular case study, the above points' importance also shine through as the blockchain case is an instance of collaboration amongst competitors of two tiers (turbine manufacturers and commodity component suppliers) primarily in the form of information-sharing across organizational boundaries. The operational period of 20-30 years is also highly important along with the sustainability focus as the blockchain case in the end is about creating traceability across organizational bounds throughout the lifetime of the wind turbine's commodity components. With the traceability comes transparency of the components events over time and this enables the opportunity for improved service conditions and better opportunity for decommissioning of wind turbines once their lifetime runs out.

6.4. Empirical Findings

The empirical data illustrates several aspects of the blockchain technology as an enabler of servitization within the wind industry. In order to structure the findings, the following will be based on changes in the various phases of the wind turbine (and its components) lifecycle.

A wind turbine's lifecycle can be described through four phases; A planning phase, an installation phase, an operational phase and a decommissioning phase. The planning phase is of little importance for this paper's scope as it precedes the acquisition of components, but the other three are all important for the service perspective in their respective ways. In order to understand the full magnitude a blockchain-enabled solution may bring with it, each of these phases are therefore presented in detail below.

6.4.1. Installation Phase

The manufacturing and installation of the wind turbine will be presented from the wind turbine manufacturers' point of view. A wind turbine consists of thousands of parts, which are acquired from a multitude of component or system suppliers. Along with the acquisition of batches of components, comes proof of the components' quality through sample testing and documentation of the as-built (design, materials etc.). The next step in the turbine's journey is the installation at the location it is going to be operating. Here further documentation may be noted by the turbine manufacturer as to where the components bought from the supplier is located, not only in the turbine schematics, but also in terms of geographic location.

The documentation shared between supplier and turbine manufacturer as well as the documentation within the turbine manufacturer's own processes is, however, not always stored digitally. This causes issues in book-keeping and makes the process of finding information slow and unreliable. In the case of data from the supplier, the turbine manufacturer may realize at a later stage of the component's life that the acquired data is not comprehensive enough for service or decommissioning purposes. The supplier's will typically have further information regarding the components they sell, but this information is not always stored digitally either.

With a 20+ years lifetime for a wind turbine, there is not only risk of things getting lost along the years due to them not being digitalized, but also due to suppliers potentially shutting down along with their databases with potentially important documentation. During the data collection, several representatives from the wind turbine manufacturers have mentioned situations where documentation was needed, but impossible to get since suppliers had been shut down or similar. Examples were also given of forced vertical acquisition as the turbine manufacturers had suppliers with critical information within their organization going bankrupt. In the situation, the turbine manufacturer had no other way of obtaining the manufacturing data for the supplier's components than to buy the company. In other words, documentation can be lost quite easily as time passes in many situations while the preservation of data can be very expensive in others. With the blockchain, these problems are gone; as all relevant information will be stored in the distributed record that blockchain is, making for a situation where all involved parties would have to shut down in order for the data to be lost.

In addition, since current information (digitalized or physical) is stored within the supplier's and wind turbine manufacturers organizations respectively, situations may occur where one party (accidently or not) changes the documentation that has been shared between the two companies. This is dangerous if disputes of what is "true" documentation comes to play, as neither may be able to prove they are in the right. With blockchain however, any changes made to the documentation will require both parties to consent to any changes. Even if something is changed without the notice of one party, a former block in the blockchain will have the originally agreed upon documentation stored as nothing is ever deleted from the blockchain.

6.4.2. Operation and Maintenance Phase

This phase refers to the operational period of the turbine and its components, which lasts a minimum of 20 years. An important note in the ownership situation of wind turbines should be explained here. While turbine manufacturers can be the owners of wind turbines, more often than not other companies or governmental organizations own the turbines and as such, the turbine manufacturers are suppliers to turbine owners.

In order for the wind turbine to be functioning, many components must be maintained regularly over time to ensure nothing breaks or malfunctions. With thousands of parts to take care of in each turbine and with thousands of turbines in existence, this is no small task to handle. Further complicating this task is the fact that service may (and in all likelihood will) be performed by different companies over the span of the turbine's life – even for specific parts. The reason for this is that turbine manufacturers' typically provide 5-10 years of service of the turbines they manufacture. However, after this period is over, there will in most be tenders in which various companies bid on the service business of turbines or specific components in them. The companies bidding on the service business can be other turbine manufacturers (direct competitors of the original equipment manufacturer), service-specialists who does not manufacture turbines themselves or the wind turbine owners may take over service contracts themselves. This causes a complex situation in which information on maintenance events on components often need to be transferred to other organizations over time – and as mentioned sometimes even to direct competitors.

In the current situation this leads to a situation where lacking (or even no) information on former service events may be available to a service technician, which ultimately hinders ideal maintenance of the wind turbine. With blockchain, this information would be made accessible through the records stored in the distributed platform and since the data is immutable, a new service provider would not have to fear tampering or lacking information in the documentation as the data stored in the blockchain would not be possible to change over time.

Another valuable aspect the blockchain enables is the possibility of a more proactive approach to component maintenance that would help reduce risk and costs of component malfunctions and ultimately help prevent downtime for the wind turbine. Since all events occurring in the lifecycle of the components would be stored in the blockchain, it means that if something were to break in one turbine, the cause would be easier to find. For instance, the blockchain might reveal that the former service technician did not comply with the maintenance demands or the service technician may note that there seems to be material problem, which could then be tied back to the manufacturer. Regardless of where the error is expected to have happened, the blockchain would enable the possibility of identifying the origin of the event. Moreover, since other components information would be stored in the blockchain as well, whoever or whatever that is believed to have caused a malfunction would be traceable in the blockchain. So for example if a component is believed to have broken due to a manufacturing error, all other components from the same batch, could be located and proactively be checked to see if action was needed. This way a faulty batch of components scattered across countless turbines would be identifiable and accurate actions could be taken to prevent further issues.

6.4.3. Decommissioning Phase

The final phase of the wind turbine is the decommissioning phase and refers to the events taking place after the turbine has served its function. Ideally, the aim is to reuse or recycle as many components as possible to ensure a sustainable business, but practically it may also involve the termination of some components. This process is heavily dependent on information on the components' material qualities, so that things are sorted properly. For instance it would be important to know if a component is made purely of steel or if it's a composite of some variety, as it would change the procedure for reuse or repurposing. Similarly, some components may still be in good enough condition to be reused as they are, but in order to ensure this proper documentation of their lifecycle events would be needed as documentation for their quality and safety in use. This is currently some of the problems that decommissioning of wind turbines is facing. Since the wind turbine industry only really started to grow 25-30 years ago and the lifetime of turbines is roughly that, it means decommissioning is a relatively new territory to deal with. One thing that can be clearly seen, however, is that component provenance is key to dealing with decommissioning effectively. This makes for one more reason why blockchain would be able to improve the industry conditions significantly, as the immutability of the data in it would allow for accurate assessments of component repurposing.

6.5. Discussion

This section outlines the theoretical and practical implications of the blockchain-enabled servitization.

6.5.1. Theoretical contribution and relevance

Theoretically, this paper adds to the existing body of literature in several ways.

Firstly, connectivity-based servitization has traditionally been perceived as a matter of connectedness within a smaller portion of the value chain. In most of the literature, the ability of one actor to monitor the installed base (for instance a production facility) with another actor is perceived as a means to have more reliable information about the use of the installed base. Hence, the connectedness is seen as a way to create performance contracts (Hunhevicz et al., 2022). However, as illustrated in the case study presented in this paper, in order to harvest a broader potential from the blockchain technology, a wider set of actors need to be involved into both the conceptualization and implementation of the solution. The nature of the wind industry and the wind turbines in terms of both the number of actors needed to produce and install the final offering, and the lifetime of the turbines (Jensen 2019), necessitates a shift from a dyadic to an ecosystem perspective on servitization (Kamalaldin et al., 2021), which is one of the prominent characteristics of the blockchain technology (Cole et al. 2019).

Secondly, and as a consequence of the first theoretical contribution, this paper illustrates the drastically increasing complexity of understanding the blockchain technology in the context of an entire value chain. The fact that not only a broader set of actors need to be involved but also the fact that the technology should take into account the temporal perspectives (i.e. the traceability should not merely be aimed at the current state but incorporate future needs and requirements). The need to be able to navigate in both ecosystem and temporal complexity creates a substantial pressure on the capabilities of the organizations involved in the blockchain solution (Hastig and Sodhi 2020).

Thirdly and finally, this paper makes a contribution by adding a "public good perspective" (Cerf et al., 2020) to the traditional perception of the role of servitization. Collaboration around servitization within a blockchain solution is not merely a matter of commercial strengthening of the individual companies but creating a fertile ground for a more efficient industry (Friedman and Ormiston, 2022). The wind industry is a key player in the global, green transition of the societies. Hence, creating better conditions for a blockchain solution might be seen more as a public good than narrowly defined commercial interests of the individual organizations within the industry (Kewell et al., 2017). In case of a lack of involvement of non-commercial third parties, blockchain solution might not be instigated, which would represent a market failure.

6.5.2. Practical implications

On a company-level, this paper alludes to the fact that organizations need to understand the broader aspects of the creation of a blockchain solution. Myopic, self-centered perspectives on the role of blockchain technology, and the servitization that can be build on the basis of this, drastically decreases the chances of harvesting the full potential of the solution. In other words, this paper has implications on the ability of the commercial actors within the wind industry but also within other industries to acknowledge the need for and value of transparency throughout the entire value chain and (in turn) a broad set of actors within the ecosystem.

From a more societal perspective, decision- and policymakers potentially need to acknowledge their role in establishing blockchain solutions in industries that are marked by public interest. This paper concerns one of the key players within the green transition. An enhanced level of transparency within the wind industry, including a more efficient approach to servitization of the installed base (with more competitive green energy as an ultimate consequence) is a public good. However, creating a blockchain solution, which can serve as an enabler of these positive externalities, is not a trivial task and decision- and policymakers could have an active role in facilitating the process which can lead to creation of the solution.

6.5.3. Limitations and future research opportunities

This paper is limited to focus on a single case study from the wind turbine industry and as such, an obvious opportunity for future research is to identify and evaluate similar blockchain cases from other industries. Servitization literature is generally lacking empirical cases of servitization enabled by digital technology and while this paper adds some insight on blockchain technology, there is ample opportunity for further research on other digital technologies role in servitization.

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6.7. Further details on methodology

It should be made clear to the reader that this section is not a part of the published paper, but rather a section exclusive to the dissertation, which purpose is to provide the reader with further information on the data used and analyzed in the paper. Below is first a more in-depth representation the data utilized in the paper, which did not make the cut in the original paper and following this is an introduction to the data analysis.

Semi-structured interviews

Table 6: List of semi-structured interviews

Description of interview respondents	Company type	Documented with	Length (min.)
Supply chain specialist in procurement	OEM	Extensive notes	45
1 middle manager in digitalization 1 specialist supply chain management	OEM	Extensive notes	60
Middle manager of procurement unit	OEM	Extensive notes	90

Specialist in digital business development	Supplier	Recording + notes	60
Middle manager in digitalization	OEM	Recording + notes	90
1 middle manager within digitalization 1 specialist within digitalization	Supplier	Recording + notes	60
Supply chain manager	OEM	Recording + notes	90
Supply chain manager	OEM	Recording + notes	60
Middle manager working within R&D	OEM	Recording + notes	50
Digitalization specialist	OEM	Recording + notes	60
2 specialists within digitalization	OEM	Recording + notes	90
Middle manager within supply chain management	Supplier	Recording + notes	60

The initial respondents were interviewed based on the network of the partners on the publically-funded blockchain project which the authors of this paper were amongst. As several project partners were chosen based on having extensive experience within the industry including a partner that works full time on networking within the wind energy sector. Subsequent respondents were either identified by former respondents or through interactions (presentations, meetings etc.) with the OEMs involved in the blockchain case. All interviews included in this table were semi-structured and the respondents are included based on them having experience in either digitalization, supply chain management or blockchain specifically.

13 informal, unstructured interviews were held in addition to these semi-structured interviews providing the authors of this paper further insights into the industry. Ten interviews were conducted with OEMs while the remaining three were with suppliers. All respondents were tied to either supply chain or digitalization initiatives. The analysis and discussion of empirical findings in this paper is, however, limited to the information gathered in the semi-structured interviews and workshops (Table 6 and 7), while these informal interviews were used to ensure the researchers that the data collection and analysis was valid, accurate and exhaustive.

Workshops

The main source of empirical data comes from the 21 workshops that have been conducted during the development of the blockchain use case.

Table 7: List of workshops

Description of workshop	Type of participants	Number of participants	Documented with	Length (min.)
Blockchain-project start-up meeting	Researchers and industry representatives	6	Extensive notes and Email follow-ups	90
Mapping the industry/lifecycle to understand traceability needs	Industry representatives with supply chain/cross-company collaboration as their main focus	7	Extensive notes	90
Blockchain business case workshop (cross-sector event)	Researchers and industry representatives (from several industries) with expertise on blockchain	~40	Extensive notes	420

Industry alignment with focus on quality assurance	Industry representatives with backgrounds in quality assurance and supply chain management	~15	Extensive notes and Email follow-ups	90
Development of business model for blockchain case	OEM-representatives from R&D-departments and suppliers within quality assurance	7	Extensive notes and Email follow-ups	120
Defining needs/tasks on traceability/QR beyond blockchain	OEM-representatives from R&D-departments and suppliers within quality assurance	8	Extensive notes and Email follow-ups	180
Industry procurement standard workshop 1	Representatives from 5 OEM and 12 suppliers with experience within procurement/sales	~25	Shared standard document with notes	210
QR-development meeting 1, planning tests	OEM-representatives from R&D-departments and suppliers within quality assurance	6	Extensive notes and Email follow-ups	60
Industry procurement standard workshop 2	Representatives from 5 OEM and 12 suppliers with experience within procurement/sales	~25	Shared standard document with notes	180
QR-development meeting 2, discussing test results	OEM-representatives from R&D-departments and suppliers within quality assurance	6	Extensive notes and Email follow-ups	60
Blockchain prototype development workshop 1	OEM-representatives from R&D-departments, suppliers within quality assurance and blockchain developers	7	Recorded and with notes/PowerPoints	180
Industry procurement standard workshop 3	Representatives from 5 OEM and 12 suppliers with experience within procurement/sales	~25	Shared standard document with notes	120
Industry procurement standard workshop 4	Representatives from 5 OEM and 12 suppliers with experience within procurement/sales	~25	Shared standard document with notes	120
Blockchain prototype development workshop 2	OEM-representatives from R&D-departments, suppliers within quality assurance and blockchain developers	7	Recorded and with notes/PowerPoints	120
Industry procurement standard workshop 5	Representatives from 5 OEM and 12 suppliers with experience within procurement/sales	~25	Shared standard document with notes	120

Industry procurement standard workshop 6	Representatives from 5 OEM and 12 suppliers with experience within procurement/sales	~25	Shared standard document with notes	120
Blockchain prototype development workshop 3	OEM-representatives from R&D-departments, suppliers within quality assurance and blockchain developers	7	Recorded and with notes/PowerPoints	120
Assessment of business model case with industry partners	OEM and supplier representatives all sharing experience within quality assurance	~12	Recorded and with notes/PowerPoints	60
Blockchain prototype development workshop 4	OEM-representatives from R&D-departments, suppliers within quality assurance and blockchain developers	7	Recorded and with notes/PowerPoints	120
Workshop on the potential expansion of the blockchain case	OEM-representatives from R&D-departments and suppliers within quality assurance	5	Extensive notes and Email follow-ups	240
Industry procurement standard workshop 7	Representatives from 5 OEM and 12 suppliers with experience within procurement/sales	~25	Shared standard document with notes	120

Seven of the 21 workshops have been based on the development of an industry standardization (yellow) for the procurement process of standard components. These workshops only indirectly relate to the blockchain case, but nonetheless relate to the coopetition of the same partners that are part of the blockchain solution. Both suppliers and OEMs participated in these workshops with all the involved participants sharing a connection to quality management.

Four workshops have been based on the development of a blockchain prototype (green) with mostly OEMs-respondents being involved from the industry. In addition technical partners from the publically-funded blockchain was involved as the technical experts on the matter of blockchain development. Suppliers were asked if they were interested in participating, but none responded with interest. Several suppliers have said that they see the blockchain solution's specific design to be outside the scope of their interest as it is the OEMs and their subsequent customers who will be the primary users of the solution.

Six workshops (orange) have been focused on the general business case and are documented through a combination of field notes, summaries of meetings, and in some cases photos (when illustrative modelling has been appropriate). The business case workshops have primarily involved OEMs with input from suppliers at two of the workshops.

The remaining four workshops (blue) were based on the development of a QR-code-based solution intended to tie the physical components to the digitally based blockchain. The QR-based workshops have been documented by field notes and are summarized in e-mail exchanges in which the next developing goals and tests results are of primary focus. While OEMS were the primary participants in these workshops, suppliers were consulted prior to and informed after the workshops. Furthermore, it should be noted that the suppliers were welcomed to participate, but chose to have the OEMs develop the wanted solution with the argument that it was the OEMs who wanted the QRs included and that the suppliers simply would consider it a deliverable and not a new business opportunity.

6.7.1. Data analysis

The qualitative data is analysed by taking the raw data from the data collection process and transforming it into themes similar to what Gioia et al. (2013) suggests. First, interview transcriptions and notes were reviewed, and any mentioning of collaboration, competition, or information-sharing was underlined as the first step in the multi-phased coding. Four main themes were identified using inductive logic during the coding procedure (See Figure 1 for details). Practically these themes were identified by categorizing the main points and themes from the semi-structured interviews and workshops.

As a second step of analysis, the presented themes are related to the theoretical foundations of coopetition in the discussion section of this paper. Specifically the themes will challenge the current theories tied to the multilateral perspective and the idea of coopetitive dichotomy before the role of digital integration in the context of the blockchain technology is analysed.

7. General Discussion and Conclusions

The purpose of this chapter is to discuss the findings and implications of the research carried out in the PhD that goes across and beyond individual papers. This chapter will first reflect on the findings in the individual papers from chapters 4-6 and connect said findings to illustrate the synergies between each paper. The chapter proceeds to address the theoretical implications, then the managerial ones and finally the social implications of the PhD-research. Subsequently the limitations of the research are presented and the consequences associated with the limitations are discussed for the purpose of unveiling new research directions by considering the opportunities (and challenges) that would arise by reducing limitations of the PhD-research. Finally, an answer to the overarching research question will be presented as the conclusion of the PhD.

7.1. Connecting the Findings of Individual Papers

The overarching research question in the PhD seeks to answer how blockchain-enabled information affect interorganizational collaboration. In order to understand this, different important aspects of collaboration has been explored such as investigating both horizontal and vertical collaboration schemes as well as understanding the impact of blockchain on key social phenomenon such as trust, information-sharing and the sensitive balance that is between collaboration and competition. Furthermore, in order to understand a specific case of interorganizational collaboration better, the transformational process the technology enable is explored in the context of manufacturing companies becoming servitized and thereby moving towards a different kind of value-delivery service than they originated in.

The first paper presented in chapter 4 focused on understanding the role of trust in blockchain-based information-sharing in horizontal collaboration. The paper’s findings include that current blockchain research on trust lacks empirical context and a more nuanced view on the nature of trust as well as whether the phenomenon should be considered a pre-requisite or an outcome of introducing blockchain into a supply chain setting. The paper suggests that trust may evolve from being based on a digital trust in the mechanisms of the blockchain to becoming competence- and integrity-based overtime as the blockchain-based ecosystem and interorganizational relationships of the involved parties evolves.

The second paper presented in chapter 5 focused on vertical collaboration and the concept of coopetition where companies simultaneously compete and collaborate. Findings of the paper include some of the first empirical evidence that blockchain can be an enabler in interorganizational collaboration amongst competitors as the technology has a unique set of traits including transparency, immutability and possibilities of information asymmetry that allows for a flexible solution of cross-organizational lifecycle management of long-lasting products such as wind turbines and their components.

The third paper presented in chapter 6 focused on unveiling the potential blockchain has a business-transforming and enabling technology for service. Specially it looked at the opportunities the technology provides through connectivity, traceability and transparency to enable servitization of manufacturing companies. The blockchain was found to be an effective enabler of service activities tied to product provenance and data integrity due to its immutable nature that ensures an accurate history of events. This in turn helps secure companies better opportunities for effective and even proactive services due to more accurate information being available on the condition of products monitored through the blockchain’s information storage.

Across the three papers, several characteristics repeated themselves. First, blockchain while being a technological solution, should be considered more than technology as the interorganizational relations tied to using it is essential for its success. Regardless of whether it is trust, competitor-collaboration or servitization what seems to be essential is the fact that blockchain has a synergetic relationship with whatever social phenomenon and business process it seeks to be utilized for. The social aspects surrounding the technology should be considered both antecedent and outcome in using the technology and in extension the nature of the social phenomenon transforms over time as the blockchain ecosystem evolves.

Another common finding across the three papers and for that matter other parts of the PhD-research is that in order to properly involve and gain understanding of respondents perceived value of blockchain, it is often beneficial not to center the conversation on the technology, but rather the processual context it is to be used within. Regardless of whether it is lifecycle management, traceability or something else, the true potential of the technology and novelty for research is revealed when addressing the existing context the technology may end up being a part of.

Considering the overall research question of this dissertation it can therefore be considered that the blockchain's key features of immutability, transparency, democratization and accuracy affect interorganizational collaboration positively, although the complex nature of the technology and requirement of potential users to trust and involve their larger ecosystem is detrimental for the successful implementation of the technology.

7.2. Theoretical Implications

In this sub-section theoretical implications and empirical anomalies challenging current literature stands are presented. Furthermore, the gaps presented in the introduction chapter are addressed and the "filling" in the gaps are presented.

7.2.1. The Hen and the Egg – Interorganizational Collaboration and Blockchain

As was mentioned briefly in the general methodology, one of the interesting realizations that have come along the journey of the PhD is the fact that it is sometimes tough to determine whether blockchain leads to interorganizational collaboration or if interorganizational leads to blockchain. The situation is reminiscent to the hen and the egg situation, but perhaps a bit easier to break down than the famous saying. Interorganizational collaboration proceeds blockchain in literature and can exist without the technology just fine. Ultimately, blockchain is just a tool for facilitating interorganizational collaboration, but this does not mean that the technology is not able to enhance interorganizational collaboration anyway. Similarly, to how Dyer and Chu describes information-sharing and trust to be antecedents and outcomes of one another (Dyer and Chu, 2003), blockchain and interorganizational collaboration can be said to have similar roles.

Willingness to collaborate is required for blockchain to be used (Pedersen *et al.*, 2019) and wide-spread ecosystem collaboration is necessary for the technology to be successful (Lacity and van Hoek, 2021) and as such interorganizational collaboration is clearly a necessary pre-requisites of implementing blockchain. However, as discussed in Theme 1 when the focus was on trust and blockchain, the blockchain technology may also enable new levels of trust and collaboration due to its distributed, transparent nature. Indeed, blockchain enabling a digital form of trust may lead to the involved parties to develop trust in the competencies (Connelly *et al.*, 2018) of their peers in the blockchain network as the data transparency will make it clearer who are capable and skilled players in the ecosystem. As organizations learn to trust the competencies of their blockchain-partners, more information-sharing is likely to occur and more tactical interactions with other organizations may arrive thus boosting the degree of interorganizational collaboration. Furthermore, as trust in competencies grow and tactical information starts to be shared, the higher degree of collaboration across organizational bounds is likely to lead to trust in not just the competencies of the blockchain-partners, but also to trust in their integrity, which may further enhance a collaborative relationship amongst the organization (Holm *et al.*, 2022).

This type of development have been observable during the span of some of the workshops already. As an observer to the interactions of the present organizations, the author could see how the work put into standardizing procurement and traceability standards in the industry quickly led to the representative of the organizations to trust each other more. Just as interestingly, an atmosphere seemed to be building up in regards to less trust being have for organizations who had been invited to the same workshops, but who had chosen not to participate. In other words, even in the design phase of the blockchain, before it actually started to be used, there seemed to be implications on the trust levels of industry players in the sense that active participants who bought in on the blockchain premise were "rewarded" more trust from their industry partners. While those who did not see potential in using (and trusting) the blockchain as a new step was "rewarded" less trust as they were deemed less likely to collaborate and be open in order for the industry to grow.

So while Dyer and Chu's (2003) ideas that information-sharing and trust should be considered to have mutually causal relationship, the research of this PhD, would expand that it goes beyond these two dimensions of trust and information-sharing – interorganizational collaboration seems to have mutually causal relationship with information-sharing (and therefore trust) as well. Furthermore, modern technologies such as blockchain may need to be considered to have a larger impact than just on trust, which is of course already a hot topic in blockchain literature (Engelhardt, 2017; Ferrer-Gomila *et al.*, 2019; Pedersen *et al.*, 2019; Seidel, 2018). However, the consequences and opportunities for information-sharing and interorganizational collaboration are not anywhere near as explored for blockchain and as such, there seems to be potential in further exploring the relation between these concepts.

Coopetition as a specific form of interorganizational collaboration also seems to share the characteristic of being both an antecedent and an outcome of using blockchain. In order for a blockchain solution to be effective in an industry, it is necessary for several organization at the same tiers in the supply chain to collaborate. If they do not and instead for instance go with a blockchain solution each on their own, the benefits for their suppliers and customers dwindle considerably as they will have to keep up with several blockchain and procedures instead of simply using one that the industry agrees on. Further coopetition as an outcome of using blockchain also seems to hold up, as the experience organizations gain from having shared data more openly on some parts may lead to understand that there is actually quite a few things that are unnecessary to compete on. In the UnWind-project specifically, it was interesting to see how OEMs in particular seemed to be increasingly open to share data on more and more types of components. In the early discussions with the industry partners, the information that was discussed to be shared via a blockchain solution was rather simplistic and the components that was discussed to be a part of the blockchain's transactional history was basically items that were not a part of the competitive scene anyway. However, later on as the blockchain technology began to be better understood and its possibilities unveiled, the industry partners began to discuss whether or not there could be an idea in including slightly more complex/competitive products in the blockchain platform as well. Furthermore, it was interesting to see how some of the information regarding components that became more acceptable to share, actually started to be hindered as a possibility, not because of a lack of trust, but because of a competition laws getting in the way.

7.2.2. Connecting Servitization to Interorganizational Collaboration

While the idea of manufacturing companies transforming their business into becoming more service-oriented (Kohtamäki *et al.*, 2019) lacks an obvious connection interorganizational collaboration on the surface, the connection between the two actually becomes quite clear in the context of blockchain. Before diving into the blockchain connection directly, however, consider Håkansson and Snehota's (2006) famous *no business is island* (Håkansson and Snehota, 2006). If manufacturing companies seeks to transform into becoming more service-oriented they must first better understand the life that their products go through and as they traditionally sell them and are done past that point, it could be argued that companies prior to a servitization process are considering themselves an island. In other words, purely focusing on the product is as short-sighted as considering your business model to only include your own company. So in a sense servitization could be argued to be a way of taking an organization out of the old school thought of considering themselves and their products to be isolated from the rest of the ecosystem (the island if you will). So the question comes how you expand your horizons and not just consider the product, but the journey it will be on when delivering value in its lifecycle. Here, a key feature for an organization to improve itself with is to stay in contact with the product and the customer that bought it past the point of sale. In order to do that, a form of communication is needed. This is where the blockchain technology comes in as an intriguing opportunity. As the blockchain is a distributed (Wang *et al.*, 2019) network per definition, the manufacturing company undergoing servitization being part of such as network will enable them an opportunity for not just better information-sharing, but also a higher degree of interorganizational collaboration. This is needed for them to be successful in identifying what services they should offer in addition to or in replacement of their products and for this reason, blockchain is a direct enabler of servitization.

In a sense, interorganizational collaboration in the form of information-sharing can therefore be considered a pre-requisite for servitization, as the manufacturing company needs information in order to develop their services. Connectivity and transparency (De Keyser *et al.*, 2019; Nandi *et al.*, 2020) have already been identified as promising directions for servitization to go in, and as such adding information-sharing to that list becomes natural, in particular in the context of using blockchain. Interestingly, continuing in the line of thought of the former sub-section, servitization could also be seen as a potential outcome of interorganizational collaboration as more information, will lead to further understanding of where services are needed and can be valuable.

7.2.3. Filling the Empirical and Practical-knowledge Gaps

In the introduction two gaps in the literature was identified to be present in the current literature on blockchain. First, was the empirical gap (Miles, 2017) in the sense that current literature lacks examples of non-conceptual blockchain use cases (van Hoek, 2020; Holm and Goduscheit, 2020b). During the PhD several papers have been published and presented concerning the UnWind-project and its associated Fastener-case and this dissertation in itself is helping fill empirical gap by presenting learnings from the UnWind-project. The findings of this project is of course already discussed thoroughly here, but there are however, still some interesting insights of the case that are not presented in too much detail. For instance, one of the overall findings of this project and its case has been that when a blockchain case is being developed, one key advice is not to focus too much on the blockchain. This might sound somewhat confusing at first, but reality is that it is the minority of people and organizations that truly understand what blockchain is and for that reason, it makes better sense to talk about what problems they have than it does to talk about what blockchain is and what it may solve. In other words a pragmatic approach seems to be ideal when interacting with industrial partners as it is much easier for a representative of a company to take offset in a known problem, rather than having to hear about a novel technology that is ultimately still pretty immature in its business applications.

This line of thought is also part of the findings for the second gap concerning practical-knowledge. As mentioned in the introduction section the empirical data suggests that practitioners does not believe blockchain should provide full transparency per default. The interesting thing is that they actually seek a deeper dive into the blockchain technology by having a wish of taking advantage of smart contracts and the encryption possibilities blockchain provides to monetize and automate information-sharing instead of making it immediately available to all blockchain-partners.

7.3. Managerial Implications

The biggest challenges managers and practitioners should keep in mind when looking at the possibilities of using blockchain, lies in some of the same points that were introduced in the theoretical implication. When considering the use of blockchain, it is important to consider what the actual problem that is sought be solved is. Blockchain is not a solve-all solution to information-sharing across organizational bounds. The technology holds a lot of promise for organizations and industries where traceability and transparency are of importance. For the same reasons, blockchain may be of particular interest for industries that are centered on products with longer lifecycles and more complex and expensive products such as wind turbines or cars. Of course, consumer goods such as food and medicine has also had a lot of attention in blockchain literature, but it is for different reasons, mainly consumption safety. The underlying reason why food and medicine is interesting in blockchain context, however, still comes back to traceability. So any industry with a need for high levels of traceability across organizational bounds may have potential in exploring whether blockchain is a business opportunity for them. Of course, there are many factors that determine whether blockchain or another technological option is the better choice (Pedersen *et al.*, 2019).

Another important aspect for managers to consider is the prerequisites needed for blockchain to be useful. Blockchain is of little use to companies lacking a strong digital presence and understanding as the blockchain technology is something that exist purely in the digital world. It therefore works best along other digital technologies such as IoT or as the blockchain's immutable nature is only useful if the data that stored in it, can be trusted to be correctly input to begin with. An IoT approach is faster, cheaper and more reliable as it is unable to put in incorrect values unlike humans that can both make mistakes and have malicious intent. Another important pre-requisite is that has already been discussed is the need for collaboration in the ecosystem for the blockchain to become a business success.

7.4. Social Implications

The blockchain technology and the opportunities for interorganizational collaboration it enable, creates a more transparent information flow, which in extension have several social implications. For one blockchain has great potential to help enforce sustainability (Holm, 2022; Saberi *et al.*, 2019) as it enables new and better lifecycle assessment opportunities. The UnWind-project is one example of this as the blockchain solution enables wind turbine to be more efficiently maintained, thus producing more renewable energy. In addition to that the lifecycle traceability of components enable better opportunities for decommissioning as there is better documentation for what is in the wind turbine and its components.

Blockchain's governance mechanisms also allows for other socially potentially impactful opportunities. The possibilities of democratizing decisions in new ways, due to the distributed nature of the technology and the many options that are for voting and validation with the technology depending on how it is use.

7.5. Limitations and Suggestions for Future Research

One of the major limitations of this study of course lies in the fact that the PhD is built on a single case study. The challenges regarding this has already been discussed in 3.2.1 (p. 28), however, the opportunities for future research has not. Going beyond the obvious in suggesting further case studies and conducting a multi-case study to confirm the findings of this PhD, it would be particularly interesting to see, what the development phase of a blockchain solution would like in a n industry that has a less-ideal history in regards to experience in collaborating across the supply chain and with competitors.

It would also provide meaningful insight to see what the difference in following an already established blockchain case, as opposed to the Fastener-case that was built from the bottom up during the project, in regards to what the respondents views on the process of developing a blockchain solution would be. Furthermore, since the UnWind-project and this PhD was executed in a way where the author was actively involved in the development process of the blockchain, it would be interesting to see what difference it would make in both result and learnings if a case was followed purely through observation and without any direct interactions.

Since this project has been conducted using qualitative methods, there could be different findings if a more quantitative method was used to analyze blockchain case or interorganizational collaboration more generally. Such a quantitative study would likely also benefit from being a multi-case study, so the combination of these two different methodological aspects would make for an intriguing comparison with this dissertation, especially if roughly the same research questions would be utilized in said study

While this project has focused on both vertical and horizontal collaboration cases, one aspect of the broader ecosystem remains unexplored and that is when considering more than two vertical layers of collaboration. In this dissertation only the OEM and (first tier) supplier perspectives are included, but there are undoubtedly further novel insights to be explored by involving more tiers of the supply chain and more members of the larger ecosystem. At one point, it was considered for this PhD to involve a third tier of the supply chain, specifically wind turbine farm owners in order to gain their insights on the value and challenges that could come from having increased transparency, traceability, accuracy etc. for lifecycle management of turbines and their components. In principle since this tier of the supply chain is one step further downstream than the OEM, there should be even more potential in being able to ensure the validity of events through data storage and sharing across organizational bounds, but this of course remains a hypothesis since data was not collected. Nevertheless, it remains an intriguing new path for further research to investigate a three or more tiered case of a supply chain using blockchain technology.

7.5.1. Potential for Methodological Learnings

While the main research strategy for this project has been the case study method, an underlying research inspiration from action research has been present in the strategic approach to the empirical context of this PhD. The sub-focus on action research during the practical execution of the Unwind-project and Fastener-case in which the author has assisted in the development of a blockchain case for the wind industry concurrently with his work in the PhD has revealed that there could be potential in contributing in a methodological way to the blockchain field through this method as well. By having the researcher actively be part of the development of a blockchain solution while researching the topic academically, a unique situation occurs in which new methods for generating new methods occurs because not only knowledge is generated, but actions as well. Considering the rarity and relative immaturity of enterprise and ecosystem-level blockchain solutions, there is potential for exiting and important research by applying a more dedicated action research strategy in blockchain research articles. For instance, a design science approach may prove insightful as to how blockchain design and decision-making processes occur in complex business environments such as ecosystems as opposed to the currently existing design science studies on blockchain that tends to have a much more narrow scope in terms of the blockchain's intended use case scenario.

7.6. Conclusion

In this PhD-research the author has sought to answer the overarching research question: **How does blockchain-enabled information-sharing affect interorganizational collaboration?**

Blockchain differs from most other information-sharing technologies in the fact that it is a distributed ledger technology, meaning that everyone in the blockchain-network all share a copy of the full dataset. However, due to its cryptographic nature, it is possible and typically utilized in a way, so that some blockchain-partners have access to more information than others do. This is possible because the data in the blockchain is encrypted per default and turned into a unique hash-code that is visible in the stead of the readable data. The hash that is generated through the encryption is unique, and if anything is changed in the data the hash is based upon, the hash-code will change as well. This means that while everyone in the network share an encrypted copy of the transactional history, it is still an immutable record, as any attempted change to past blocks of transaction will produce a different hash, which the rest of the network can identify, thereby preventing fraud or accidental errors. This way of sharing data across organizational bounds where the technology both enables for privacy of data, but also transparency in whether anything is changed by others, allows for a high degree of trust in the technology.

The effect of being able to trust the blockchain technology, while also being able to share parts of the content in the blockchain transparently, allows for new ways of organizing collaborations. Specific transactional chains of information, such as those tied to a specific product can be shared openly between anyone in the supply chain that needs information access, while others in the blockchain-network cannot access the data. This means that high levels of traceability can be created for specific products such as fasteners in wind turbines, where the organization currently responsible will be able to log data securely without others seeing it, while still sharing the history of what occurs to a component with the rest of the blockchain network. In case something goes wrong with component that requires for back-tracing of events, the blockchain-participants involved in the data history can then open up the history to identify where issues occurred. Furthermore, other components that have gone through similar events is possible to track in the blockchain so that they can be checked for whether they have similar issues, thus enabling more proactive service and maintenance of a component in a supply chain.

Of course, the blockchain participants can also choose to have a completely transparent history available to all involved parties allowing for faster traceability and a higher degree of transparency. In this case, as the transaction history is more transparent, the network may be able to improve their industrial network further by enabling more efficient service through the blockchain. This particular situation creates unique opportunities for servitization of manufacturing companies as they can create new or better services for the products they produce and sell.

While the open, fully transparent version is limited to be useful for information that organizations are willing to share openly, it still holds a lot of promise, as commodity components and other non-competitive-related information can be shared open even with competitors, thus enabling coopetition opportunities that may help improve the blockchain network as a whole.

In conclusion, blockchain-enabled information-sharing affect interorganizational collaboration by providing new opportunities for sharing data across organizational bounds in a fashion that can be adjusted appropriately to the situation at hand. The primary collaboration opportunities enabled are tied to traceability, such as lifecycle assessment and improved service opportunities across and beyond the supply chain.

7.7. References for Chapter 1, 2, 3 and 7

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8. Appendix

8.1. Other contributions

In the following, scientific contributions not included in the dissertation is included. All contributions are made during the PhD-period. The list does not include the contributions directly included in Sections 4, 5 and 6 of this thesis, as they are already available in their full length in the dissertation.

Paper A: Holm, K. and Goduscheit, R.C. (2020) 'Assessing the Technology Readiness Level of Current Blockchain Use Cases'. *2020 IEEE Technology and Engineering Management Conference, TEMSCON 2020*

Paper B: Holm, K. (2020) 'Application of Blockchain in the Wind Industry'. *CEUR Workshop Proceedings* 2673, 61–66

Paper C: Holm, K. and Goduscheit, R.C. (2020) 'B2B-Blockchain : Transparency in Data-Sharing as a Path to Open Innovation'. *7th Annual World Open Innovation Conference*

Paper D: Holm, K. (2021) 'Stakeholders in Supply Chain-Based Blockchains'. *The 28th EurOMA Conference: Managing the "New Normal": The Future of Operations and Supply Chain Management in Unprecedented Times IEEE,.*

Paper E: Ionita, A., Holm, K., Goduscheit, R.C., Lauritsen, P.H., Jacobsen, K.N., and Thomsen, K.I. (2021) 'Developing a Blockchain-Based Prototype for Wind Turbine Fasteners'. in *Konferenzband Zum Scientific Track Der Blockchain Autumn School 2021.* 81–85

Paper F: Holm, K. and Goduscheit, R.C. (2021) 'Blockchain-Enabled Coopetition: Limits and Opportunities'. *Proceedings of the 22nd International CINet Conference. Continuous Innovation Network*. 229–238

Paper G: Holm, K. (2022) 'Blockchain as a Sustainable Service-Enabler: A Case of Wind Turbine Traceability'. *Lecture Notes in Mechanical Engineering* 516–523

Paper H: Goduscheit, R.C. and Holm, K. (2022) 'Blockchain as an Enabler of Servitisation within the Wind Industry.' *The 6th World Conference on Production and Operations Management*

Paper I: Singh, P., Holm, K., Beliatis, M.J., and Io-, A. (2022) 'Blockchain for Economy of Scale in Wind Industry: A Demo Case'. *Lecture Notes in Computer Science*.

8.2. Co-author Statement Paper 1

AARHUS BSS SCHOOL OF BUSINESS AND SOCIAL SCIENCES
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Declaration of co-authorship*

Full name of the PhD student: Kristoffer Holm

This declaration concerns the following article/manuscript:

Title:	Dissolving Organizational Bounds - Does Blockchain Digitalize Trust?
Authors:	Kristoffer Holm, John Bang Mathiasen, René Chester Goduscheit, Henning de Haas

The article/manuscript is: Published ☒ Accepted ☐ Submitted ☐ In preparation ☐

If published, state full reference: Holm, K., Mathiasen, J., Goduscheit, R.C., and De Haas, H. (2022) 'Dissolving Organizational Bounds - Does Blockchain Digitalize Trust?' Academy of Management Proceedings 2022 (1), 11934

If accepted or submitted, state journal:

Has the article/manuscript previously been used in other PhD or doctoral dissertations?

No ☒ Yes ☐ If yes, give details:

The PhD student has contributed to the elements of this article/manuscript as follows:

A. Has essentially done all the work
B. Major contribution
C. Equal contribution
D. Minor contribution
E. Not relevant

Element	Extent (A-E)
1. Formulation/identification of the scientific problem	C
2. Planning of the experiments/methodology design and development	B
3. Involvement in the experimental work/clinical studies/data collection	B
4. Interpretation of the results	D
5. Writing of the first draft of the manuscript	B
6. Finalization of the manuscript and submission	A

Signatures of the co-authors

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Title:	Exploring the Opportunities of Blockchain-Enabled Coopetition: Learnings From the Wind Turbine Industry
Authors:	Kristoffer Holm, René Chester Goduscheit

The article/manuscript is: Published ☐ Accepted ☒ Submitted ☐ In preparation ☐

If published, state full reference:

If accepted or submitted, state journal: International Journal of Technology Management

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No ☒ Yes ☐ If yes, give details:

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A. Has essentially done all the work
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2. Planning of the experiments/methodology design and development	C
3. Involvement in the experimental work/clinical studies/data collection	B
4. Interpretation of the results	A
5. Writing of the first draft of the manuscript	B
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8.4. Co-author statement Paper 3

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This declaration concerns the following article/manuscript:

Title:	Blockchain-Enabled Servitization
Authors:	Kristoffer Holm, René Chester Goduscheit

The article/manuscript is: Published ☐ Accepted ☒ Submitted ☐ In preparation ☐

If published, state full reference:

If accepted or submitted, state journal: Proceedings of the 23rd International CINet Conference

Has the article/manuscript previously been used in other PhD or doctoral dissertations?

No ☒ Yes ☐ If yes, give details:

The PhD student has contributed to the elements of this article/manuscript as follows:

- A. Has essentially done all the work
- B. Major contribution
- C. Equal contribution
- D. Minor contribution
- E. Not relevant

Element	Extent (A-E)
1. Formulation/identification of the scientific problem	C
2. Planning of the experiments/methodology design and development	C
3. Involvement in the experimental work/clinical studies/data collection	B
4. Interpretation of the results	B
5. Writing of the first draft of the manuscript	B
6. Finalization of the manuscript and submission	B

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