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Blockchain Technology and the Potential for Implementation in Shipping Supply Chains with focus on Vetting

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MASTER THESIS

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Preface

This master's thesis is written as part of a specialization in Maritime Systems Design and Logistics at the Department of Marine Technology. The work has been carried out at the Norwegian University of Science and Technology (NTNU) and DNV GL's office in Høvik during the spring semester of 2019. This thesis is a follow up of a project paper which was written during the autumn semester of 2018 and focus on the concept of blockchain technology and its potential impact on shipping supply chains and vetting. The workload is equivalent to 30,0 ECTS.

I want to thank several people for their guidance and help during the writing of this thesis. Firstly, my supervisor, Professor Bjørn Egil Asbjørnslett, for guidance and fruitful discussions. I also offer my sincere thanks to my contacts at DNV GL, Kenneth Variede, Eskil Kjemperud, Catrine Vestereng, Nina Rygh, and other of the DNV GL staff at Høvik. I especially thank Kenneth Vareide for providing me with guidance and valuable conversation during the period of writing this thesis.

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H.J.H.R.

Summary

The shipping industry is facing a rapid change towards digitalization where blockchain based solutions may be part of the Shipping 4.0 revolution. Many types of maritime supply chains have large potentials for improvement - opening for modernized solutions based on innovation and new technology. Blockchain technology has been proposed to contain the properties needed to solve pain points in several areas and thereby also improve the managing of supply chains. The disruptive technology behind blockchain could, therefore, challenge conventional methods where trust and information-sharing among stakeholders are important.

The objective of this master's work was to evaluate the potential of blockchain technology in supply chains related to shipping. This acted as a ground layer for the first research question: *What are the potential advantages and challenges of the implementation of blockchain technology in shipping supply chains?* The conclusion to this question is that blockchain represents a complex technology with several exiting and beneficial properties but also severe challenges. These advantages and challenges are discussed in the thesis. The complex picture of blockchain technology is both a result of its recent development as well as the tremendous interest created by the technology - causing a wide range of suggested and initiated applications. This complexity is a challenge to the implementation of standardized solutions highly requested by the industry.

Due to the semi-explored nature of the technology, it is important to have access to analytic tools that can be used to assess the complexity and uncertainty associated with the technology's implementation. This formed the basis for the second research question: *Which methodologies exist to provide decision support for the use of blockchain technology?* To answer the research questions, a comprehensive literature search on blockchain technology in different scientific databases was performed. The systematic search resulted in 92 peer-reviewed papers. These papers, together with other secondary sources of information, were used to extract credible information for a critical assessment of the properties of blockchain technology as well as its potential for applications within supply chains related to shipping.

On the second research question, it was concluded that few analysis tools had been developed and used - making it difficult to conclude on their reliability and usability for blockchain evaluation. No models for cost-benefit analysis have been updated to allow a quantitative analysis when implementing the technology in supply chains. Some scientifically designed frameworks are, however, available in the literature which can be used to perform a qualitative analysis to provide decision support for potential implementation. Such a framework was used to analyze the data from the case interviews.

The information from the literature search was also the basis for the case study where stakeholders within the ecosystem of vetting were interviewed to identify pain points and evaluate the potential for blockchain based solutions. It was previously reported that lack of trust between vetting stakeholders resulted in similar inspections being performed on top of each other. A central question underlying the case study was therefore if blockchain technology could decrease the number of executed unnecessary inspections.

The main conclusion from the case study was that blockchain technology is applicable to vetting information management. However, because of the recent improvements in trust, efficiency, and satisfaction among the vetting ecosystem stakeholders, a cost-benefit analysis should be performed before the potential implementation of blockchain is executed. Another finding from the case study was the strong request from many of the vetting stakeholders for a standardized and integrated system to collect, prepare, and manage the many different types of data involved in the vetting process. In this context, the importance of transaction data integrity was highlighted to provide immutable information, and the tracking of assets through the handling process and altered ownerships.

Sammendrag

Sjøfartsnæringen står overfor en rask endring i retning av digitalisering der blokkjedeteknologi kan være en viktig del av fremtidige løsninger. Mange maritime forsyningskjeder har et stort forbedringspotensial – noe som åpner opp for moderne løsninger basert på innovasjon og ny teknologi. Blokkjedeteknologi har blitt foreslått å inneholde egenskaper som kan løse utfordringer på flere områder, og dermed også forbedre styringssystemer for forsyningskjeder. Den banebrytende teknologien bak blokkjeder kan derfor utfordre konvensjonelle metoder der tillit og informasjonsdeling mellom de involverte står sentralt.

Målet med masteroppgaven var å evaluere potensialet for bruk av blokkjedeteknologi i forsyningskjeder i sjørfartsnæringen. Dette var utgangspunkt for det første forskningsspørsmålet: *Hvilke mulige fordeler og utfordringer har implementeringen av blokkjedeteknologi i sjøfartsrelaterte forsyningskjeder?* Konklusjonen er at blokkkjeder representerer en kompleks teknologi med flere spennende og fordelaktige egenskaper, men også mange kritiske utfordringer. Disse fordelene og utfordringene er diskutert i avhandlingen. Det komplekse bildet av blokkjeder er et resultat av at teknologien er ny, samt at den har fått en enorm interesse, noe som har ført til en lang rekke både foreslåtte og igangsatte applikasjoner. Denne kompleksiteten er en utfordring for implementering av standardiserte løsninger som er sterkt etterspurt i bransjen.

Det er viktig å ha tilgang til analytiske verktøy for å vurdere kompleksiteten og usikkerheten knyttet til implementering av ny teknologi. Dette dannet grunnlaget for det andre forskningsspørsmålet: *Hvilke metoder eksisterer som kan gi beslutningsstøtte for implementering av blokkjedeteknologi?* For å besvare dette ble det utført et omfattende litteratursøk i ulike vitenskapelige databaser. Det systematiske søket resulterte i 92 fagfellevurderte rapporter. Disse rapportene sammen med andre sekundære informasjonskilder ble brukt til å samle troverdig informasjon til en kritisk vurdering av egenskapene til blokkjedeteknologi, samt mulige anvendelser i sjørfartsrelaterte forsyningskjeder. På det andre forskningsspørsmålet ble det konkludert med at få analyseverktøy for blokkjeder har blitt utviklet og utprøvd. Ingen modeller har blitt oppdatert til å muliggjøre en kvantitativ kost-nytte-analyse av implementering av blokkjedeteknologi i forsyningskjeder.

Noen kvalitative metoder er imidlertid tilgjengelige i vitenskapelig litteratur og kan brukes til å gi beslutningsstøtte ved en mulig implementering. En slik metode ble brukt til å analysere dataene fra intervjuene av interessenter i vetting.

Informasjonen fra litteratursøket var også grunnlaget for case-studien der personer involvert i vetting ble intervjuet for å identifisere utfordringer samt evaluere potensialet for blokkjedebaserte løsninger. Det har tidligere blitt rapportert at på grunn av manglende tillit ble det av ulike selskaper utført flere nesten identiske vetting-inspeksjoner av de samme skipene. Et viktig spørsmål som case-studien skulle gi svar på var om bruk av blokkjedeteknologi kunne redusere antallet slike unødvendige inspeksjoner.

Hovedkonklusjonen fra case-studien var at blokkjedeteknologi er anvendbar for informasjonshåndtering av vetting-relaterte prosesser. På grunn av nylige forbedringer relatert til tillit, effektivitet og tilfredshet i vettingsystemet, bør det imidlertid utføres kost-nytte-analyser før implemetering av teknologien igangsettes. En annen konklusjon fra case-studiet var et sterkt ønske om utvikling av et standardisert og integrert system for å samle, forberede og administrere de mange nødvendige typer data i vettingprosessen. I denne sammenheng ble viktigheten av tillit til de foreliggende transaksjonsdata fremhevet - dette for å garantere tilgang til korrekt informasjon relatert til blant annet eierskap og sporing av gods.

Terminology

Application Programming Interface (API) / A set of clearly defined methods, protocols, and tools for communicating among other various components.

Bill of lading (BOL) / A document issued by a carrier (or their agent) to acknowledge receipt of cargo for shipment.

Blockchain / A structure for storing data in which groups of valid transactions, called blocks, form a chronological chain, where each block is cryptographically linked to the previous one.

Consensus protocol/mechanism / A process, encoded in software, by which computers in a network, called nodes, reach an agreement about a set of data.

Cryptocurrency / A digital asset defined by a blockchain protocol and exchanged via that blockchain system.

Decentralization / A hard-to-quantify measure of a network's resistance to attack, a function of how broadly control is distributed among different actors.

Distributed ledger technology (DLT / A system, most commonly a blockchain, for creating a shared cryptographically secure database.

Disruptive / A technology or innovation creating a new value network and market replacing an already existing value network and market within the ecosystem.

Double spending problem / Ensuring that a digital asset cannot be copied or used more than once.

Hash function / A cryptography tool that turns any input into a string of characters that serves as a virtually unforgeable digital fingerprint of the data, called a hash.

Internet of Things (IoT) / The network of devices containing software, electronics, connectivity, and actuators allowing these to interconnect and exchange data.

Ledger / An account book in which business transactions are recorded.

Mining / The process by which nodes in Bitcoin, Ethereum, and other blockchain systems add new blocks to their respective chains.

Permissioned blockchain / A shared database with a blockchain structure that requires participants to obtain permission before reading or writing to the chain.

Permissionless blockchain / The same as a permissioned blockchain but where anyone can join the network.

Public blockchain / A blockchain without any access restrictions. Anyone with a computer and internet connection can read and write transactions within the network.

Private blockchain / A blockchain where joining is granted by the administrators within the network. The permission to read and write within the network is restricted.

Proof-of-Work (PoW) / A consensus protocol used in Bitcoin and many other cryptocurrencies. To add a new block, miners must calculate a hash that meets certain narrow criteria. Doing so requires an enormous amount of random guesses, making it a costly process that deters attempts to commit fraud.

Proof-of-Stake (PoS) / A novel consensus protocol in which, instead of mining, nodes can validate and make changes to the blockchain on the basis of their existing economic state.

Scalability / The amount of transactions the network is able to process.

Smart contract / A computer program stored in a blockchain that automatically moves digital assets between accounts if conditions encoded in the program are met. It serves as a way to create a mathematically guaranteed promise between parties.

51% attack / Referring to an attack on a blockchain where a group of miners control more than 50% of the network's computing power.

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Chapter 1

Introduction

Shipping plays an important role in today's global economy. Transportation of goods by sea is the most economical mode of transport. This gave rise to the building of ships used for trade along waterways both locally and between continents - which has gradually increased through the dependence on different products, both agricultural and industrial.

In the mid 19th century, the transporting of cargo in wooden chests between China and London would take more than three months, in comparison to about 30 days today. In the 1960s, the shipping industry was introduced to the standard-size steel container which replaced wooden crates, chests, and sacks that until then had been used for centuries. This became a revolution for the shipping industry together with improved ships.

A similar revolution in the world trade has taken place during the last decades - better known as Shipping 4.0. The increase in trade also resulted in increased amounts of paperwork and need for the handling of complex logistics networks, so-called supply chains [13].

Today, supply chains are mainly based on centralized information management systems. Such systems may, however, lack transparency in ecosystems heavily relying on trust, and where single point failures are seen as threats. The storing of sensitive and valuable information leaves the system vulnerable to errors, hacking, and corruption [14].

1.1 Background

Improvements in computer science during the last decades have resulted in a technological revolution within almost every industry. Part of the maritime industry, such as shipping, has however remained more traditional and slow-forward-moving in terms of the implementation of new technology than other industries [15]. Part of today's shipping industry contains a plethora of paper processes in different languages, such as charter agreements, sales contracts, bills of lading, port documents, letters of credit and component documentation history, circulating among manufacturers, banks, insurers, brokers and port authorities. According to the World Economic Forum, the costs of the processing of trade documents are as much as one-fifth of those for shipping the goods [13]. Globalization has resulted in more advanced trading networks than ever before with continuously improved vessels concerning size and speed, robot-operated ports, as well as systems for tracking cargo. The focus has, however, been elsewhere than towards the streamlining of these paper processes, resulting in higher costs, both concerning resources and time.

Recently, the use of blockchain technology has been suggested to simplify and make the process of information transfer between business partners more secure, efficient, and cost-effective.

1.2 Research Questions

The background for this master's work is the potentially disruptive properties of the blockchain technology. Concerning this, the main goal of this thesis was to evaluate and analyze the potential of blockchain technology in supply chains focusing on shipping and vetting inspections. This led to the first research question:

1. *What are the potential advantages and challenges of implementing blockchain technology in shipping supply chains?*

Blockchain technology is relatively new - especially when it comes to implementation within supply chains in the maritime industry. The technology is barely a decade old, and part of the shipping industry is also a conservative and slow-forward moving business. As a new, innovative, and disruptive technology, it is important to develop a standardized methodology framework that can be used to evaluate the implementation of blockchain technology in supply chains related to shipping. How existing methodologies can be used to evaluate such an implementation in the best possible way led to the second research question:

2. *Which methodologies exist to provide decision support for the use of blockchain technology?*

1.3 Objectives

To address the research questions stated above, the following objectives are covered:

1. Identify scientific research literature to document the following:
   (a) A general introduction of the technical aspects of blockchain technology.
   (b) Advantages and challenges related to the implementation of the technology.
2. Methodologies and approaches for the evaluation of blockchain implementation:
   (a) Relevant methods to analyze shipping supply chains.
   (b) Applicable methods to be used in the case study.
3. Perform an in-depth study of the processes in vetting:
   (a) Identify specific areas within the vetting ecosystem that could benefit from the implementation of blockchain technology.
   (b) Identify methodologies that can be used to provide decision support on the potential use of blockchain technology.
4. Perform a case study that illustrates the process of decision analysis of blockchain implementation.
5. Discuss how blockchain technology will affect supply chains in shipping.

1.4 Limitation

Blockchain is a new technology and few tools for the cost-benefit analysis of its implementation have been developed. Thus, only qualitative analysis is performed.

1.5 Approach

The approach to cover objectives 1-2 and 3(b) has been to perform literature search as described in Chapter 2, Methods, and present the findings in a report to meet the intentions of the objectives. Objective 3(a) and 4-5 was dealt with through interviewing relevant stakeholders in the ecosystem of vetting and analyze the findings to conclude on the possible benefits of blockchain technology implementation.

1.6 Structure of the Master's Thesis

The report is structured as follows:

- Introduction

  Chapter 1 sets background for the study introducing the problem objective, the research questions and introduction to the paper.

- Methods

  Chapter 2 describes the importance and characteristics of scientific research, the approach and results from the systematic literature mapping study.

- Literature Review

  Chapter 3 describes the concept, properties and usability of blockchain technology.
  Chapter 4 deals with blockchain technology in relation to supply chains, focusing on importance and barriers.

- Case Study

  Chapter 5 describes the field of marine safety with focus on inspection routines, and a case study performed to assess the potential of new technology including blockchain in the process of vetting.

- Discussion
  Chapter 6 contains the discussion of the literature and case-based findings.

- Conclusion and Further Work
  Chapter 7 concludes on the research questions described in Chapter 1 and presents thoughts and recommendations for further work.

Chapter 2

Methods

2.1 Research Methodology

The intention of this chapter on research methodology is to provide information on the strategic choices underlying the study. The chapter includes a brief presentation of research strategies in general and describes the principal aspects of trustworthy research [1].

Research has been defined as 'a systematic search for knowledge on a specific topic' [16]. Thus, research refers to a systematic methodology consisting of defining the problem, formulating a hypothesis, collecting necessary data, analyzing the data, and reaching a conclusion. The purpose of research is to obtain answers to questions through scientific procedures, with the aim to discover a hidden or unknown truth.

2.1.1 Types of Research

Research may be exploratory, i.e., to become familiar with a certain phenomenon; descriptive, i.e., describe the characteristics of a certain problem area; diagnostic, i.e., determine the frequency of association with which something occurs; or hypothesis testing, i.e., test a hypothesis of a relationship between variables. Descriptive research is the description of a situation as it exists at present. In analytic research, however, the researcher uses available facts and performs a critical evaluation of the material. Applied research aims to find a solution for a new and practical problem while fundamental research is concerned with general questions related to theory. Quantitative research is based on the measuring of quantities or amounts - while qualitative research is concerned with phenomena in a more explicitly way, without the same focus on quantities. Conceptual research is related to abstract ideas or theories, while empirical research often relates to experiments and other observations. Research can classify as conclusion-oriented or decision-oriented. In conclusion-oriented research, the scientists are supposed to define their problems themselves, while in decision-oriented research, the researcher is often presented with the problem by others. Although decision-making may not be a part of the research, research is often essential for the decisions of the policymaker.

2.1.2 Research Approaches

There are two basic approaches to research - the quantitative and the qualitative approach. The quantitative type often involves the generation or collection of quantitative data, which can be analyzed formally. The qualitative approach deals with a more subjective assessment of attitudes and behavior and is, therefore, more dependent on the insights and attitude of the researcher, and results in non-quantitative conclusions. The techniques used in qualitative research often focus on group interviews, projective techniques, and depth interviews.

2.1.3 Importance of Research

The focus on research in business and industry has increased in modern times. The complex nature of business and governments has resulted in more use of research in solving operational problems. Operation and market research is considered a crucial part of business decisions. Operations research refers, for instance, to the application of analytic techniques to solve business problems of cost minimization or profit maximization.

2.1.4 Research Methods versus Methodology

There is a difference between research methods and research methodology. Research methods mean the collection of all processes and techniques that are used in the conducted research, while Research methodology, on the other hand, refers to the type of systematic approach that is used to solve the research problem. It is essential for the researcher to know not only the research methods and techniques but also the methodology. The purpose is that the scientifically gathered information works as a basis for the conclusions obtained by the researchers. The scientific process should be logic and objective and rely on empirical evidence, relevant concepts, objective considerations, ethical neutrality, probabilistic predictions, and documented methodology. The process should be devoid of personal bias or prejudice [17]. Research methods in social relations with particular reference to prejudice [17].

The Chart shown in Figure 2.1 illustrates a research process.

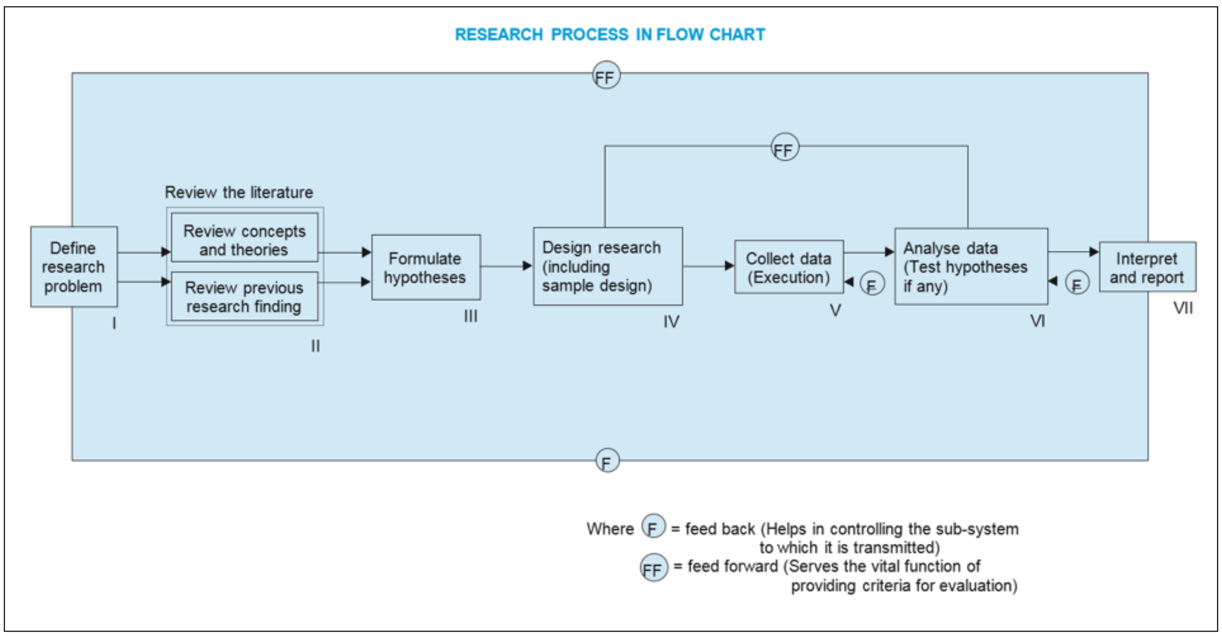

Figure 2.1. Research process in flow chart. From C. R. Kothari [1].

The research process consists of closely related activities I to VII, as shown in Chart. The sequence does not necessarily have to be strictly followed, but the following order constitutes a useful guideline regarding the research process: (I) formulate the research problem; (II) extensive literature survey; (III) develop the hypothesis; (IV) determine the research and sample design; (V) collect the data; (VI) analyze data and test hypothesis (if any); (VII) prepare the report and present the results.

2.1.5 What is Good Research?

The purpose, procedure, methods, and research report should be defined, explained, and prepared in a way that another researcher can repeat the process. The reliability of the data should be checked carefully, and only conclusions justified by the data analysis should be presented. In other words: Good research is systematic, logical, empirical, and replicable.

2.1.6 Methods of Data Collection

Data collection depends on how the research problem has been defined and a description of the research plan. Primary data are original data that is collected for the first time, while secondary data are those already reported by someone else. The methods used to collect primary and secondary data differ. Primary data are collected during the course of the research process - either as experimental data or as descriptive information obtained by performing surveys. Such primary data are collected either through observations, communication with respondents, or through personal interviews. Primary data for descriptive research can be collected by (1) observation, (2) interview (3) questionnaires, (4) schedules, plus several other more specific methods.

Observations are divided into two types, controlled and uncontrolled observations. Observations taking place in a natural setting is termed as uncontrolled observations, while observations obtained from a pre-arranged plan or experimental procedure is termed controlled observations. Controlled observations are often obtained from experiments performed in a laboratory or under other controlled conditions. Uncontrolled observation is collected from exploratory studies without the use of precision instruments. A pitfall of non-controlled observations is the potential for subjective interpretation since there is a danger of believing that more is known about the observed phenomena than there is. Since interviews and questionnaires are the most suitable methods for the collection of primary data in the present work, they are described in more detail.

2.1.7 Interview Methods

Interviews may be performed through personal interviews or telephone/Skype interviews. In personal interviews, the interviewer asks questions in face-to-face contact with the other person. An interview may be in the form of direct contact with the object in question, or it may be an indirect oral investigation related to people who may know about the problem under investigation. Personal interviews should preferably be performed in a structured way and involve the use of a set of pre-determined questions and standardized recording techniques. An unstructured interview is characterized by a more flexible approach without pre-determined questions and standardized techniques. In this case, the interviewer is allowed greater freedom to ask questions and supplement the answers with new questions. This will, however, reduce the comparability with other interviews and complicate the analysis. Unstructured interviews are more demanding on behalf of the interviewer and are the most used technique for the collection of information in exploratory studies. For descriptive studies, however, structured interviews are preferred because they are simpler and less expensive, gives a basis for generalization and are less demanding on the part of the interviewer. In a focused interview, the interviewer may have the freedom to explore reasons and motives, and where the task is to include the respondent in a discussion of issues related to the topic. This is an important type of interview for the development of hypotheses. A non-directive interview is performed to encourage the respondent to talk about a certain topic with only a minimum of questions asked. In this case, the interviewer has the role of a catalyst to obtain the respondents' feelings and beliefs on the relevant topic. Although there is a large spectrum of interview techniques the intentions and properties include: the obtaining of in-depth information; obtain information representing the involved population; large spectrum of flexibility; low non-response; known respondent; may obtain spontaneous reactions; less prone to misunderstandings; possibility of bias on behalf of both interviewer and respondent.

The interviewer must appear friendly and unbiased and not show surprise or disapproval of a respondent's answer. The interview may be performed by telephone, mail, Skype, or in person. Telephone interviews are faster and more flexible than by mail and cheaper than personal interviews. They may, however, not be suitable for surveys where comprehensive answers are required. Collection of data through questionnaires is particularly useful for big inquiries. A questionnaire is sent, usually by post or e-mail to persons who are requested to return the questionnaire with answers. The questionnaire consists of selected questions printed in a form and intended to be answered by the respondents. The use of questionnaires has the following advantages: low cost even when geographically spread; free from interviewer bias; adequate time for the respondents to answer; easy approach of respondents; larger samples creates better reliability. There are also limitations: slow method; low rate of questionnaire return creates bias; dependent on respondent cooperation; low flexibility on the follow-up of questions; difficult interpretation of ambiguous or missing replies. The use and structure of questionnaires should be carefully considered. If not properly constructed and conducted the risk of severe bias is considerable.

2.1.8 Collection of Secondary Data

Secondary data are existing data that have been collected and analyzed by someone else. Such data are obtained from different sources and may be either published or unpublished data. The sources include publications and reports from associations, organizations, and governments; journals; books; magazines and newspapers; public records and statistics; historical documents. Unpublished may be obtained from diaries, letters, biographies, and public or private individuals and organizations. Secondary data should be used with care and a critical approach since their quality and reliability may be severely diverse. The source of secondary data should always be given.

2.1.9 Literature Search

The frame of references has been presented in Chapter 1. Blockchain technology and supply chains are defined and explained separately in Chapter 3 and 4. Findings in the literature about the connection between these topics were presented to give insight into the potential impacts of the use of blockchain technology in supply chains. Processes from vetting were chosen for the case study. Literature reviews can be performed using a systematic or traditional approach. In this thesis, the search was done using both approaches. The systematic search is presented in Chapter 2.2. A traditional literature search is not comprehensive but focuses on finding the literature with the highest relevance for the topic under study. Such a search is best suited when the number of available publications is very high and allows to summarize the most relevant sources. A systematic literature review is less subjective since it includes all relevant publications about a topic and provides better transparency and replicability [18]. However, when a high number of research articles exist, such as for supply chains, a traditional review approach may provide more relevant publications. For a topic such as research on blockchain technology, many of the studies focus on the financial aspect of cryptocurrencies, and therefore, a critical attitude is needed to select for research publications on additional fields of application. The combined literature search approaches enabled the finding of the most relevant publication in both the specific fields and in the combination. The articles were scanned for potential relevance for the purpose. A 'snowball approach' was also used, which means to identify useful references in the most relevant and often cited articles [19]. This approach was especially valuable for the finding of items on the combined aspects of blockchain and supply chain since the direct search resulted in hits with very different content. It was also considered valuable to go back to the source when a reference was mentioned in the articles. This allowed finding the most relevant literature for the study. After collecting a sufficient number of items, the content of each piece was sorted to the different subtopics - providing a reasonable overview on various topics, and helped to present the most relevant aspects related to the research objectives.

2.1.10 Research Approach

Academic research can be inductive, deductive, or abductive. Inductive research starts with empirical observations to develop a new theory. A deductive approach starts with an existing theory which is used to analyze collected empirical data. Abductive research is a combination of inductive or deductive research, which may include both base itself on existing theory but also test new findings concerning existing theories [20]. This thesis aims to combine existing theories on blockchain solutions and the ecosystem of vetting using a mixed approach more similar to an abductive method. To relate theory to empirical findings, the abductive research process requires theoretical knowledge, which is compared to real-life observations to gain new understanding and draw conclusions on the research topic [21]. The abductive approach has also been suggested for studies investigating company relations in a business context [22]. Thus, the abductive approach should be considered useful for the analysis of the potential impacts of blockchain technology on different company processes.

2.1.11 Qualitative Approach

A qualitative approach for the thesis was chosen since it opens for studies of different perspectives of the selected topic. Qualitative research can be used to analyze the roles and impact of different phenomena such as social settings, and as a tool to investigate existing problems or challenges in society [23, 24]. An argument against qualitative research is that it cannot address general questions. It is, however, considered as a suitable approach to analyze the depth of a challenge, rather than the quantitative implications. Also, to be aware of the risk of personal influence that could result in interpretation bias is of importance [23]. The role of blockchain in the vetting ecosystem have been analyzed qualitatively because it has been difficult to obtain quantitative measures. This is in part caused by what is conceived as lack of trust in the ecosystem, but also because the findings from the interviews on the potential opportunities of blockchain cannot be measured in numbers - also because the implementation of blockchain technology is still pending. This qualitative approach is intended to suggest the impacts of blockchain technology on vetting processes, especially on information sharing and trust. Thus, the question of trust in the ecosystem has been in special focus in the interviews [25].

2.1.12 Case Studies

Several different research strategies are presented in the literature, such as 'action research,' 'archival research,' 'ethnography,' 'narrative methods,' 'grounded theory,' and 'case study' [18]. It is not necessary that a research project strictly follows a certain strategy type, but more than the strategy or mix of strategies fits the purpose of the project [26]. For this thesis, a combination of literature survey and case study has been used, since this may help to understand the existing challenges in the ecosystem of vetting [25, 27]. In this study, different sides of an ecosystem have been explored by listening to the opinions of different stakeholders within the system. This is done to throw light on the totality of challenges in the chain, to be able to better assess the potential impact of blockchain technology for different purposes. It is of importance to gain knowledge if different stakeholders have similar or different expectations and view on the impacts of blockchain technology on the processes, and their intentions concerning information sharing. It has been argued that a case study lacks the property that allows for general conclusions [27]. It Each stakeholder is acting under different conditions, which also affects possible generalization [25], and also that the amount of empirical data is critical for the ability to structure the findings. Because of time limits and other restrictions, it is important to have a critical view of the arguments and conclusions that can be drawn from the study. To avoid over-interpretation, it is especially important to have a clear structure where all details on every part are thoroughly described and explained [18]. As is evident from the literature search, several publications on the potential implication of blockchain technology in supply chains are available, and the abductive approach of combining literature studies with the interviews of the case study will strengthen the findings and conclusions. The study of Simatupang and Sridharan [28] is one good example of how the implementation of blockchain technology may impact a supply chain. However, more studies on different supply chain environments are needed.

2.1.13 Data Collection

Data Collection was done through qualitative interviews. The interview acts as a conversation where mutual reflection, understanding, and knowledge is expressed and shared by the interviewer and the person that is being interviewed [29]. This is considered a suitable method to obtain opinions and experiences from a company employee, which could else be difficult to observe from the outside. It is, however, important to realize that interviews are also prone to possible disadvantages. Interview bias, being possible effects of the interview situation where the personal opinions of the interviewer and the interviewee may influence what is expressed as a result of the interview on behalf of the company [18]. Such bias is, however, mitigated by the combined use of additional supporting secondary data, extending the data collection strategy and thus providing information from several sources [25]. Such additional information includes available company documents provided by the participating companies after the interviews.

To obtain information on the opinion and experience of the company representatives, semi-structured interviews with fixed questions, and more flexible answering structure were applied [18]. Such semi-structured interviews provide a balance between open conversation and the use of closed questionnaires and have been considered appropriately effective and flexible to obtain proper information from an interview situation [30, 31]. Using this technique, it is possible for the interviewer to present follow up questions, and thereby obtain more of the information of interest. It is, however, important to realize the ability of this technique to allow change of plan during the interview and be aware of the possible introduction of bias. The interview process and questions were planned in detail, with questions linked to the topics of interest. Although different types of companies were interviewed, the interview plans were the same for all companies, but some of the follow-up questions could vary - both as a consequence of company type, but also because of individual differences in the way the respondents answered. The process was reflected after each interview to consider necessary adjustments [32].

2.1.14 Research Sample

Since the purpose was to study the potential impacts of blockchain technology in the vetting process, different types of stakeholders in the ecosystem were selected for interview. Blockchain solutions in supply chains are, however, relatively new, and the knowledge on this may differ among the companies and employees. The secondary data from the companies could provide additional input of value for the study, and the combination of these data inputs was used to obtain a picture of the way the company considered the potential of the blockchain technology in processes related to vetting. To obtain company contacts, a search for companies in the vetting field was conducted, and these companies were contacted for possible interviews. Employees at DNV GL were helpful with suggestions on whom to approach for interview contacts. Also, snowball sampling was used, meaning that new candidates for an interview could occur as a result of information obtained in another interview [18]. Since blockchain is new for many companies, snowball sampling became an important and helpful way to meet suitable interview candidates [18].

2.1.15 Data Gathering Process

After deciding which companies and employees to contact, an e-mail was sent where the project was presented, including the research topic and the questions that would be focused on in the interview. In several cases, the e-mail was followed up with a significant number of phone calls to locate the person that was both willing and interested in participating in the interview. The interest was diverse; some were not willing or interested at all; others considered the approach both meaningful and exciting and were very willing to participate. The interviews were done by telephone, by Skype, in personal meetings or written answers, and were semi-structured, meaning that the same central questions were asked to all participants, but that the follow-up questions differed depending on the situation. Semi-structured interviews are relatively open, and the length varied between 16 and 68 minutes.

2.1.16 Research Ethics

It would be naive not to recognize that there are many potential pitfalls in a study such as this. The semi-structured interview process opens for the subjective influence of the person who performs the interviews. Many dilemmas occurring through all phases in the research process [31, 33] has presented seven stages in the interview process. Ethical issues; selection of theme, study design, interview situation, transcription of data, analysis of data, verification of data, and reporting the results should all be considered. It cannot be said for sure that all pitfalls had been avoided in the present work, but awareness on the issues may at least have prevented the falling into all of them.

2.2 Systematic Literature Mapping Study on Blockchain

The importance of addressing the topics that already have been studied related to blockchain in supply chains is crucial to set the basis for this report. This issue has been addressed carrying out a systematic mapping study process [34] in March 2019. The mapping was intended to identify the current research status on blockchain technology concerning supply chains in shipping. The search, therefore, exclusively focused on scientifically documented research - meaning that initially only peer-reviewed articles were considered. Grey literature from the study such as white papers was therefore not part of the mapping - leaving most on-going visions and projects out. See the previous project paper for on-going visions and projects (December 2018). An important thing to mention is that after realizing that quite a lot of interesting information also were found in other sources. From the peer review, it was decided that if such sources were found to be referenced to in peer-reviewed literature, they could also be included. Exclusively given that they provided relevant information not found elsewhere.

The goal of a systematic mapping study is to establish an overview related to the topic, finding out if there exists evidence, and quantify the amount of evidence [2]. The systematic mapping process by Petersen et al. [34] was applied to address the aim of the paper and by that identify and explore already existing studies related to blockchain technology. A guideline for systematic literature review by Kitchenham and Charters [2] has also been applied to search for relevant papers. The systematic mapping process is illustrated in Figure 2.2.

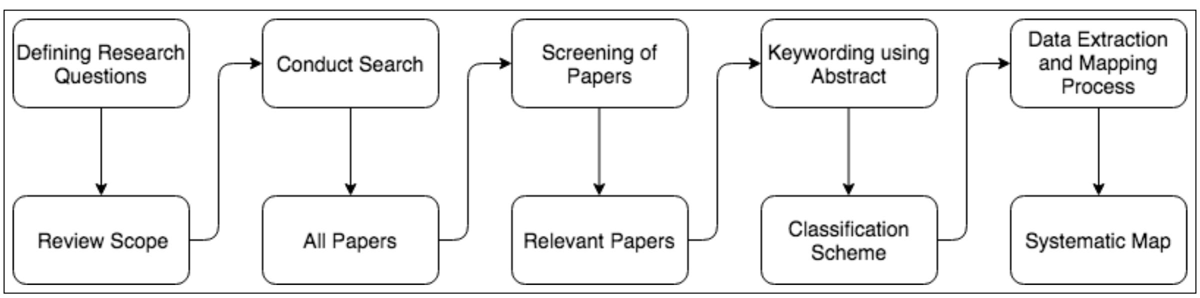

Figure 2.2. Systematic mapping process. From Kitchenham and Charters [2].

2.2.1 Defining the Literature Research Goals

The first part of the systematic mapping process is to define the goals of the literature research. Three different search strings have been developed to cover the intended literature scope of the paper. These aim to focus on the general overview of the current research on blockchain technology, its relation to supply chains and shipping, and scientific methodologies used to evaluate a blockchain implementation in a supply chain. The search strings intend to gain insight into the following research goals:

RG1: What is the current state of knowledge on blockchain technology?

RG2: What research topics have been addressed on blockchain technology relevant to supply chains in shipping?

RG3: What are the current challenges, limitations and open issues related to blockchain technology?

RG4: What methodologies to evaluate blockchain implementation in supply chains are available?

2.2.2 Conducting the Search

The classification scheme consisted of five steps, as can be seen in Figure 2.3. The complete list of the 92 primary papers is provided in B.3 in the Appendix, giving an overview of the selected primary papers from each of the four databases.

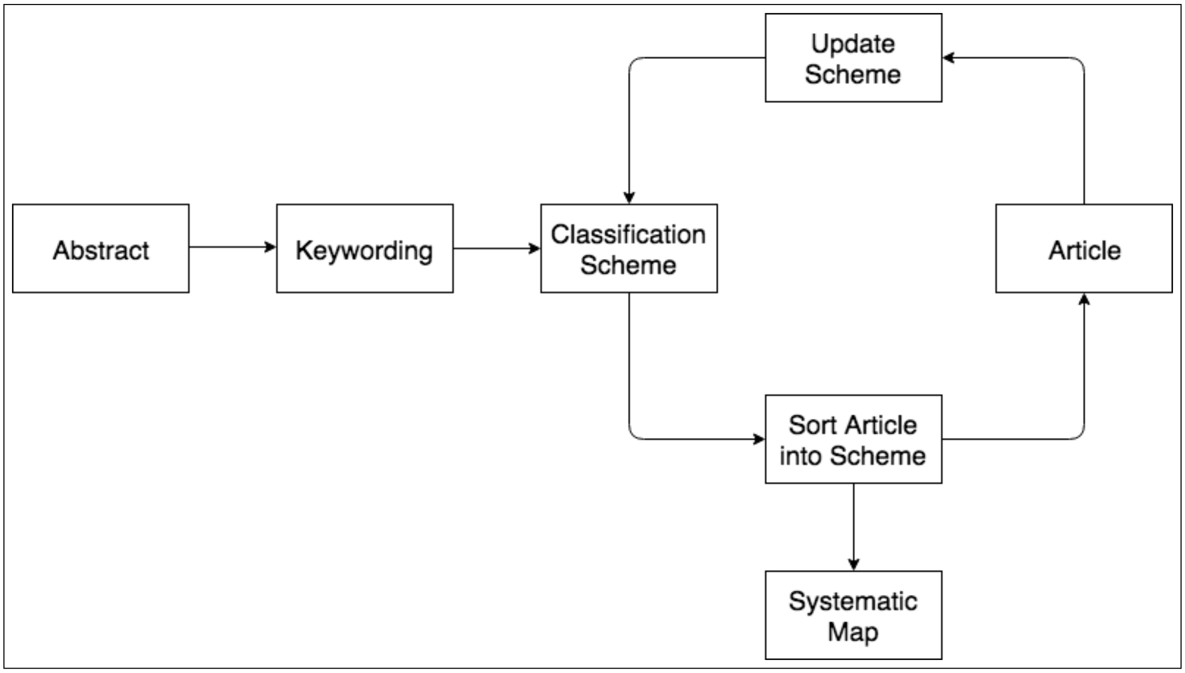

Figure 2.3. Building the classification scheme. From Kitchenham and Charters [2].

The second step of the systematic mapping study is searching for the research topics in each selected scientific paper. A set of pre-defined search strings have been developed. These strings are necessary to reduce researcher bias.

The strings were determined after several pilot searches consisting of various logical keywords related to the topic of the thesis. This approach aimed to collect relevant and trustworthy information. The strings applied and their research goal can be seen in Table 2.1.

Table 2.1. Search strings and their respective goals. Search date: 12/03-2019.

Search string	Research goal
blockchain AND technology AND systematic review	Gain an overview on the current research on blockchain technology
blockchain AND supply chain AND shipping	Critically addressing the potential and challenges related to blockchain technology in supply chains
supply chain AND methodology AND analysis AND blockchain	Address potential methodologies that can be used to evaluate a blockchain implementation in a supply chain

More general strings such as 'blockchain AND shipping' could have been applied. It was, however, observed that using strings containing fewer words would result in a dramatic increase in hits – too many to be further investigated. A majority of these were not related to supply chains but to cryptocurrencies and initial coin offerings (ICO) in shipping. These topics are not of interest to this paper, which is why it was decided to use the more specified strings. The author believes that even with these more specific strings, there will be sufficient information to answer the research questions.

Later, the scientific databases were selected. The databases used in this report are all scientific databases. Grey literature (e.g., Google) was avoided, focusing on peer-reviewed papers published in journals and books from conferences and workshops. The following databases were used (1) ScienceDirect, (2) Taylor and Francis, (3) Web of Science, and (4) SpringerLink. Each specific database was selected due to its relevance to the topic of the thesis and its full article access via NTNU.

2.2.3 Screening for Relevant Papers

Not every paper obtained in the searches were relevant to the research questions and had, therefore, to be assessed for relevance [35]. This led to the third stage of the mapping process - screening of the papers and was carried out as defined by Petersen et al. [34], and consisted of multiple steps. The first step was to decide whether the paper title was relevant to the research topic. Irrelevant titles that do not comply with the research topic are excluded. An example would be topics related to other technologies or exclusively focusing on different and unrelated industries. It could also be papers not relevant to computer science. These papers were considered irrelevant to the thesis and excluded from the study. Some of the titles in the search were found to have unclear relevance based on the title and was passed on to the next phase - inclusion or exclusion based on the content of their abstract. A checklist was used to filter out irrelevant papers. If any of the points in the list were fulfilled, the article was excluded from the study. The checklist consisted of five aspects: (1) papers published in other languages than English, (2) not having access to the full article, (3) documents focusing outside the computer science aspect of blockchain technology, (4) duplicated papers, (5) non-peer-reviewed papers. If a paper passed all these five exclusion criteria, it was considered relevant to the research questions.

2.2.4 Keywording Based on the Abstract

The second step in the systematic mapping study is the keywording stage (See Figure 2.3). This process is done in two phases. First, specific keywords and concepts with relevance to the paper are identified in the abstract section [34]. Second, these keywords are used to gain a higher insight and understanding of the specific keyword concepts and form mapping sections for categories in the report.

2.2.5 Data Extraction and Process Mapping

Table 2.2 was designed to extract relevant information addressing the research questions. Points 1 to 4 deals with information pertinent to the paper such as title, authors name, country of the authors, and publication source. Points 5 to 8 relates to the content of each respective study, i.e., the goal of each paper and any relevant information to the research questions of this study. Manual extraction, MS Office, and EndNote were used to sort and extract the data in an organized fashion - depending on the compatibility of the specific database.

Table 2.2. Organized data extraction hallmarks from primary papers.

#	**Data Hallmark**	**Hallmark Description**
1	Title	Paper title
2	Authors	Name of the author(s)
3	Country	Country of author(s)
4	Publication information	Name of publication source
5	Abstract	Abstracts of the paper
6	Study goal	Objective of the paper
7	Research questions	Goals of the research questions in the paper
8	Study findings	Key findings in the study

2.2.6 Search and Selecting Results

The search and selection process of the primary papers is shown in Figure 2.4. From the original search strings resulting in 476 papers, 92 ended up as the final number of primary papers after the selection process. The relatively large number of excluded papers were mainly due to many topics not related to this thesis.

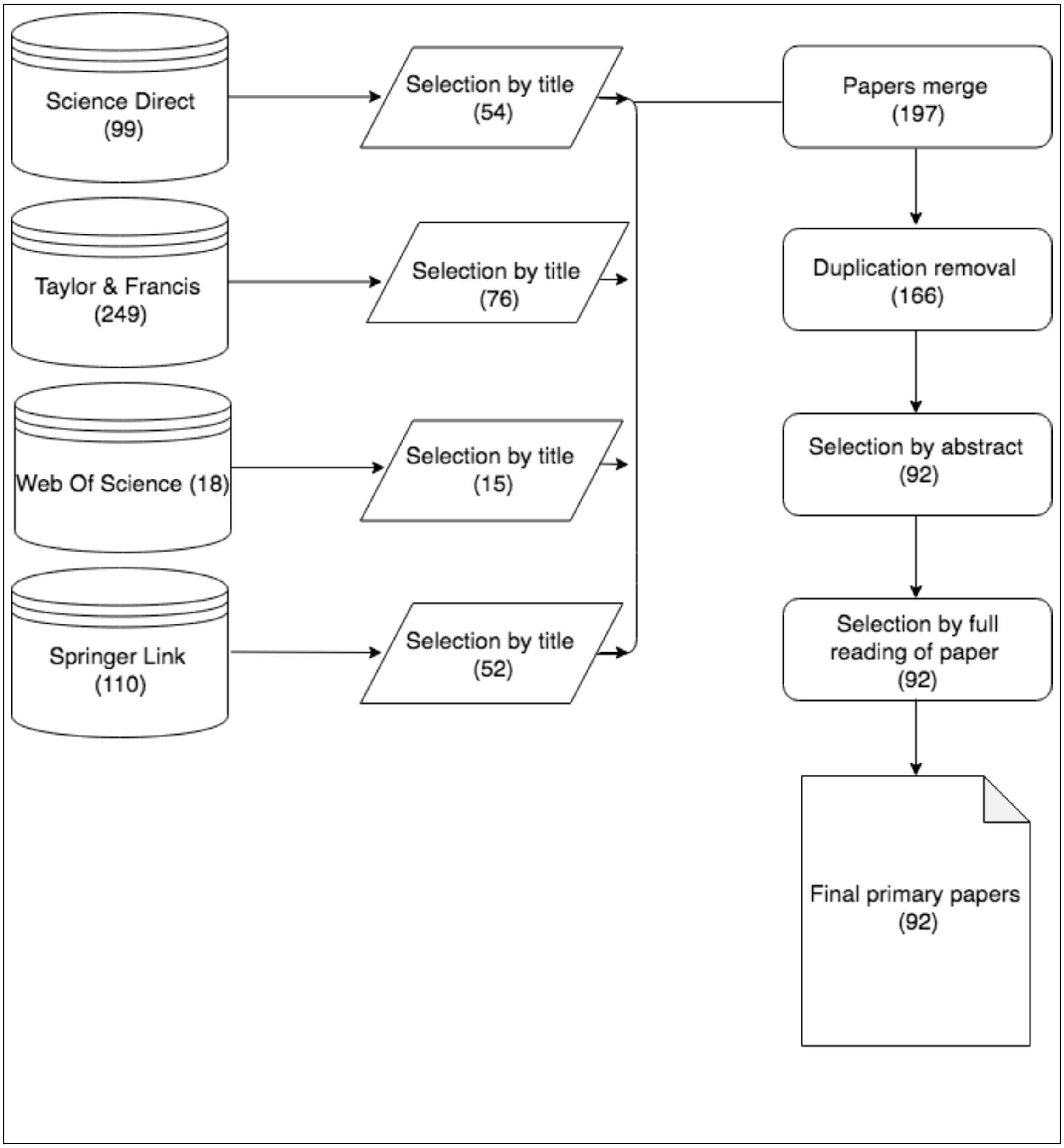

Figure 2.4. Search and selection process of the papers.

The abstracts of these were then read carefully once again by the author. This did not result in more papers being excluded. All primarily selected papers are represented in Appendix B.3.

2.3 Methods to Analyze Supply Chains

The main topic of this thesis is to evaluate the potential use of the relatively new blockchain technology in supply chains and the ecosystem of vetting inspections. Methods or models to be used to assess the performance of supply chains in a cost-benefit perspective are, therefore, essential. Several available models have been and are used to analyze supply chains. They have in common that they have been established as general models that are later updated to serve a specific purpose. Since the interest for the use of blockchain technology in supply chains is a relatively new subject, none of these models have been updated for use to analyze blockchain-related processes, and the author has considered it outside his possibility to do this as part of this thesis. The experimental work is, therefore, focusing on the determination of challenges, knowledge, interest, opinions, and perceived belief of the vetting stakeholders on the implementation of blockchain technology in their ecosystem. In Chapter 5.2 describing the case on the vetting ecosystem, the author also describes published frameworks intended for use in the decision process of whether to implement blockchain in supply chains or not.

Although not used in the thesis, the most relevant models for supply chain evaluation from the literature searches are presented, the TAM (Technology Acceptance Model) and the SCOR (Supply Chain Operations Reference) models. Hopefully, these models will soon be updated for cost-benefit evaluation of blockchain implementation in supply chains.

2.3.1 TAM (Technology Acceptance Model)

The technology acceptance model (TAM) was developed by Fred Davis in 1989 and dealt with the acceptance and use of new technology [3]. In the model, Davis defines factors that influence the decisions regarding if, when, and how new technology should be adopted. A schematic view of the model factors is shown in Figure 2.5.

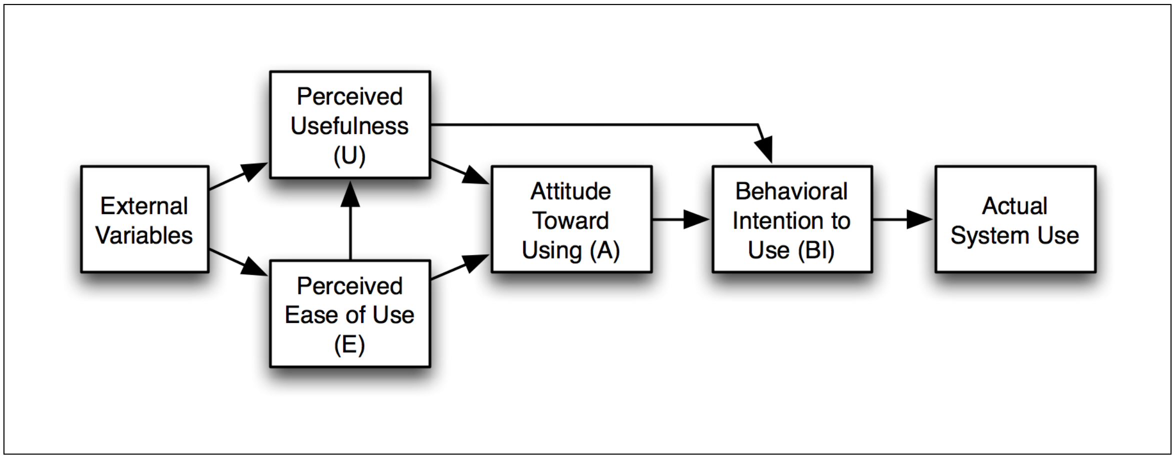

Figure 2.5. Technology Acceptance Model (TAM). From Davis et al. [3].

In TAM, version 1, Perceived Usefulness (PU) is defined as 'the degree to which a person believes that using a particular system would enhance his or her job performance', while Perceived Ease-of-Use (PEOU) is defined as 'the degree to which a person believes that using a particular system would be free from effort' [3]. The introduction of these two parameters, PU and PEOU, is a central aspect of the model. The TAM model has been upgraded several times, TAM 2 came in 2000 [36, 37], and here the perceived usefulness and usage intentions in terms of social influence and cognitive processes were explained in more detail. In the 'Unified Theory of Acceptance and Use of Technology' (UTAUT), which was published in 2003, an attempt was made to integrate the main competing user acceptance models [37]. Some recent studies have adopted UTAUT in healthcare [38]. A third version, TAM 3, was presented in 2008. In this version, the potential effects of trust and perceived risk introduced by the new technology was also included [39].

The development of TAM is built on previously published theories of reasoned action (TRA) [40], and is by many considered as the most widely applied model for the acceptance and use of technology [3, 36, 41].

It has been pointed to that TRA and TAM tend to assume unlimited freedom to act, while in the real world there are many constraints, and that actual usage of new technology may not occur as a direct consequence of intention [42]. Legris et al. [43] suggested that TAM should be extended to include parameters for change processes and that innovation model factors should be adopted. The original study of Davis [3] have been tested, evaluated and commented on by many scientists, and have provided substantial empirical evidence on the relationships between usefulness, ease of use, system use and reliability of the model [3, 44, 45, 46, 47, 48, 49, 50]. The TAM model has been used in several technological and geographical contexts, including health care [51].

Several studies have proposed many extensions of the original version of TAM. In these versions, different variables have been added to explore effects on various parameters by the actual use of new technology. Such parameters are perceived self-efficacy, facilitating conditions, and systems quality [52, 53].

Although frequently used, TAM has also been criticized for having incredible heuristic value, limited predictive power, triviality, and lack of practical importance. Many updates have attempted to answer to this critique [54, 55, 56].

2.3.2 SCOR (Supply Chain Operations Reference) Model

The Supply Chain Operations Reference (SCOR) model was developed in 1996 by two management consulting firms (PRTM, now part of PricewaterhouseCoopers LLP (PwC) and AMR Research, now part of Gartner) and endorsed by the Supply-Chain Council (SCC) for use as the standard tool for supply chain management analysis. SCC merged in 2014 with APICS (American Production and Inventory Control Society) to form APICS Supply-Chain Council (APICS SCC) and is now maintaining the SCOR methodology. APICS SCC is a nonprofit organization that works to improve supply chains through research and benchmarking. The intention is to enable corporations, academic institutions, and public organizations to address emerging challenges of supply chains and improve their performance. The SCOR model is intended to analyze the status of the supply chain processes, quantify its performance, and compare it to benchmark data. This should enable users to improve supply chain management practices in and between partners in the supply chain. The model is based on four major pillars: Process modeling; Performance measurements; Best practices; and Skills and can be applied to simple as well as complex supply chains using a set of pre-defined process elements. Thus, the model may be used to analyze a variety of different supply chains.

Processes

SCOR divides the supply chain into six different management processes: Plan, Source, Make, Deliver, Return, and Enable. 'Plan' is the overall plan for the whole intended process, while 'Source' concerns the goods and services needed. 'Make' involves the transformation to a finished product and 'Deliver' concerns the provision of the product to customers. 'Return' is related to the returning of products, including customer support and 'Enable' covers the processes involved in the running of the supply chain, such as contracts, risk, and network management. The SCOR model focuses on customer interactions, product transactions, and market interactions until the fulfillment of each order, in three levels of process detail (See Figure 2.6). The defining of scope constitute Level 1, supply chain configuration is concerned in Level 2, while the process details and performance attributes are dealt with in Level 3. In Level 3, the companies implement specific management practices and adapt to changes in the business situation. Important practices are communication between supply chain partners and collaboration both within and outside of the supply chain. The SCOR Framework Levels are shown in Figure 2.6.

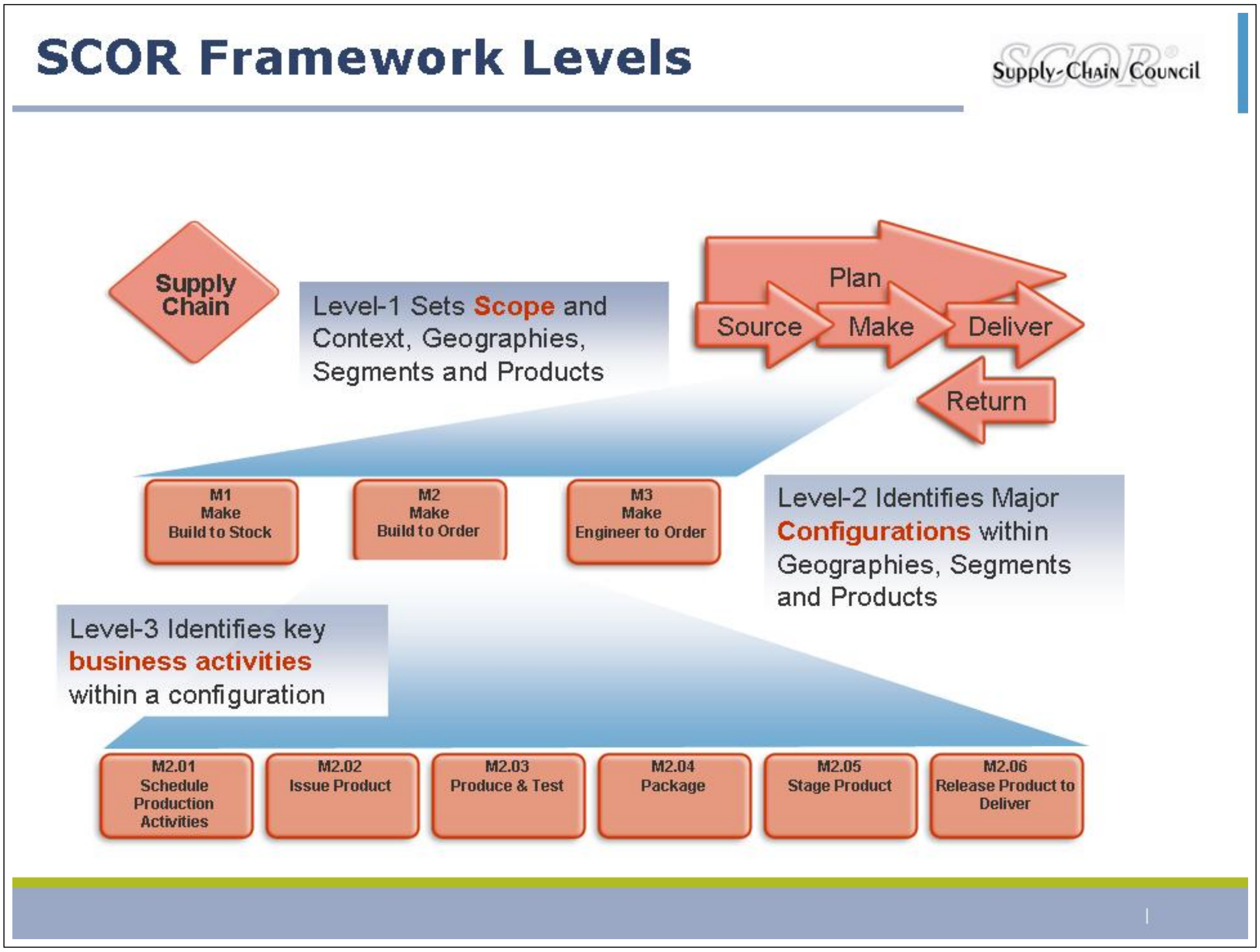

Figure 2.6. SCOR process framework. From Supply-Chain Council [4].

Performance

The SCOR model contains more than 150 key performance indicators that have been derived from the experience and contribution of users. The performance attributes are defined in a way that permits it to be analyzed and compared with other similar supply chains. This makes it possible to compare, for instance, a low-cost provider with an organization that is more focused on reliability and performance. An organization may have multiple supply chains. Thus, it is important to realize that performance measurement and benchmarking is related to the supply chain level and not to the organization. It should be noted that SCOR may not contain benchmarking data for all types of supply chains, so it is necessary to check this in advance. The improving of a supply chain in an organization may affect the entire organization.

Best-practices

When the performance of the supply chain has been tested, it is important to identify gaps and determine how such gaps could be filled. More than 400 executable practices from SCC members have been made available, and the SCOR model is supposed to provide a structured approach for this task. Empirical studies on the use of SCOR is claimed to show positive effects - either an increase in speed, revenues, and quality or reduction in cost, loss, or return.

Chapter 3

Blockchain Technology

3.1 What are Blockchains?

Blockchain technology was first described in 2008 by someone calling themselves Satoshi Nakamoto as a platform for managing the digital cryptocurrency Bitcoin [57]. Even today it is not known who this person or group of persons were. The term 'blockchain' is defined as 'a shared, distributed ledger that facilitates the process of recording transactions and tracking assets in a business network' [58]. The assets may be tangible, such as cash, cars, houses, or land properties - or it may be intangible, such as patents, certificates, or copyrights. Following Bitcoin, a substantial number of other cryptocurrencies based on blockchains has been presented. Because of this, the word blockchain is for many synonymous with Bitcoin, cryptocurrencies, and financial speculation. In the past years, a substantial effort has been initiated on projects implementing blockchain to other areas than the financial industry [59, 60, 61]. Much of this work has been performed in smaller companies, but larger corporations have also shown interest in the development of the blockchain technology. IBM has especially been interested in considering the technology to be a tool that could allow simplification and decreased the cost of transactions and collaboration between companies - securing trust among business partners in many different industries [58].

A blockchain is a sequence linking several digital signatures that have been confirmed among participants using a time-stamp server [57]. The technology is based on distributing records on a database or ledgers of digital events shared among the participants in the network [62]. The network allows its participants, called nodes, access to the same ledger updated through a peer-to-peer procedure when a new transaction occurs. It secures that each node may act as both a publisher and a subscriber to the ledger, and thus being allowed to both send and receive transactions from other nodes in a synchronized fashion as the transactions occur [58].

When a participant in the network wants a new transaction to be added to the blockchain, the transaction is first broadcasted within the network for verification and auditing. After most nodes approve the transaction under accepted rules, the transaction will be added to the chain as a new block. Records of approved transactions are kept for security in each of the network nodes.

A blockchain may, therefore, be considered as a chain of time-stamped data that cannot be altered - only appended. This creates the basis for peer-to-peer networks where non-trusting members can interact without the need for a trust-securing authority [63]. The infrastructure of blockchain technology has been illustrated as a set of interconnected mechanistic features as illustrated by Casino et al. [5] (Figure 3.1).

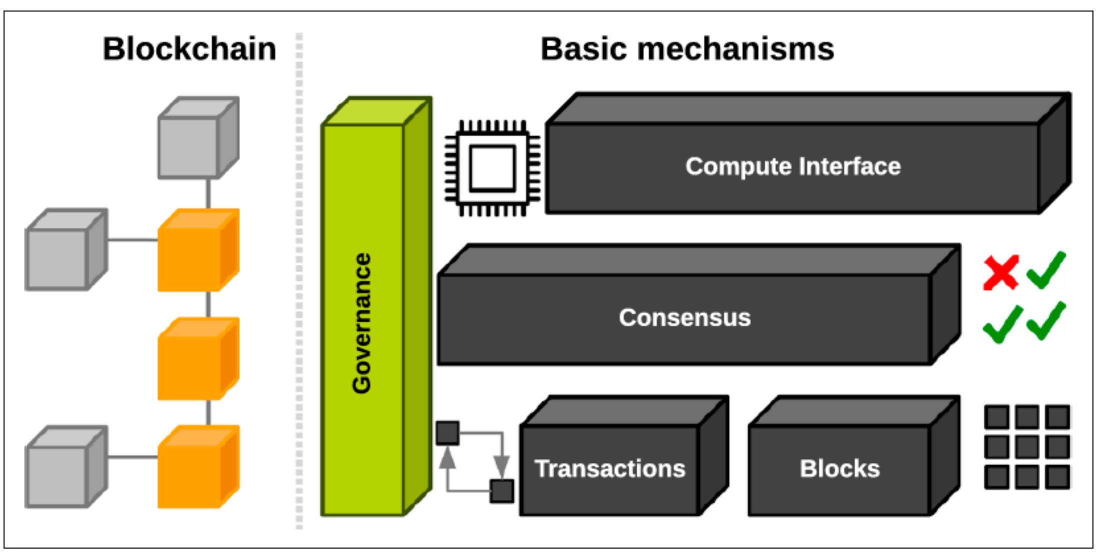

Figure 3.1. An overview of blockchain architecture. From Casino et al. [5].

The lowest level of this infrastructure represents signed transactions between peers. These transactions may, for instance, constitute an agreement between two participants concerning the transfer of physical or digital assets, the performing of a job, or the status of goods. When at least one of the partners has signed the transaction, it is distributed among the other participants within the network. Only nodes that have accepted all network rules are full nodes. The full nodes determine whether the transactions are valid and group the acceptable transactions into blocks.

Several criteria determine whether a transaction is valid or not, for instance, that the same digital asset is not used more than once, the so-called 'double spending problem.' The full nodes must reach an agreement on which transactions should enter the blockchain by the second Consensus layer [63, 64]. The Computer Interface layer makes blockchains more functional. Since the blockchain stores all the transactions made by the users, it is possible to calculate the balance of every user. For more advanced applications, it may be necessary to update the network dynamically using distributed computing - meaning that the tasks shift between the nodes according to specific criteria.

The Governance layer comprises the part of the blockchain architecture, which acts as a practical interphase between the users and the network. Blockchain protocols are often well characterized but may still be affected by new methods intended to improve the protocols and the patching of the system. This helps to improve the functionality of the blockchain by regulating how the input from different participants act together to create, maintain, or alter the data that make up the chain.

3.1.1 Public and Private Networks

In the literature, the blockchain networks are categorized according to the network's management and permissions as public, private, and federated/consortium based [63, 65, 66, 67]. Their basic concepts are similar, but they differ in accessibility and validation procedures. In public and permissionless blockchains, anyone can join the network as a node and perform transactions or operate contracts. A typical example of the public architecture is the Bitcoin transaction network. This type of network does not require that the users have software. In private or consortium based permissioned blockchains, there is a whitelist of allowed users that have been defined by specific characteristics and where the permissions are related to different types of network operations. The consortium based and private networks are decentralized among their permitted users who need a private key or password to access the chain [68]. An example of a consortium-based network is TradeLens by IBM and Maersk.

Different types of blockchains have different mechanisms of consensus [69]. Proof-of-Work (PoW) is known from Bitcoin and requires the solving of a complicated mathematical problem, such as the finding of hash values with specific patterns to certify authentication and verifiability [70]. Proof-of-Stake (PoS), another consensus mechanism, is less dependent on mining power - thereby preventing the wealthiest participants from dominating the network [68]. Many blockchains, such as Ethereum [71], are changing the consensus mechanism to PoS because of its decreased demand for power consumption and improved scalability. Private blockchain networks have reduced risk of attacks and may, therefore, avoid the use of the more expensive PoW consensus mechanism [72]. A federated, or consortium based blockchain, can be viewed as a hybrid between public and private blockchains and is similar to a private blockchain concerning scalability and privacy protection [65, 66]. The main difference between private and consortium-based blockchains is that for the consortium-based type, a group of full nodes is selected to verify the transaction processes, while for the private network, a single entity is responsible. The shared responsibility creates a decentralized design where the leader node(s) may grant permissions to other users. In addition to ownership and management of the information shared in the blockchain, additional features such as transaction approval time, security and anonymity are essential features [63, 65, 66, 67].

The best-known use of public blockchains include cryptocurrencies such as Bitcoin, Ethereum and Litecoin [57, 73], and their main advantages are low infrastructure costs since the network is self-maintaining. In a private blockchain, the cost is mainly related to database management, auditing, and performance [66]. Multichain is an example of an open platform that allows the establishment of private blockchains [74]. The federated blockchains are mainly used in the finance and industry sector [75]. One example being the Hyperledger project [76] which is a permission-based blockchain framework used within and between different industries. Recently, Ethereum has also presented tools for the building of federated blockchains. Additional types of blockchain categories have also been described [72, 77]. Wüst and Gervais [7] have identified different properties for various blockchain types compared to a central database shown in Table 3.1.

Table 3.1. Properties of permissionless blockchains, permissioned blockchains, and a central database. From Wüst and Gervais [7].

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

An essential difference between the Internet and the blockchain technology is that the Internet was created to move information and copies of things between users. In blockchains, the value represented by the transactions is recorded in a shared ledger and secured by verifiable and time-stamped records of transactions. This will provide both secure and auditable transfer of information and values through a verification process consistent with pre-agreed network consensus rules [78]. When the participants verify a new record, and after that added to the blockchain, multiple copies of the block are created in a decentralized manner - securing immutability of the transaction and affirming trust among partners in the network. See Figure 3.2 describing the relation between the information and transactions performed in the blockchain.

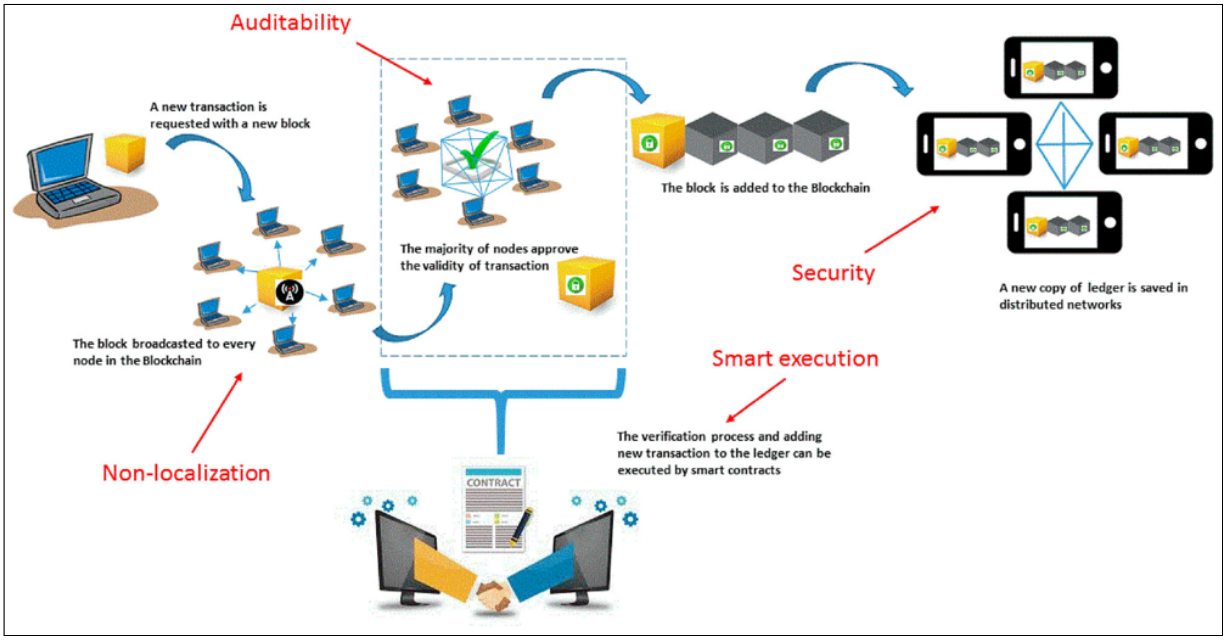

Figure 3.2. Steps in blockchain information and transactions. From Casino et al. [5].

The consortium blockchain network operates under the surveillance of one of the participants - confirming every block and thereby every transaction [79]. This surveillance is often based on the use of smart contracts, which may result in automatic execution if particular demands are fulfilled - for instance, if all of the parties agree. Such a smart contract may combine public and private keys to access and execute a block. The private type of network is similar to the consortium based but is usually restricted to being used in one company [80]. Different algorithms to determine blockchain consensus have been developed in addition to PoW, such as Proof of Stake, Practical Byzantine Fault Tolerance, Delegated Proof of Stake, Ripple, and Tendermint [66]. The design may also depend on the network participants and the rules determined to manage the blockchain. In a private and closed blockchain, the participants may know each other well, and no anonymity is needed. In such networks, there will be appointed certifiers to supply the chain network with participants and provide maintenance of the network. On the other hand, in a public and open blockchain, cryptographic methods will be applied to allow users to enter the network - maintaining trust among anonymous users and record their transactions [68]. An overview of the main characteristics of each blockchain architecture can be seen in Table 3.2.

Table 3.2. Summary of the main characteristics of different types of blockchain networks regarding efficiency, security and consensus mechanism. Modified from Casino et al. [5].

Property	**Public**	**Private**	**Federated/ Consortium**
Consensus Mechanism	- Costly PoW - All miners	- Light PoW - Centralized organization	- Light PoW - Leader node set
Identity Anonymity	- (Pseudo) Anonymous - Malicious?	- Identified users - Trusted	- Identified users - Trusted
Protocol Efficiency & Consumption	- Low efficiency - High energy	- High efficiency - Low energy	- High efficiency - Low energy
Immutability	- Almost impossible	- Collusion attacks	- Collusion attacks
Ownership & Management	- Public - Permissionless	- Centralized - Permissioned whitelist	- Semi-Centralized - Permissioned nodes
Transaction Approval	- Order of minutes	- Order of milliseconds	- Order of milliseconds

3.1.2 Decentralization, Trust, Transparency and Security

The time-stamp server, the ledger distribution, and the proof-of-work concept constitute the consensus underlying the validation process of the blockchain [57], securing that the transactions are verified and authenticated [81]. As a result, a blockchain network may provide trust in a trustless environment. Thus, blockchain technology differs from other information systems by four key characteristics; decentralization, security, auditability, and smart execution [82].

The decentralization of information is an important property of blockchain technology and secures the validity of the shared information and transactions. This makes the removing of collectively maintained records difficult since the verified records of performed transactions would be accessible to the network participants through the distributed ledgers [62]. A centralized database is more prone to hacking, corruption, or accidental crashing [60]. Thus, an important consequence of decentralization is improved trust among participants in the network considering the information in the blockchain is easily viewed and compared [83].

The underlying technology protects the integrity of the system even in the presence of dishonesty since participants may still view the ledgers and analyze the transactions. This provides transparency [60] and at the same time anonymity because records may be encrypted [62]. Blockchains may be linked to predetermined and agreed rules, securing that neither the users nor the operators of the system may interfere in an unwanted way. This may create a unique platform for applications involving multiple parties where little trust is required - such as in supply chains.

3.1.3 Smart Contracts

An important part of the blockchain technology applicability is the so-called smart contracts. A smart contract comprises a software program that includes rules and policies for terms and actions between parties. It may automatically verify that the contractual terms have been met and execute a predetermined transaction [84]. The network players settle consensus on the outcome of the smart contract execution. The contract executes its code when a message is obtained from a participant in the network or another contract - updating the ledgers if the terms are met [85].

A Smart Contract is self-enforcing or made so that it is costly to break the contract [86]. The blockchain technology is well suited for smart contracts since it can be used without a trusted participant. Ethereum [65] was the first blockchain that would support arbitrary code execution - thereby allowing different types of smart contracts.

Smart contracts could especially be useful if connected to other digital information systems and beyond that to the physical world. This could open up for many possibilities for usage - such as supply chain management and IoT. The use of smart contracts is, however, a relatively new technology, and to what extent it will live up to its expectancy remains to be evaluated. One thing that remains to be clarified is the legal questions and the jurisdiction involved.

3.1.4 Internet of Things (IoT)

The Internet of Things (IoT) is a concept for the network of different everyday devices, such as home appliances that contain electronics, and vehicles, made possible via computers, smartphones, and tablets. Thus, the devices are made able to communicate and be remotely monitored via the Internet. Such networks may, however, be vulnerable to challenges concerning privacy and security, since they may act as open doors for the hacking of information systems.

It has been suggested that blockchain technology and Internet of Things (IoT) in combination with smart contracts would provide cost-effective autonomous systems. However, also, in this case, good intentions are only scarcely backed by practical case evaluations. One challenge is the interface between the physical and the digital world. The intention would be that computers should supply values directly from sensors to the blockchain. The blockchain does, however, not guarantee that the values are correct. This depends on who is in control of the sensors and needs to be trusted. Thus, the question concerning trust must be carefully studied and evaluated to determine the provided additional value obtained by the use of blockchain and IoT.

3.2 Blockchain in Business and Industrial Applications

Blockchain has been suggested to contain the potential necessary to contribute to disruptive innovations in business management [87, 88, 89]. Several business models have been suggested [90, 91, 92, 93, 94, 95, 96, 97, 98, 99].

Blockchain technology is expected to improve accountability, transparency, and trust in supply chain networks [100, 101, 102, 103]. It has also been suggested to benefit chain logistics, decrease paper load processing, facilitate online tracking and traceability of goods, and improve security without the need for intermediaries [47, 60, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113].

If this holds up, it could provide better information and performance management across the whole supply chain [103, 114, 115, 116, 117, 118, 119], and provide smarter transportation systems and better customer service through more advanced and efficient handling of data and information [120, 121, 122, 123, 124, 125, 126].

3.2.1 Suitability of Blockchain

Although the potential use of blockchain technology has created excitement in many sectors, caution has also been raised concerning the optimism - underlining that the benefit of the technology has to be evaluated in each project before implementation [127]. As an example, if there is no need for data to be stored, blockchain technology will not provide an additional advantage to established technical solutions. Also, if there is only one writer in a system, a blockchain will not be better than a regular database - which also will be preferable from a transaction speed perspective [74]. Blockchain may, however, be suitable when it comes to transactions between trustless sources and when a historical record should be preserved unchanged. Thus, in a system where multiple mutually mistrusting entities need to interact, blockchain could be a suitable solution [7]. The suitability of blockchain implemented systems should, therefore, be strictly evaluated against the specific system requirements [6].

Umeh [127] explains that companies in general are welcoming new technology and its potential to drive digital transformation to solve real-life problems. The issue is that they often do not understand the specific use case for implementation. This especially holds from a data management perspective. To establish such decisions, technical frameworks are needed. These frameworks can easily be used to decide whether blockchain technology should be implemented or not. It is still in the early days of development of such frameworks - but they are crucial for businesses to make decisions whether they should implement the technology as well as the type of blockchain framework. According to Lo et al. [6], businesses should examine the suitability of the blockchain technology against the use cases requirements. As of today, these frameworks are limited in scientific literature. Lo published in 2017 a decision-based framework aiming to help businesses to assess the suitability of blockchain-enabled applications. The framework is featured in Figure 3.3 and is meant to be used in decision-making for a variety of industries such as electronic health care records, identity management, the stock market and supply chains considering implementing blockchain-based solutions in their operations [6].

Wüst and Gervais [7] report on ways to analyze for potential advantages of different types of blockchain architectures and offer a methodological framework to identify the suitability of blockchain implementation in several areas.

It is important to realize that databases by nature are mutable and entirely dependent on entities that have the authority to add or update data. The entities may have specific roles where their identities are known, but they may still be in a position to alter the content and structure of the database. The consensus mechanisms in blockchain networks offer multiple writers the ability to modify the database by an authoritative transaction log in which all participants probably agree on [128]. Casino et al. [5] have highlighted requirements of different sectors which can be seen in Table 3.3.

Table 3.3. Characteristics/requirements that enable/require each family of blockchain applications. YES indicates that this requirement is mandatory, MAYBE denotes that it depends on the case. From Casino et al. [5].

	Scalability	**Privacy**	**Interoperability**	**Audit**	**Latency**	**Visibility**
Finance	YES	MAYBE	YES	YES	YES	YES
Citizenship Services	NO	YES	YES	YES	NO	NO
Integrity Verification	NO	NO	NO	YES	NO	YES
Governance	MAYBE	YES	YES	YES	NO	NO
IoT	YES	YES	NO	NO	YES	NO
Health	YES	YES	YES	YES	NO	NO
Privacy & Security	NO	YES	NO	YES	NO	NO
Business	MAYBE	MAYBE	YES	YES	MAYBE	YES
Education	NO	YES	YES	YES	NO	NO
Data Management	YES	NO	YES	YES	MAYBE	YES

Table 3.4 presented a framework to evaluate the suitability of blockchain-based solutions showing the identified attributes as well as prerequisites of blockchain databases versus a conventional database. They compared the potential of blockchain against conventional databases on

four different areas: ’required trust assumptions,’ ’context requirements,’ ’performance characteristics’ and ’required consensus mechanisms’ on a three-level scale, low, medium and high. The authors offer the framework as a tool for the evaluation of whether a system will benefit from blockchain or not.

Table 3.4 shows the identified attributes and prerequisites of blockchain databases and a traditional database.

Table 3.4. Analysis of attributes and prerequisites of blockchain versus traditional database. Modified from Casino et al. [5].

Attributes	**Prerequisites & determinants**	**Permissionless**	**Permissioned**	**Database**
Trust	Lack of Trusted Third Parties Accountability Immutability Multiple non-trusting writers Peer-to-peer transactions	High High High High High	High High High High High	Low High Medium Low Low
Context	Traceability of transactions Verifiability of transactions Data/transaction notarization Data transparency Security Privacy	High High High High High	High High High High Medium	Low Low Low Low Low
Preformance	Latency and transaction speed Maintenance costs Redundancy Scalability	Low High High Low	Medium High High Medium	High Low Medium High
Consensus	Rules of engagement Need for verifiers Autonomous/dynamic interactions between transactions of different writers	High High High	High High High	Low Low Low

Blockchain avoids the need for trusted third parties, which a database often relies on, and thereby enhances reliability and verifiability of the content. The technology is also considered beneficial when transactions and operations need to be traced, or when strong security and privacy are essential since a centralized structure is considered more vulnerable to attacks than decentralized structures [129]. Blockchains may also provide a significant reduction in cost - considering it does not require hosting.

3.2.2 Usability, Adaptability, and Interoperability

The number of blockchain-based applications has skyrocketed in the past years. As a result, this wide range of applications stands in the way of standardization because of interoperability issues. This can be seen in cryptocurrencies. Many international funds would invest in Bitcoin if they had easy access to investments. If regulation took place, currencies such as Bitcoin would bring Bitcoin exchange-traded fund to the market [130].

Kosba et al. [131] highlight the difficulty level of the API usability in cryptocurrencies by proposing a solution for more interoperability architectures. Blockstream [132] is trying to solve these issues using hardware and software to coordinate transactions across different blockchains introducing a set of new blockchain-based networks.

Another problem with blockchain technology is its challenging compatibility with already existing systems. Businesses have expressed concerns related to this, (see Section 3.2.1 on Suitability) and its absence of governmental regulations [133]. Governments must deal with bureaucracy such as management and administrative tasks - expressing their need for efficiency, digitization, big data storage as well as privacy and security.

Several sources [134, 135] claims that in relation to interoperability, governments, companies, and businesses are working towards the automation and configuration of smart contract procedures - aiming to decrease the gaps in interoperability architectures resulting in standards and facilitating auditing tasks. Eventually, this will result in more efficient and practical entities. It has been claimed that this will improve and structure the data storage used in the healthcare sector, citizenship, data management, and education services - providing interoperable services.

3.2.3 Evaluation of Potential use of Blockchain Technology

Blockchain is a new emerging technology for use in networks of untrusted participants and has both advantages and disadvantages compared with conventional techniques. The technology may be appropriate for some use cases, while others may be better off with conventional technologies. It is, however, difficult for potential users to decide whether to use blockchain for a certain purpose. This is because the technology is relatively new and that there is limited availability of reliable evaluation methods to assess its suitability.

Lo et al. [6] have proposed an evaluation framework listing criteria for the assessment of suitability for implementing the technology for different industrial purposes. The framework suggests a process consisting of the answering of seven main questions - illustrated in white boxes in Figure 3.3. Answers to the main questions lead to sub-questions - shown in grey boxes in the figure.

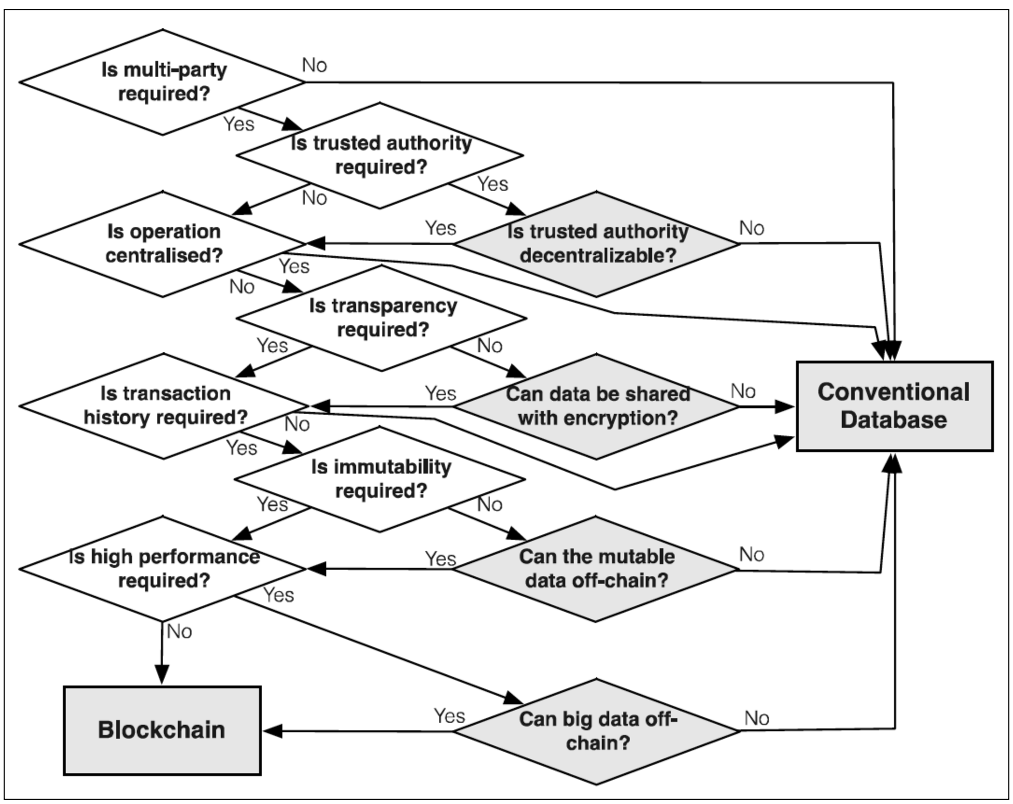

Figure 3.3. Suitability evaluation framework. From Lo et al. [6].

The seven main questions relate to: (1) If there are multiple parties involved; (2) If a trusted authority is necessary; (3) If the application is centralized; (4) If transparency is required; (5) If there is a need for integrity in the transaction history; (6) If data immutability is important; and finally (7) If high performance is required.

Blockchain is suitable for applications that involve multiple parties and would remove silos of information controlled by individual participants. A system comprising only a single party will be better served with a traditional system without blockchains.

A trusted authority could be a bank or government. The occurrence of problems in a trusted authority will affect all parties. Blockchain is suitable for scenarios where a trusted authority is not wanted. In this case, the users replace the trusted intermediary with blockchain technology.

Some operations need to be centralized by nature. Such applications are not suitable for a blockchain-based system because no single party can control such a system.

There is a delicate balance between transparency and confidentiality. Blockchain allows all participants to see the published data, although encrypting it before storing it on a blockchain may provide some confidentiality. Thus, transparency is in tension with commercial confidentiality, and there is a trade-off between the advantages of sharing data within the system and the privacy keeping towards competitors.

It is crucial to preserve the data integrity of transactions to be able to track assets through a change in ownership and handling. Blockchain may according to Lo et al. [6] be a relatively expensive solution for this and consider that other existing tracking mechanisms may not benefit from the implementation of blockchain technology.

A significant benefit of blockchain systems is the active support of data immutability through the linking of blocks in a chain of cryptographic hashes. Data in blockchains are difficult to alter because they are continually replicated in different locations and organizations. Attempts to do so will be perceived as an attack on the system and be rejected. This is ordinarily advantageous but may present some problems when it comes to the removal of faulty data as well as adaptability to systems controlled by trusted third party organizations.

Blockchains are currently not scalable to very high performance and are therefore not suitable for storing large amounts of data. This problem is more severe in public than in private systems and an inherent limitation because of the large number of processing nodes which keeps a complete copy of the distributed ledger. This can, in part, be avoided by storing some of the data off-chain to prevent duplication of all data to all parties.

Lo et al. [6] have used the proposed framework to evaluate the potential of blockchain implementation in four use cases for the Australian government. Case 1 is a supply chain; Case 2 concerns electronic health records; Case 3 relates to identity records; and Case 4 to the stock market. Table 3.5 summarizes the evaluation results based on the seven questions in the framework shown in Figure 3.3. As shown in the table, the evaluation gave the conclusion that the cases 1 and 3, supply chain and identity management, could benefit from the implementation of blockchain technology, For Cases 2 and 4, electronic health records and the stock market, the evaluations suggest that these systems will be better off without blockchain technology.

Table 3.5. Result of suitability evaluation. From Lo et al. [6].

	Supply chain	**Electronic health records**	**Identity**	**Stock Market**
A	Required	Required	Required	Required
B	Not required	Decentralized	Not required	Not required
C	Not required	Not required	Not required	Not required
D	Transparent	Confidential	Transparent	Confidential
E	Required	Required	Required	Required
F	Required	Required	Required	Required
G	Not required	Not required	Not required	Required
Result	Blockchain	Database	Blockchain	Database

This framework would serve as a guide for practitioners that plan to apply blockchain and help to reduce the waste of effort on the unviable use case.

3.2.4 Where will Blockchains be Beneficial?

Wüst and Gervais have published an article titled 'Do you need a Blockchain' [7]. In this publication, they present an analysis framework of whether blockchain technology is an appropriate technical solution for a particular application scenario. In the analysis, they also differentiate between permissionless and permissioned blockchains and compare them to the properties of a centrally managed database. Using a structured methodology, they analyzed three use cases - supply chain management, bank service for international payments, and decentralized organizations.

In a permissionless blockchain, any participant can read and write to the chain. In a permissioned blockchain, however, an authorized set of entities can write and read the respective blockchain. The permissioned blockchain shares similarities with a centralized database, and its suitability must, therefore, be compared with such a traditional database. The authors analyze the properties of permissioned and permissionless blockchains and compare their features to those of a centrally managed database.

Wüst and Gervais [7] have presented a flow chart describing a blockchain architecture decision tree (Figure 3.4). An open, or permissioned blockchain, is relevant when several mistrusting parties need to interact but cannot agree on a trusted third party. If no data needs to be stored, there is no need for a database - meaning blockchains used as a form of database is not useful. Also, if only one partner will write to the database, a blockchain will not give additional guarantees to that of a regular database. A conventional database is then the best choice since it provides more efficient performance. If a trusted third party is existing, the write operations may be delegated to it. Alternatively, the third party can act as a certificate authority and manage a permissioned blockchain where all writers in the system are known. If all the writers trust each other, a traditional database with shared write permission is probably the best solution - while in the case of mistrust, a permissioned blockchain would be preferred. If public verifiability is required, anyone could be allowed to read, i.e., a public permissioned blockchain, or the number of readers may also be restricted, as in a private permissioned blockchain.

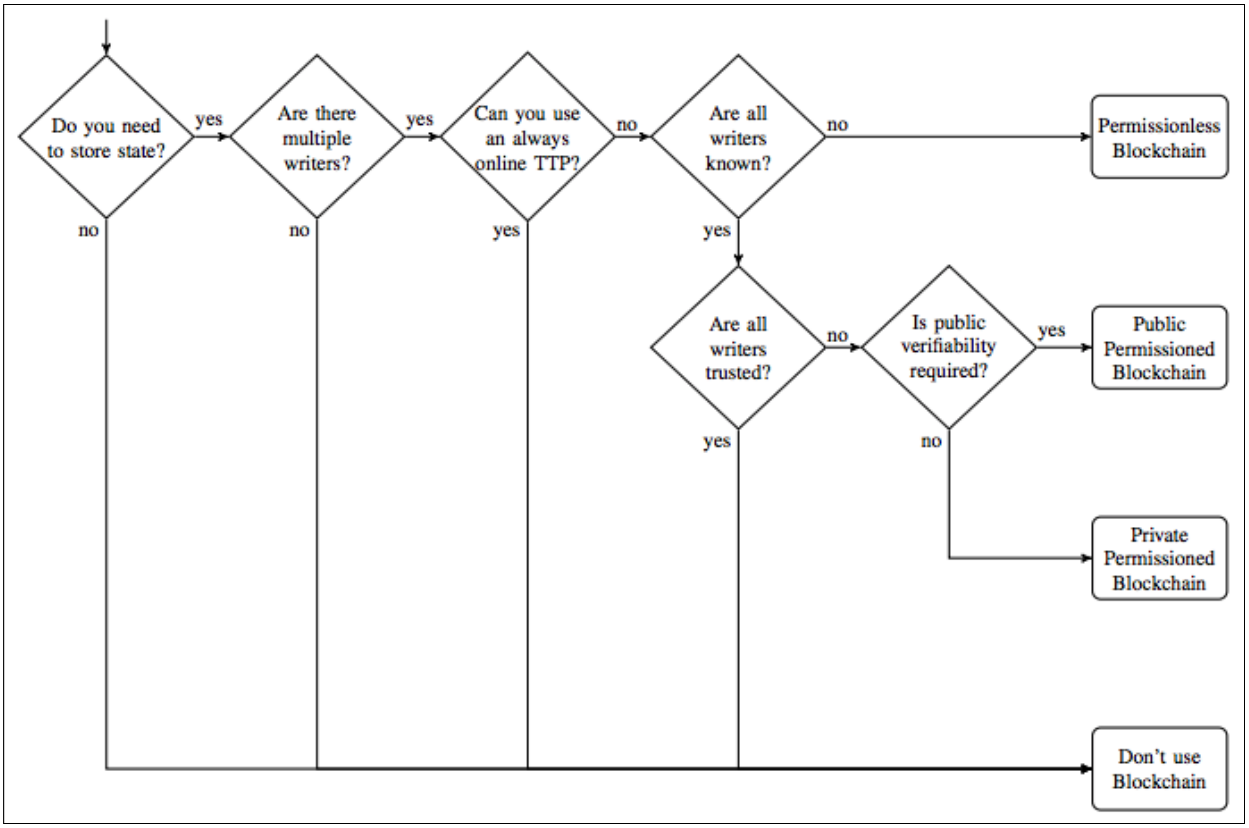

Figure 3.4. A flow chart to determine whether a blockchain is the appropriate technical solution to solve a problem. Figure 3.3 should be considered in the decision making process as well. Writers refer to entities with write access to the database/blockchain, i.e. in a blockchain setting, a writer corresponds to a consensus participant. If a trusted third party (TTP) is available that is not always online, this can be used to establish a known group of writers, i.e. the TTP can function as a certificate authority in such a setting. Public and private permissioned blockchains differ in that a public blockchain allows anyone to read the contents of the chain and thus verify the validity of the stored data, while a private blockchain only allows a limited number of participants to read the chain. Note that for any blockchain based solution it is possible to make use of cryptographic primitives. From Wüst and Gervais [7]

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In a centralized system, the performance and throughput are generally better than in a blockchain based system, since blockchains cause increased complexity through the use of encryption technology to secure privacy. There is a trade-off between decentralization, i.e., the allowance of many distrusted writers, and throughput, i.e., the number of updates that the system can handle per time. This trade-off should be considered before deciding whether to use a blockchain system or not. In the literature, several industrial use cases have been outlined on whether blockchain technology has been or probably will be considered. One of them is supply chain management, which has been looked at in detail.

3.3 Blockchain Challenges

3.3.1 Sustainability and Waste Resources

Waste resources in terms of energy use related to mining is a massive concern in public blockchains. Today, this is mostly relevant for cryptocurrencies such as Bitcoin. As of 2017, Bitcoin is extremely more energy intensive transaction wise than VISA [136].

Zheng [66] introduced the 'rich get richer phenomenon' explaining that algorithms such as PoW and PoS can be moving towards more centralization. This relates mainly to cryptocurrencies and is by itself not related to issues on energy consumption and blockchain technology. To solve the energy consumption problem, a variety of different consensus mechanisms have been developed, such as the GHOST chain - simplifying the mining process by emphasizing some branches according to specific parameters [137]. Another consensus mechanism that aims to make the protocol safer is if the nodes prune full blocks. This is not needed for mining but is mentioned by Chepurnoy who introduces a consensus protocol where a node gains permission to generate a block - providing non-interactive proofs of storing a subset of the past snapshots [138]. Kraft [139] presented a consensus methodology guaranteeing to stabilize average block times by avoiding multiple hash-rate scenarios. Decker et al. [140] established the PeerCensus system enabling durable consistency in blockchain systems with cryptocurrencies such as Discoin on top of it that decouples the operation of block creation and transaction confirmation - leading to a higher efficiency within the consensus network. Other networks use alternatives to compute hashes by finding chains of prime numbers [141] or encouraging the use of renewable energy [142].

3.3.2 Data Management, Privacy, and Security

Blockchain technology faces several limitations and weaknesses [143, 27, 144]. Even though blockchains are considered to benefit storage and secure data management, privacy and confidentiality is still an issue in public blockchains [74]. Proposals for the solving of these issues using mechanisms for encryption and anonymization have been addressed [74], but these can be difficult to combine with existing systems such as IoT networks [63]. Several authors express that the file sharing method in the network should be performed using a secure protocol such as the Telehash [145], Whisper [71] or directly via a content-addressed peer-to-peer file system such as IPFS [146].

Transaction privacy is a common challenge in blockchain related to the concern for the traceability of information on smart contracts and transaction operations across the network [147]. It has been confirmed that sensitive information of Bitcoin transactions have been disclosed [148, 149, 150]. Kosba et al. [131] further explain that the use of pseudonyms does not guarantee anonymity. This is based on approaches used to analyze transaction structures and thereby remove the anonymity being used in cryptocurrencies [151, 152].

Smart contracts have also been shown to contain a variety of errors and are therefore sensitive to attacks. There are many examples of losses such as the Parity wallet bug [153] and the DAO attack leading to losses of 280 mill USD and 47 mill USD, respectively. Pearson [154] has covered a variety of vulnerable smart contracts claiming that the programming aspect can be challenging to master considering its differences from traditional programming settings and that this can result in holes within the system. Such an example is the Ponzi scam [155]. Suiche [156] have suggested a variety of proposals for avoiding vulnerable smart contracts to prevent theft or abuse. One project focuses on the improvement of the programming language used - being one of the more economical and efficient solutions [71]. Frameworks concentrating on the verification and quality of smart contracts have also been suggested [157, 158].

51% attack refers to an attack on a blockchain by a group of miners that have more than 50% of the computing power in the network. Such attacks can prevent the verification of new transactions and thereby stop operations between users and reverse ongoing transactions, meaning the possibility of double-spending assets [123]. This is mainly relevant for blockchain related to cryptocurrencies and is not likely to be fatal to the blockchain-based currencies, but still be severely damaging. Krypton and Shift, two blockchains based on Ethereum, suffered 51% attacks in August 2016 while Bitcoin Gold was attacked in May 2018. The attackers on Bitcoin Gold controlled a large amount of Bitcoin Gold's hash power over several days and were able to steal more than $18 million worth of Bitcoin Gold through double-spending [159].

3.3.3 Latency and Scalability

Cryptocurrencies have a relatively low transaction rate. While VISA can handle up to 65,000 transactions per second [tsp], the Bitcoin network can only handle 10 [tsp] [160]. Swan [161] addressed this latency issue among cryptocurrencies. In the case of Bitcoin, a new block is processed on average every 10 min, which is due to security checks primarily to avoid double spending in subsequent transactions [57]. This is the case for public blockchains while the scalability increases as they become private and permissionless. Either way, the blockchain architectures are facing latency issues which have not met the required needs so far.

Data storage issues have also been highlighted in the literature. Several examples to improve these issues have been proposed - for instance by as removing old transactions [162]. This improves the transaction validation step by decreasing the number of transactions stored by the nodes. Other initiatives, such as the Bitcoin-Next Generation, decouples a block into a key block or a microblock. This separates the leader election and the transactions, making the miners strive to become a leader of the microblock generation [143].

Centralized architecture generally means higher transaction processing throughput for IoT networks. According to Vukolić [64], inadequacy is further exacerbated considering the costly consensus mechanisms used in public blockchains. The Ethereum blockchain is trying to overcome this by partitioning the blockchain into shards. This is referred to as 'sharding' [163] where each shard is storing its transaction history and state resulting in nodes processing transactions for a specific shard - dividing the blockchain into smaller pieces and thereby increasing it's all over performance.

A high scalable blockchain is crucial within a supply chain, considering the amount of information. Research shows that while there are still is a long way to go, solutions are developing rapidly along the way.

3.3.4 Quantum Resilience

At the center of the blockchain technology, there are two cryptographic cornerstones: hashes and public key encryption used to sign the transactions.

The most common hash algorithm is SHA-256. A quantum computer needs to perform 2128 operations to solve this algorithm. This makes the SHA-256 algorithm resistant to attacks. The challenge is, however, bigger when it comes to the public key encryption algorithms. The ECDSA algorithm will, for instance, not resist a big quantum computer - making most blockchains potentially insecure. A large effort is, therefore, made to create and evaluate post-quantum computer cryptographic methods.

Quantum resilience is by many considered the most challenging issue for blockchain platforms as it is for many other security-related technologies. The most promising candidates for the public keys come from lattice and code-based cryptography [164, 165].

Blockchain-based quantum-resilient approaches are described in the literature. Kiktenko et al. [166] are developing a quantum safe blockchain platform using quantum key distribution across a fiber network for secure authentication and Rajan and Visser [167] have suggested a method which they claim will be a quantum networked time machine.

3.3.5 Artificial Intelligence and Big Data

Artificial intelligence is used to manage particular characteristics or behaviors, such as autonomous drones or cars. Intelligent transactions between entities or devices may also provide a wide range of possibilities. The standardization of public blockchain systems will increase the usability of AI algorithms and market prediction since data are available in a public ledger. This will make it possible with scalable and more accurate solutions as well as improved AI models [168]. Secure and verifiable blockchain structures may be used to ease the management of big data [169]. A challenge is, however, also here the amount of data to be dealt with, although blockchain systems capable of storing big data have been presented [170]. Thus, many challenges remain to be solved, and the use of big data and AI may enable numerous exciting and innovative blockchain-based applications.

All the identified challenges related to blockchain technology are visualized in Figure 3.5.

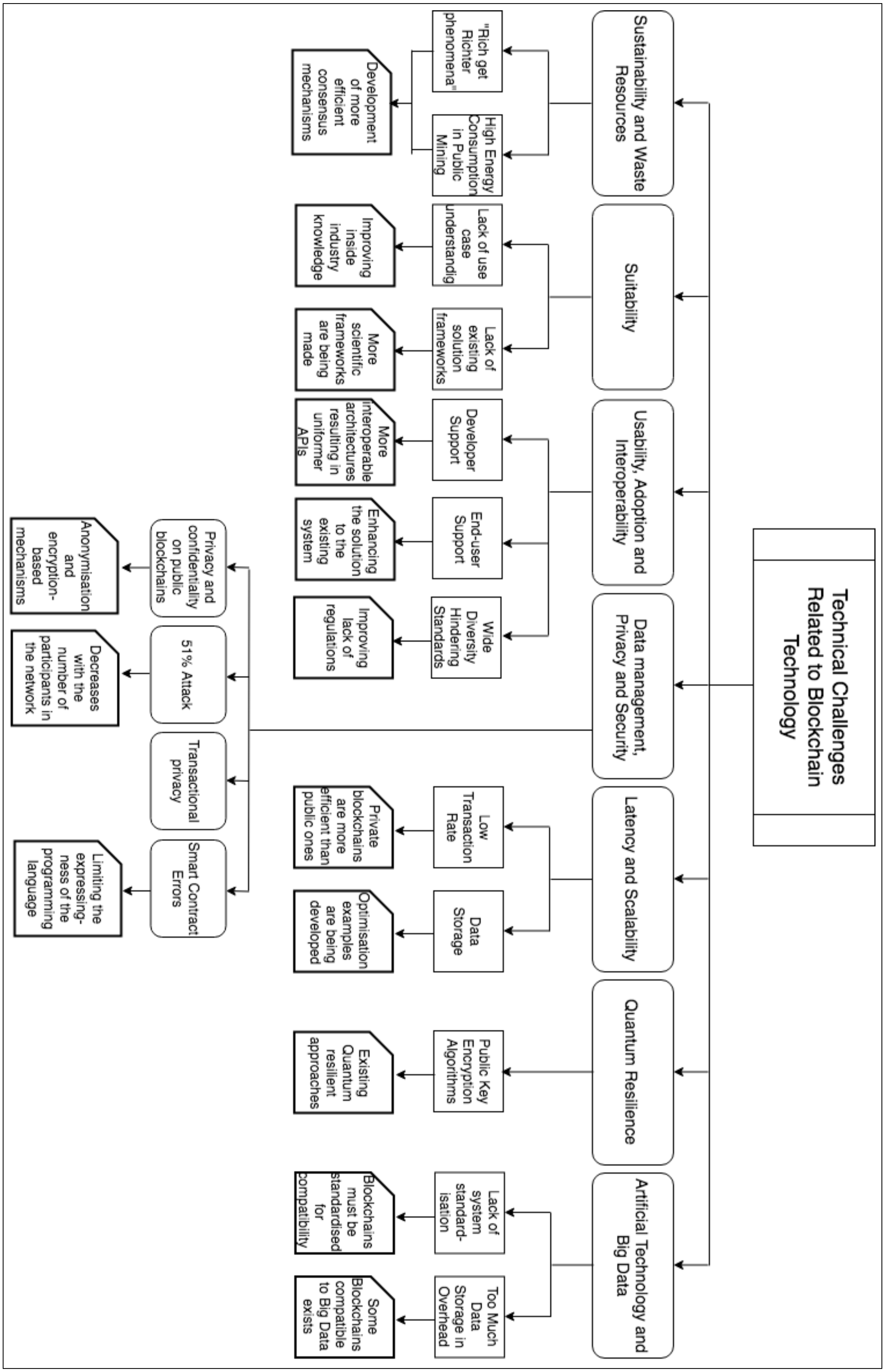

Figure 3.5. Summary of the present identified challenges related to blockchain technology and their suggested solutions.

Chapter 4

Blockchain Technology and Supply Chains

Current status on challenges related to blockchain technology has been obtained from the systematic literature mapping study. Blockchain is today considered for adoption into a variety of activities. This chapter discusses concerns and possibilities of relevance for the implementation of blockchain technology in supply chains.

4.1 Innovation Drivers in the Maritime Industry

The present study intends to explore the literature on innovation and blockchain technology and to present possibilities and knowledge gaps related to non-engineering changes within the maritime industry, especially on the management of supply chains [171]. The aim is to clarify the possibilities and barriers of blockchain implementation and explore the potential influence of blockchain on inter-firm collaboration. This includes the identification of the main drivers and barriers of innovation, and explore the possibilities of blockchain applications within the maritime industry.

The present literature review and case study are used to provide insight to answer these questions. A project on vetting has been selected as the case study. The maritime industry is highly innovative in technical and engineering areas but needs cost reduction to stay competitive. Tidd and Bessant [172] describe the 4P's of innovation as the four categories: Product, Process, Position, and Paradigm. 'Product' deals with changes in products or services provided by a company, 'Process' deals with how the products are made and delivered. 'Position' is concerned with changes in the products/services context, and 'Paradigm' affects the organization's activities. In the framework of Tidd and Bessant, the application of blockchain may be considered crucial at both component and system levels, since the technology provided is new, and may have an impact on the whole maritime industry and its supply chains.

What are the main drivers of innovation in the marine industry? Unexpectedly, one main driver has been recognized as external regulations of the sector by governmental and international organizations [173]. Such provisions may be related to the development of 'green' technologies and 'green' supply chains, and the maritime industry has shown a positive attitude towards such eco-friendly goals. Some early attempts to adopt blockchain exist, but few academic studies of its possible applicability have been observed so far within the shipping industry. Blockchain may help regulatory bodies by making them able to issue certificates in electronic form and secure them using codes that are impossible to counterfeit [174]. This has lead to several initiatives towards the utilization of big data, crewless vessels, artificial intelligence (AI), and the Internet of Things (IoT) [175].

Another driver of innovation in the maritime industry are related to cost reduction, search for new business opportunities, and improved safety and security against cyber-crimes and piracy. Cybersecurity is becoming more critical as the industry connects to and becomes more dependent on cyber networks [176].

4.2 Supply Chain Management

Today's supply chains manage complex processes involving a large number of diverse partners of different nationalities who compete in providing the best service to the consumers [177, 178]. Globalization results in needs to cope with different regulatory policies and cultures, as well as diverse history and traditions related to behavior in supply chain networks. This diversity creates challenges and makes it difficult to evaluate available information and make an adequate risk assessment in such intricate networks [179, 180]. This may result in poorly performing supply chains, inefficient transactions, fraud, and loss of trust among business partners, and may ultimately lead to low efficiency and increased costs.

Better information sharing, verifiability, and traceability is, therefore, a requested requirement in many supply chain industries. Examples often mentioned are the agro-food sector [181], pharmaceutical and medical products [182], and goods of high value [61]. Luxury and high-cost items may still be dependent on paper certificates and receipts that can be lost or changed. Thus, the lack of transparency on the documented value of such items may prevent supply chain managers and customers from verifying and validating their correct value. The cost, reliability, and transparency related to the involvement of intermediaries further complicate the managing of the supply chain, and may result in competitive and reputational issues arising from unforeseen matters and lack of transparency.

An outbreak of Salmonella infection linked to papayas resulted in several hundred people in the United States falling ill, and examplifies some of the challenges in a supply chain. The disease control reported the disease origin to be the contaminated papayas, but the shipments could not be traced, which caused severe safety concerns. A similar E. coli outbreak in a food outlet left several customers sick. Lack of transparency and accountability of the supply chains resulted not only in increased health risk but also in a bad reputation and lost business opportunities for the suppliers involved. The capability to monitor multiple suppliers in real-time could have prevented at least some of the problems.

Supply chains often rely on centralized and stand-alone information management systems within one single organization only depending on that single organization for the storing of sensitive information [59]. This makes it prone to single point failures which may put the whole system vulnerable to computer crashes, hacking or corruption [14].

Supply chains may also be considered for certification of sustainability. Supply chain sustainability has been defined as a balance between environmental, social, and business-related components in the managing of the chain [183]. An important issue here is to confirm that processes, products, and activities in the supply chain are in agreement with certain criteria and certificates [184]. This includes the confirmation that the information systems can provide the necessary information for the processes to be transparent, robust, and trustworthy. This requires integrity, transparency, security, and durability of the supply chain and its processes. Blockchain technology has been pointed to as a possible part of the solution, and recent technological improvements and suggested applications have made these improvement goals more technologically, organizationally and economically feasible [59, 161].

The number of reported blockchain use cases have dramatically increased in recent years, but as for other disruptive technologies, blockchain also face several obstacles and barriers in its adoption and implementation in supply chain networks - being in its early stage of development, and with different challenges still to be resolved [62, 27, 185]. In this thesis, the author seeks to update the debate not only on blockchain-based supply chain challenges, obstacles, and barriers, but also on the potential benefits and applications. The relationship to current supply chain management systems and the need for research are also discussed, with some specific research suggestions.

Innovation in a supply chain may affect the whole supply chain network, both process, and technology - resulting in a boost of new values for the stakeholders [186]. The possible enhancement of supply chain performance may provide benefits to the involved parties, such as customer response times, lower inventory levels, improved decision-making processes, and result in enhanced transparency of the whole chain [187, 188]. The application of blockchain in the maritime industry may, therefore, involve all the 4P's and result in substantial cultural changes [171].

Not all types of innovation are fitted for the whole maritime industry. Companies should carefully select among available processes [189]. To obtain the best result, it is necessary to analyze each type of industry separately, and focus on the company's size, goals, vision and financial capacity to evaluate the possible benefit of the specific innovation in question.

Maritime transport provides lower prices compared to an airborne, railroad, or automobile transport. Some challenges exist; however, one of them being shipping cycles [190]. The shipping industry is competitive, and there is a strong incentive among companies to decrease costs to win the competition. The industry is also facing more strict environmental demands from governments and international maritime organizations [191].

Concerning digitalization, different sectors within the maritime industry seem to be at different levels of implementation, although many shipping companies have utilized digital technologies for a long time [192]. The cruise industry seems to be the most advanced segment, while the status for cargo and on-shore activities lags. The situation also varies between companies [192].

Blockchain technology is considered a possibly disruptive technology based on decentralized databases for global direct and disinter-mediated transactions between network partners [62]. Some recent use cases exemplify the possibilities and concerns. A joint venture between Maersk and IBM, TradeLens, was initiated to create a blockchain-based platform for a shipping supply chain. The platform is promoted as an open industry platform through IBM with the expressed intention to benefit all parts of the shipping ecosystem. The partnership has created a blockchain-based bill of lading, claiming to result in an administrative cost reduction of 15%. Radio Frequency Identification (RFID) systems are intended to be united through IoT to create benefits for the logistics network and Global Positions System (GPS) labeling of containers will support their handling through transportation hubs [186]. Although the initiative has been suggested to result in tremendous cost savings through more accurate and trustworthy container bills of lading [193], it seems that several questions are remaining. It is, for instance, not clear if a full-scale implementation is possible due to scaling issues. Questions have also been raised on the perspective of sustainability. The blockchain service provider Provenance has attempted to apply blockchain technology in the seafood supply chain, where transparency and validity of sustainable practices have been reported to be critical [82]. Thus, several concerns related to environmental, economic, or social issues have been discussed in the professional literature.

Digitalization has also been implemented in several ports. Port of Hamburg demands all parties to connect to a shared data system [186], and the Port Authority of Singapore has implemented the so-called Smart Port Challenge 2017 together with the Port of Rotterdam to improve the managing of maritime logistics chains [194].

4.3 Blockchain in Supply Chain Management

The maritime industry is both complex and information-intensive. It consists of organizations that are globally distributed. The industry includes infrastructures that support world trade, such as transport and port authorities. Part of the maritime industry is technologically advanced, especially in sectors related to ship construction, oil and gas exploration, and other engineering-based innovations. The situation is, however, different when it comes to operational procedures and logistics. In this area, the industry lacks innovation, which represents both a challenge and an opportunity. A promising area of maritime innovation is related to digitalization, including the development of smart ships and global logistics [171]. Lack of proper information management results in increased expenses and has been estimated to account for 20% of an operational budget [195]. Blockchains have been considered a potentially disruptive technology for the management of supply chains because of its reliability, traceability, and authenticity of the information. The use of ledger technology and smart contracts have been suggested to provide trust in a trustless environment, an essential challenge in the management of supply chains. The use of blockchain technology to control supply chains is, however, still in its very early phase and open to interpretation and development.

In financial blockchain applications, such as for Bitcoin and other cryptocurrencies, the networks are often public, while in supply chains a closed, private, and permissioned blockchain system with selected participants may be preferred. The preferred level of privacy may, however, depend on several factors and should be determined for each case as one of the initial decisions.

Four unique players participate in the management of blockchain-based supply chains and differ from those in traditional supply chains; Registrars provide the participants in the network with individual identities. Standard organizations define and issues traditional schemes, for instance, related to sustainable supply chains, blockchain policies, and technological requirements. Certifiers provide certifications needed for supply chain network participation. Participants/actors, such as manufacturers, retailers, and customers, must be certified by a registered certifier/auditor to maintain trust in the system [82]. Concerns related to the flow of products in the supply chain should also be taken. All products should ideally be digitally marked so that all relevant participants could have direct access to the product profile in the process. This access can be regulated using digital keys. Several types of data are applicable for online access by the network participants, such as location, type, status, and the implemented standards for a product [60]. Information labels could be attached to the product as an identifier that links the physical product to its state in the blockchain [59].

A relevant part of the product flow management is how a particular actor treats a product in the chain. Such actors may then enter new information into the product's profile, pending permissions and use of smart contracts, to update other participants in the chain. Transferring of the product to another actor may be conferred in a digital contract, by a smart contract requirement, to authenticate the exchange. When all involved participants have met the contractual obligations, the transaction details should be updated in the blockchain ledger. Whenever any record of the data transactions is later changed, it will be automatically updated by the system [59].

The blockchain technology can be used to keep track of at least five key types of product information: the nature of the product, the quality, the quantity, the location and the ownership at any moment. Thus, the blockchain obliterates the need for an intermediary organization that operates the system and allows the inspection of the complete supply chain from the raw materials to the sale of the finished product. The entire collection of information is recorded chronologically in ledgers as the transactions occur with verifiable updates. The reliability and transparency of blockchains may provide more efficient control of the information flow through the supply chain, and thus give customers the possibility to track the detailed information of products which will increase their trust in product characteristics [60].

Smart contracts are software comprising rules agreed upon by the blockchain network and can help to define and perform interaction among participants within the system. Certifiers and standard organizations may, for instance, digitally verify the profiles of participants and products by such contracts and thereby provide participants and products with their digital profile in the network. Such profiles may contain location, certificates, and product characteristics. Each participant may, therefore, have online access to vital information about a product and its status in the network [60].

Included in the smart contracts and consensus process rules in a blockchain-based supply are the certificates of each participant where his role is described, what process he is allowed to access, and what is required for execution. Data on a specific participant and the trigger defined by a smart contract may be different between supply chains. Such rules can, however, only be changed through some form of consensus process [61]. Smart contracts may also be used for procurement, and a contract between two partners may update the automated record of what goods were bought, sold, and delivered in real-time to end users. An ordinary supply chain compared to a blockchain-based supply chain is visualized in Figure 4.1.

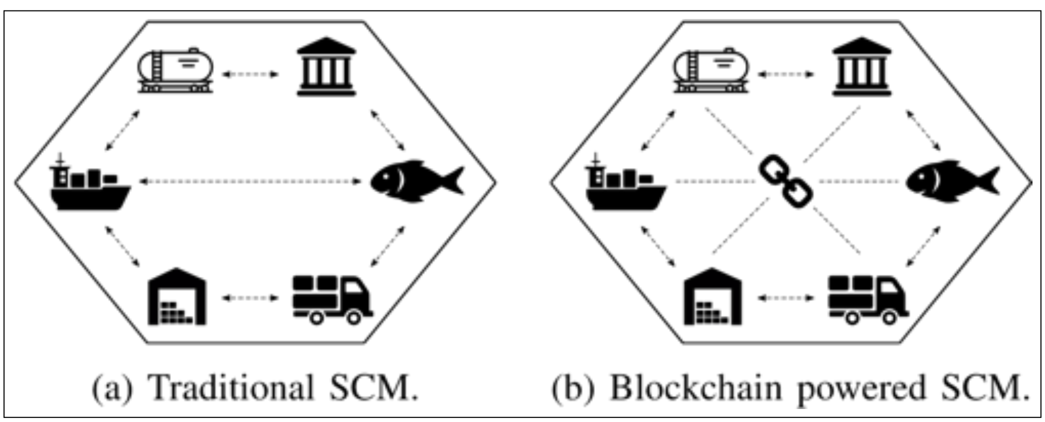

Figure 4.1. Traditional SCM versus blockchain powered SCM. From Wüst and Gervais [7].

The use of blockchain may influence both the supply chain process, product management, and the financial transactions between the network partners [196]. A central advantage is the abolished need for financial intermediaries, including payment and money transfer services [87].

This will simplify and make the trading processes between partners more efficient and cost-effective.

Reduced efficiency in the financial flows can be improved by supply chain finance processes and techniques such as reverse factoring and dynamic discounting [197, 198], which may reduce network costs significantly [199]. Smart contracts may be used to create financial arrangements, ensure that sufficient funds are available to the projects and payments are performed in due time [200]. Such contracts also support secure and timely transactions between different currencies and multiple sources in globally distributed supply chains [143]. Several types of blockchain technology-based applications for supply chains with a focus on industries, products, service, or governance have been presented. One focus has been to implement blockchain technology to improve the sustainability of supply chains. This is a focus of increasing interest and demand from both governmental and global organizations. A growing pressure has emerged from regulators, consumers, and communities on businesses to improve the sustainability of their supply chains and products [201].

Supply chains concern all processes involved in the production and distribution of goods, from raw material and of finished products to the consumers. Deloitte has suggested that 42% of consumer goods companies planned to invest in blockchain technology in 2017 [202]. Supply chains are complex multi-party systems that may include very different types of participants. Data transparency is wanted because other participants need to know to what step the different items have reached for them to be prepared for their part. Complete transaction history and data immutability are desired since this enables the historical tracing of commodities and the possible auditing of their conditions.

Many of the supply chain systems used today, especially when using paper-based documents, cannot be updated in real time. Lo et al. [6] have proposed a suitability evaluation framework to be used before deciding to implement blockchain-based applications. The framework is suggested as a starter guide for organizations to examine the suitability of blockchain in the intended use case. The authors conclude that a supply chain is a promising area for blockchain-based applications and that it will benefit from the digital nature of blockchain while its current limitations will be of lesser importance.

Several companies (e.g., Skuchain [203], Provenance [204], Walmart [205] and Everledger [206]) claim to have implemented blockchain based solutions to improve the efficiency of supply chain management, and that business will benefit from improved flexibility and better update on changes, delays or errors. The improvements may allow stakeholders to have real-time visibility of the supply chain status but require that all parties of the chain are connected within the network.

The participants in supply chains play different roles across the chains. The basis for different actors, is, for instance, defined by their relation and ownership to the products. This means that different types of blockchain may be required for the various supply chains that a participant is involved in. The management of supply chains is challenged by the interface between the digital and the physical state. Without trust, all writers to the database may be suspected of malicious intents. If, however, all writers are trusted, the use of blockchain technology is not needed since a regular database with shared access can preferably be used. Many companies are looking for possibilities to get reliable data from trusted hardware into the supply chain, for instance, by the use of trusted temperature sensors for the delivery of food and medicine. In this case, the data can be managed by smart contracts and blockchain technology. It should, however, be closely evaluated whether a centralized database, a permissionless blockchain or a permissioned blockchain should be chosen for a given task - taking into account the assumptions of trust, involved parties, technical characteristics of throughput and latency. Depending on the application, there are situations where both permissionless and permissioned blockchains, as well as centralized databases, should be selected, and this needs to be carefully assessed.

4.4 Sustainable Supply Chains and Blockchain

The unique properties of blockchains as distributed, immutable, transparent, and trustworthy databases can also be of interest for the managing of sustainable supply chain networks [8].

The tracking of social and environmental conditions that could pose environmental, health, and safety concerns is a potential application for blockchain technology [44]. An example is the use of blockchains in Chinese carbon asset markets where the enterprises have been claimed to generate assets more efficiently by China's Carbon Emissions Reduction for the Paris Agreement 3. A blockchain-based supply chain has been requested to provide better assurance of human rights and fair work practice. One argument for such a claim is that transparent records of the history of products assure buyers that the goods offered are supplied and manufactured from ethically sound sources. Smart contracts may be especially suited for the autonomous tracking and controlling of sustainable terms and regulatory policy.

The managing of sustainable supply chains has caused a lot of interest [207] due to the recent expansion into environmental and social perspectives. The promising features of blockchain; openness, transparency, neutrality, reliability, and security make it especially interesting for such aspects and may serve as good examples for the breadth of blockchain technology applications [59].

Sustainability is especially important in the food and beverage industry. The use of RFID and blockchain technology to provide traceability of food items in real-time based on Hazard Analysis and Critical Control Points (HACCP) makes is an exciting possibility [60]. In this way, supply chain events in the agricultural sector can be recorded [208] and may be an essential tool to detect unethical suppliers and counterfeit products since authorized participants can only record the data. The blockchain technology can also benefit a company supply chain economically, for instance, through disintermediation resulting in lowered transaction costs and reduced time spent [209]. Blockchain technology can assure instant access to the data - allowing rapid deployment of products and reducing human errors and transaction times. Furthermore, it can ensure the authenticity of the data, which will reduce the cost of trying to prevent data from deliberate fraud and related accidents [180]. Also, since governments and customers more and more ask for transparency within supply chains, a company who can provide this will have a tremendous competitive advantage [209], which again will result in the increased trust from customers.

Blockchain technology may also contribute to the social aspects of supply chain sustainability. The creating of more stable and immutable data and information is vital for this. Since the data in blockchains cannot be modified without the agreement of the majority of the authorized participants, this may prevent corrupt individuals, governments, or organizations from illegally obtaining people's assets. A reliable record of a product's history may also help a buyer control that received goods have been obtained from ethical sources.

Better tracking of products and the identification of further transactions can decrease resource consumption and also be environment-friendly. Several platforms based on blockchain technology are claimed to reduce the waste of a supply chain, such as Echchain [210], ElectricChain [211], and Suncontract [212].

Environmentally conscious customers are interested in green products. To control that a desk made from the wood of a sustainable Indonesian forest requires that the wood must be followed from the time it is harvested through manufacturing to the final product. This is a complex process to follow but is possible with blockchain technology. An example of this is the Endorsement of the Forestry Certification program which traces around 740 million acres of certified forests all over the world using blockchain technology [213].

Blockchain technology has been suggested to improve the managing of several sustainable supply chains for different processes such as recycling [214], the measuring of carbon footprints [215, 216], the emission trading process [217], and supply chain governance and information [218]. These examples suggest a potential for economic, social, and environmental sustainable influences that should be further studied.

4.5 Challenges and Barriers for Blockchain in Supply Chain

Many applications on the use of blockchain technology in supply chain management have been suggested, and some of them have been initiated. It is, however, clear that the use of blockchain for any application is in its early phase, and care should be taken when it comes to the real benefit that may be expected. The critical question is if blockchain will become the disruptive technology of supply chain design and product flows that many people have proposed, or whether it will be the hype that many others have predicted. In this chapter, the barriers and challenges that remain to be solved are described, and a later section will contain proposals for what type of research that must be performed to address the challenges and overcome the barriers. Although blockchain technology is being suggested and adopted in many areas, as for other emerging technologies, many issues and challenges need to be evaluated. The successful use of blockchain technology in supply chain processes and product flow begins with the identification of the challenges and barriers. It is also essential that the supply chain partners fully understand the possible obstacles of blockchain implementation. Related literature, including journal articles, conference, and review papers have been selected as described in the Methods 2 section and reviewed to identify the barriers of blockchain technology in general and in supply chain information systems. The barriers are summarized and grouped into four main categories of technical barriers (Chapter 3.3), organizational barriers (Chapter 4.5.1 and 4.5.2), system related barriers (Chapter 4.5.3), and external barriers (Chapter 4.5.4). The organizational and system related barriers are summarized in Figures 4.2 - 4.6.

4.5.1 Intra-organizational Barriers

Some barriers relate to the internal activities of organizations. Since the implication is resource demanding and disruptive, it is important to have top management support. Long-term commitment and support are also vital for the adoption of new technology [219]. Lack of commitment to the management of the supply chain could be challenging to the necessary resource allocations [220], since the adoption of blockchain technology may require investing in new hardware and software for most network partners [221].

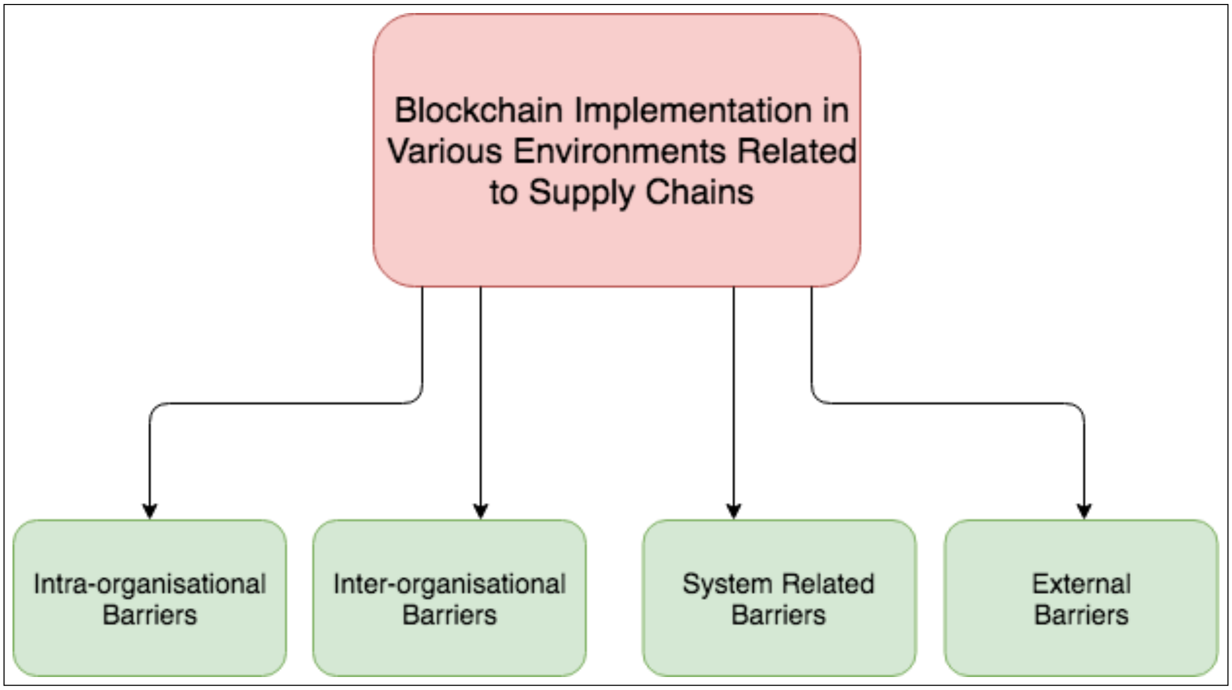

Figure 4.2. Barriers of blockchain technology adoption in sustainable supply chain. Modified from Saberi et al. [8].

The intra-organisational clarification of the proposed usage of blockchain technology is also crucial since it may change existing organizational cultures [218], such as the work cultures, values, and appropriate behavior within organizations [222]. The adoption of blockchain technology in supply chain processes also requires new roles, responsibilities, and expertise to support the unique aspects resulting from the implementation of the latest technology [218].

Technical expertise and knowledge of blockchain technology may occur as a barrier for deployment into the supply chain. The increasing interest for blockchain in the technology market may only in part compensate for the limited number of people with knowledge and technical skill on the application of blockchain [221]. Since blockchain technology is a potentially disruptive information technology [161], the altering or replacing of legacy systems may be required [221], which may alter organizational cultures or hierarchy and lead to resistance and hesitation from individuals within the organization [223]. The Technology Acceptance Model (TAM) may be used to evaluate and predict the level of applicability of a new information technology regarding its usefulness in an organization [37, 224]. To support sustainable supply chains with new information technology, the whole chain network may need to include sustainability practice in the vision of the organization [225]. The need for implementation of sustainability at all levels of the supply chain has been advocated [226]. Lack of tools and indicators for supply chain analysis have, however, been blamed for the delay of successful blockchain implementation and measurement of sustainability practices [227]. Another explanation is that the blockchain technology is in its early stage, and examples of operational supply chains that have successfully implemented the technology are challenging to find [221].

As for other parts of the maritime industry, one of the main drivers for the adoption of innovative and sustainable practices have been claimed to be new demands for environmental regulations and rules. Many organizations are, due to cost concerns, seeking to meet only minimum sustainability criteria. This may, however, impede their creativity and implementation of innovative and sustainable methods [228]. Lack of customers' and partners' willingness to pay more for sustainable products has also been considered a barrier of sustainability implementation [227, 229].

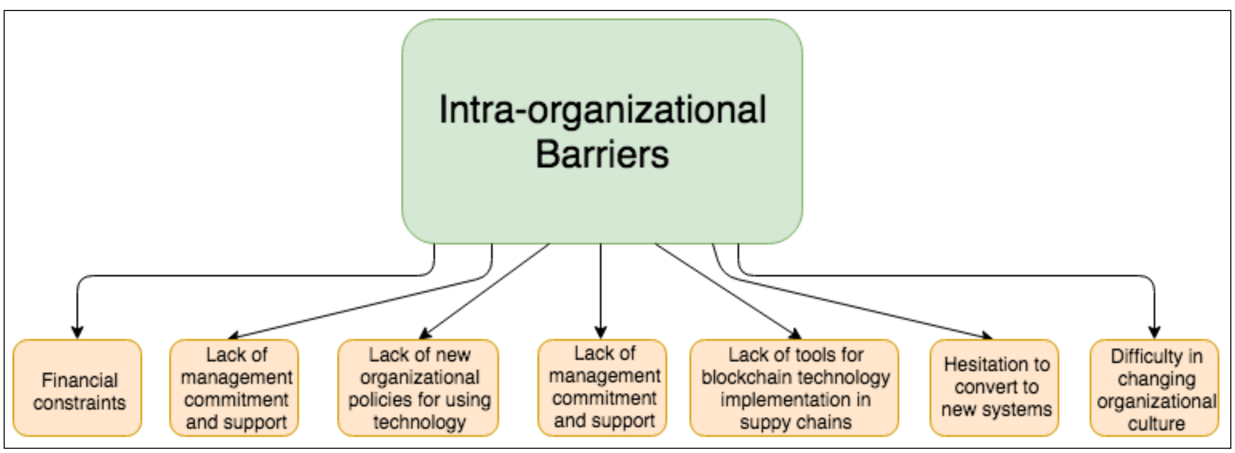

Figure 4.3. Intra-organizational barriers of blockchain technology adoption in sustainable supply chain. Modified from Saberi et al. [8].

4.5.2 Inter-organizational Barriers

Supply chain management is the managing of interactions between partners to give the best value for stakeholders [178]. The relationship between partners may, however, sometimes be challenging, for instance, when it comes to the sharing of information and the practicing of sustainability. Blockchain technology has been suggested to facilitate information sharing in a supply chain. Information transparency and verifiability is considered necessary for the sustainability performance of a supply chain [230]. Organizations may, however, look upon the information as a competitive advantage, and therefore be unwilling to share critical information [220, 231]. This hesitation to share information may also limit the benefits of using blockchain technology and block the successful implementation of the technology.

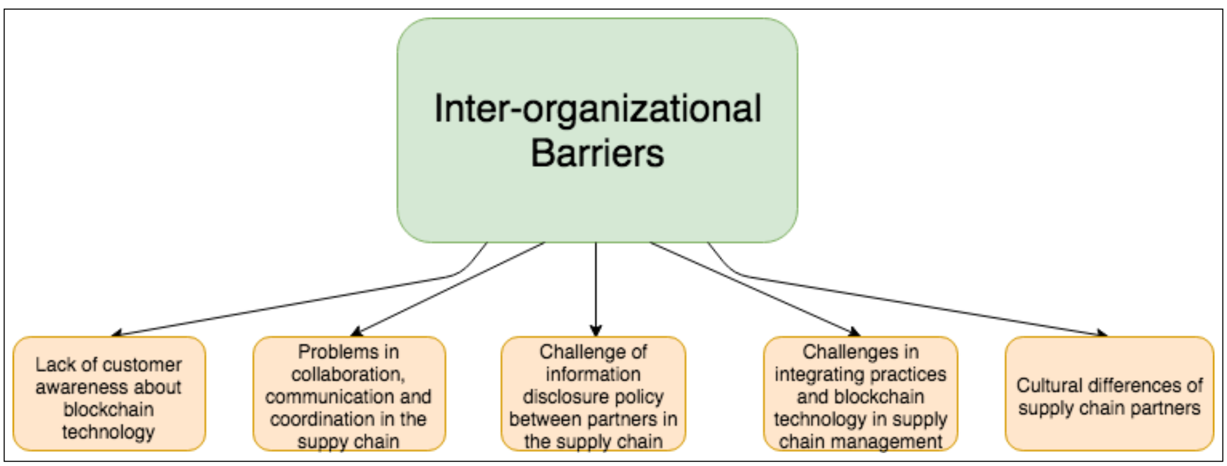

Figure 4.4. Inter-organizational barriers of blockchain technology adoption in sustainable supply chain. Modified from Saberi et al. [8].

Different organizations may have different privacy policies which may create severe challenges for the sharing of data between partners [231]. The transparency of information sharing in blockchain technology must be defined and managed by the supply chain network. The should be clear rules for information sharing among the supply chain partners [222]. Lack of such open and effective communication among network partners may be destructive to the collaboration and disturb the supply chain operations and the attempts to implement blockchain technology [227, 232]. Such communication challenges may increase when supply chain partners are geographically widespread and come from different cultures [228].

Conventional supply chain processes may lack the properties needed to perform sustainable practices. The present technologies may, therefore, have to be improved [230, 233]. Reduction of greenhouse gas emissions, carbon footprints, water pollution, energy consumption, and waste will require a costly update of the processes of supply chain management. The collection of the information needed for blockchain technology purposes will require its facilities and devices. The RFID and the IoT are two potentially important factors in such an update.

4.5.3 System Related Barriers

To obtain the best advantage of the implementation of blockchain technology for supply chain management purposes, new information (e.g., IoT) and new IT tools are needed. This will be a challenge for some of the supply chain participants [59]. All the network participants need to have the equipment needed to access the required information to take advantage of the benefits in the supply chain [220, 222]. Limitations in access to new technology, for instance, the ability to obtain information in real-time, will create a barrier to the implementation of blockchain technology.

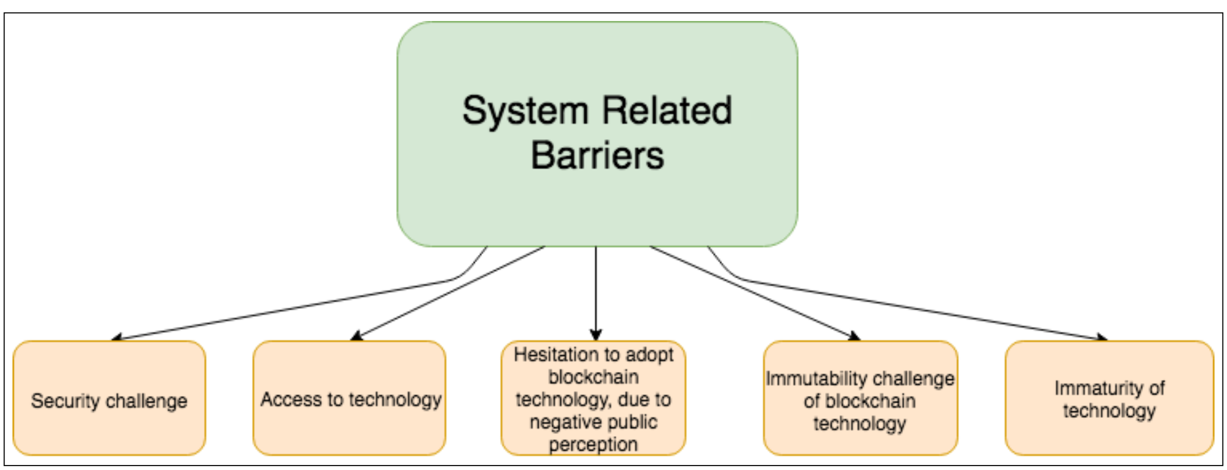

Figure 4.5. System related barriers of blockchain technology adoption in sustainable supply chain. Modified from Saberi et al. [8].

The blockchain technology is in its early developmental stages and is considered a technology with severe limitations concerning scalability - the handling of many transactions [27]. Increasing the number and size of blocks creates a challenge with regards to storage and handling of data in real-time, referred to as a 'bloat' problem in Bitcoin [161]. The management of supply chain networks is likely to involve even larger data requirements. In addition to financial data, data related to processes and practices are needed. Improvement in the management of data storage will, therefore, be required. The altering of data in a supply chain network is a significant concern [234]. Since the blockchain technology allows participants in the network to perform verification of the transactions, data tampering is possible through the obtaining of consensus from a majority of the participants [161]. Data security and privacy are also of concern when using blockchain technology [221]. The security challenges of blockchain technology in the Bitcoin network has been addressed in some research studies [235, 236]. Some solutions have been suggested to mitigate the blockchain security problems, but their efficiency has not been evaluated [27]. Since the blockchain technology is still primarily associated with cryptocurrencies such as Bitcoin [161], the reputation earned from this slows down the general adoption of the technology.

Information immutability is considered an essential feature of blockchain technology. This means that the information cannot be altered and removed from the blockchain without consensus among the network participants, which again it will prevent an unauthorized change of the data in the chain [60]. However, this does not guarantee that the recorded data in the blockchain are correct, only that they have not been tampered with after being included in a block. Although inaccurate data may be corrected by appending additional information, the erroneous record will always be present in the blockchain [237].

4.5.4 External Barriers

Barriers may also occur from external stakeholders, governments, institutions, industries, and others not directly involved in the supply chain activities. External support and critique of sustainability and other technological practices may cause the supply chain participants to try accommodating the suggestions. Legal regulations on the use of blockchain technology are to a large extent missing, and the lack of appropriate governmental and industry policy and support have been claimed to create difficulty in achieving sustainability and implementation of appropriately supporting technology [227]. Official policies issued by governments about Bitcoin has been reflected as a possible concern that may affect a broader range of the usage of blockchain for business objectives [221]. Demand uncertainty for sustainable products and customers' ambiguity may affect the market competition and delay the integration of sustainability and blockchain technology [233] since organizations need to be sure that the customers will compensate the investments in sustainable processes and new technologies. Consideration of the blockchain technology adoption obstacles is necessary to give a better understanding of the benefits of the new technology in supply chain networks. Many of the challenges have not been empirically tested or verified, but this is needed to provide a starting point for future research studies. Such research may bring additional factors beyond inter/intra-organizational environment, technical and external outlooks that will refine the managing of global supply chain networks in the future.

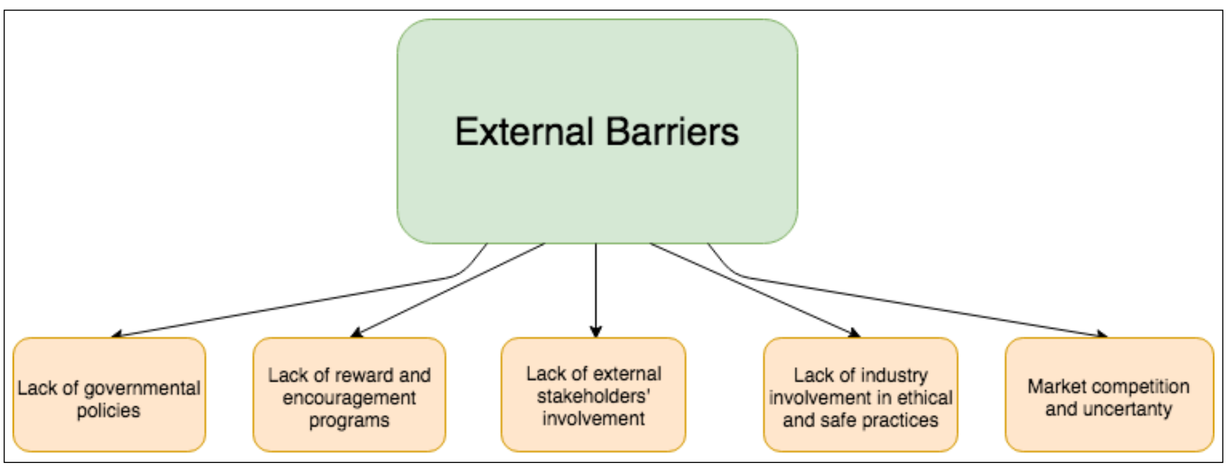

Figure 4.6. External barriers of blockchain technology adoption in sustainable supply chain. Modified from Saberi et al. [8].

Chapter 5

Case Study - Blockchain Technology in Vetting

5.1 Maritime Safety

When a ship enters a port, the state authorities can inspect the vessel and decide if the safety standards fulfill international conventions. If this is not the case, the ship can be detained until the demands have been met. Port state control in the shipping industry emerged in the 1970s in response to several tanker accidents. The Paris MoU (Memorandum of Understanding) is the port state regime covering Europe, parts of Russia and Canada, and has been shown to effectively eliminate vessels that do not live up to international convention standards [238]. There are today ten different regional regimes for port state inspections around the globe.

5.1.1 Complexity of Marine Safety

Figure 5.1 shows a schematic view of the players in marine safety. Three international organizations are central to the activity, the United Nations (UN), the International Labour Organization (ILO) and the International Maritime Organization (IMO). Also, country-specific legislation is represented by the European Union (EU) or by the Oil Pollution Act (OPA 90) for the USA.

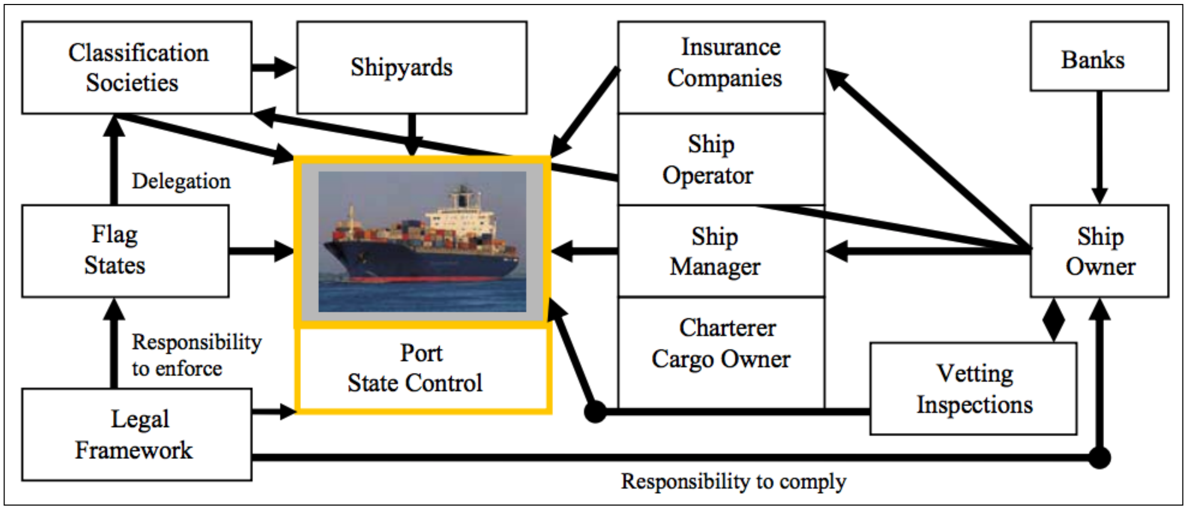

Figure 5.1. Players of the safety regime in general. From Knapp et al. [9].

There is still some uncertainty in the distribution of responsibility to comply with the legislative framework between the actual ship owner and the operator or technical manager of the vessel. This has, in many instances, complicated the enforcement of legal rules in the shipping industry. Some responsibility is distributed depending on the type of activity by different companies - such as safety or commercial management arrangements. In some instance there may be two categories of ownership, a beneficial owner, being the company of beneficial interest, and registered owner which may be related to a mailing box in a country unrelated to where the ship owner or ship operator resides [9].

A flag state is a country where the ship is registered. This can confuse since some countries specialize in open registries (e.g., Liberia, Panama, and the Bahamas) which offer tax reductions and other benefits to the ship owners. Other registries may be in countries where more restrictions apply, and there may even be a third type of registration in between these traditional flag state registries and the open registries - the so-called international registries. The Norwegian International Registry is such an example - created to prevent that all vessels under national flags would go to open registries.

All flag states are responsible to implement the international conventions into the federal legislation and to enforce it on ships flying its flag. This is, however, not always the case, and the port state control regimes were in part created because some flag states were more interested in registration to earn money - less in their obligation to enforce legislation. These apparent loopholes could attempt ship owners to operate below the required safety standards which again could lead to increased probability for accidents - resulting in loss of human lives as well as damage to the environment and the cargo.

The flag states are considered as the first, and the port state authorities as the second line of defense in eliminating ships that do not fulfill the legislative demands.

The many different registries result in a political legislation process where important technical details could be ignored or overlooked. This has, in turn, given the result that no one of the ten port state control regimes accepts the inspections performed by other governments. In some instances, inquiries within the same regime may even not be accepted in another port. Figure 5.2 illustrates the process of port state controls.

The industry contributing to this problem has been vetting inspections. Such inspections are primarily carried out to protect the cargo owners from legal consequences in case of an accident. This creates an incentive for the ship owner to respond to the vetting inspection requirements since if not, there is a significant probability that the ship will not get any cargo. Vetting is the ticket to trade.

Because of this, the shipping industry must deal with a high level of inspections which pose a significant workload to the crew onboard vessels. All inspections are carried out to improve safety - but a large part is caused by varying motivation and interests of the stakeholders.

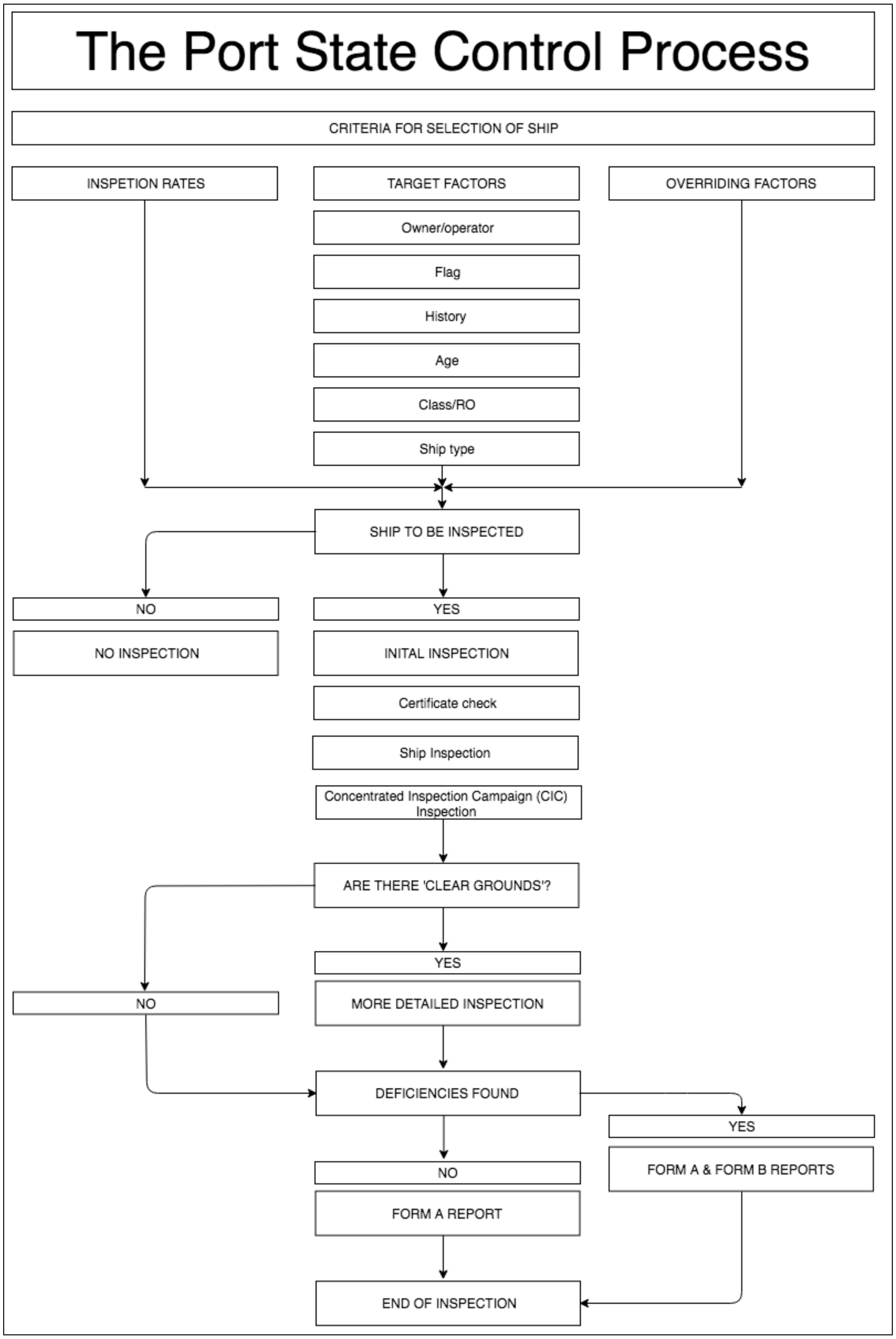

Figure 5.2. Port state control process. From INTERTANKO 2017 [10].

5.1.2 Overview of Inspections

An overview of the large number of different types of inspections is shown in Figure 5.3. The figure gives information about who is performing the inspection; what the requirements are; type of inspection/survey; the specific inspection areas; and the different ship types.

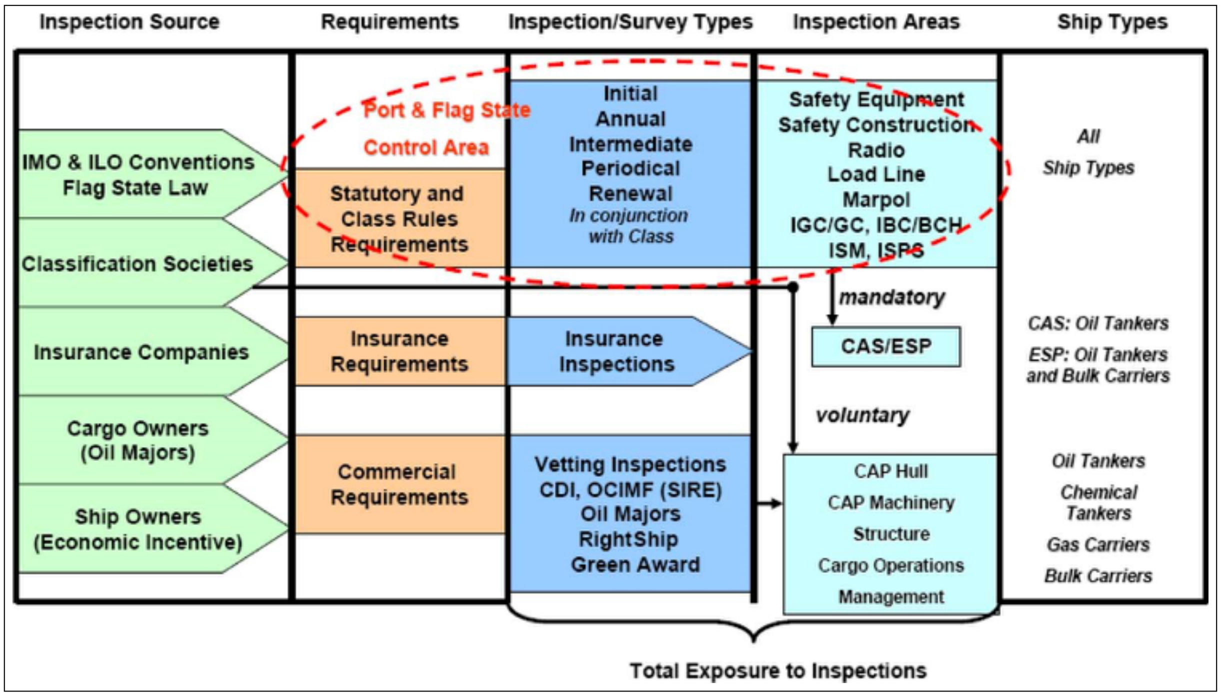

Figure 5.3. Summary of total inspection and audit exposure. Note: CAS = Condition Assessment Scheme, ESP = Enhanced Survey Program, CAP = Condition assessment Program. Source: Compiled by authors based on inspections and various legal sources (e.g. SOLAS, MARPOL). CDI (2003), Green Award Foundation (2004), OCIMF (2005) and RightShip (2006). From Knapp et al. [9]

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The port and flag state inspections are mandatory and shown in the upper part of the figure indicated by the dotted oval. The voluntary (non-mandatory) inspections are shown below the dotted oval.

The requirements underlying mandatory inspections originate from different sources such as port state control regimes and flag state legislation. The flag states are responsible for inspections to enforce their legal base, in addition to that of international conventions, and the ship owner is considered to have the overall responsibility of complying with all legal conventions [9]. In some instances, a classification society may perform the mandatory inspection on behalf of a flag state - often referred to as surveys. The purpose of such surveys is to provide the ship with the certificates needed to trade internationally.

Some inspections are performed to assure that the ship retains its classification from the time it was built. Such classification surveys are non-mandatory. There are no legislative requirements for a vessel to remain in its class according to the original classification rules, but it is often advantageous for insurance purposes. Some insurance companies also perform their own inspections.

5.2 Vetting

Most vetting inspections on oil and chemical tankers are performed by the Chemical Distribution Institute (CDI) or the Oil Companies International Marine Forum (OCIMF). According to Knapp and Franses [239], some oil majors, such as Equinor, Chevron, Shell and BP perform their own vetting inspections in addition to those from CDI or OCIMF. The vetting inspections of dry bulk vessels are done in relation to RightShip. A Green Award Certificate may be awarded following an inspection by the Green Award Foundation. Such an award will allow a reduction of port dues. Figure 5.4 shows the type of information used in the vetting evaluation.

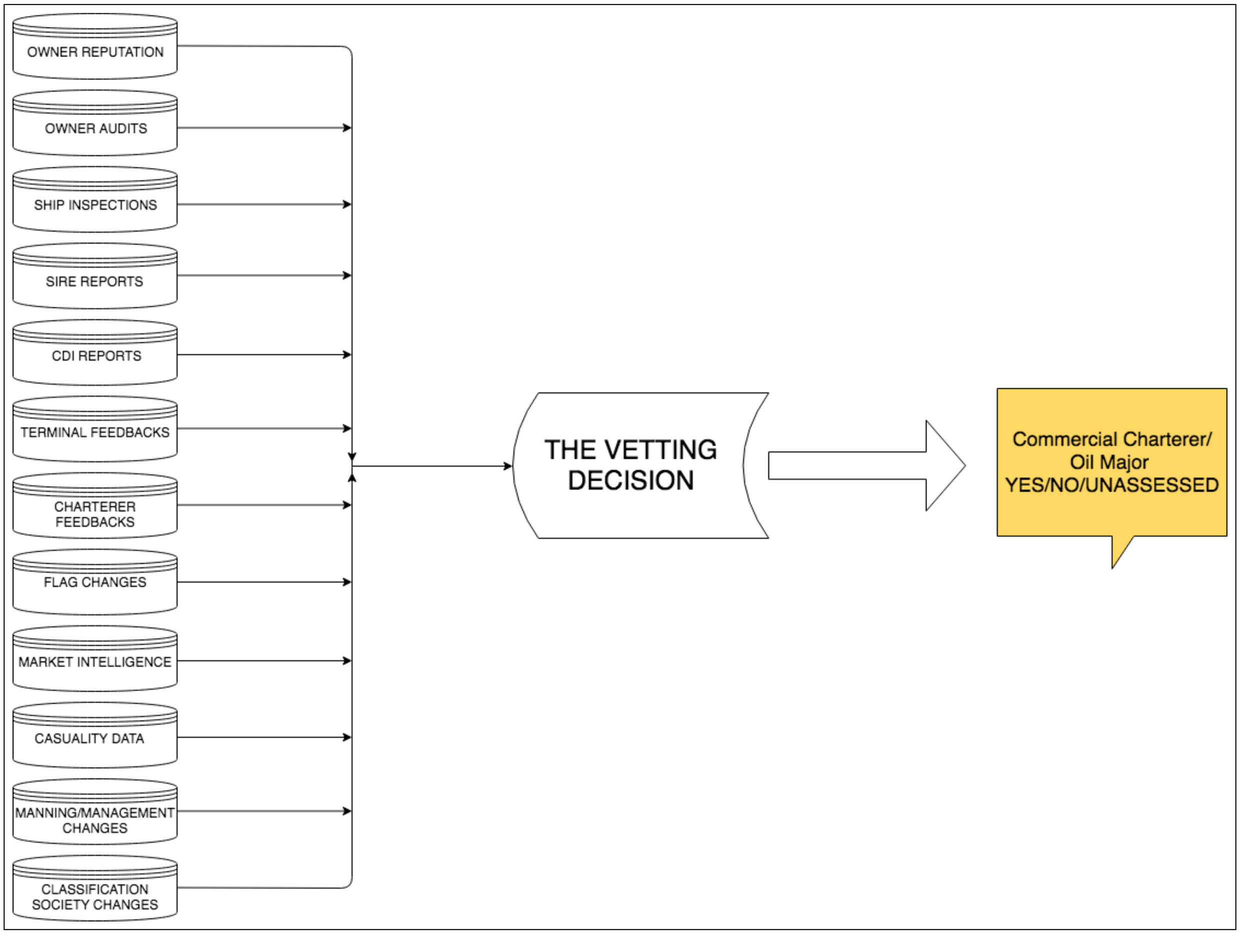

Figure 5.4. Information used in the vetting evaluation. Modified from INTERTANKO 2004 [11].

The vetting inspections are of great importance for cargo owners - especially for chemical and oil tankers, gas and bulk carriers, while the statutory requirement inspections are relevant for all ship types. There is little or no cross-recognition for the different inspection types. Many organizations and organs are involved in the vetting process. The most important are:

5.2.1 OCIMF (Oil Companies International Marine Forum)

OCIMF is a voluntary association of around 112 oil companies worldwide that was formed in 1970 following some severe pollution accidents and the rise of antipollution awareness. Its role has been broadened to account for many different maritime activities such as tankers, barges, offshore support vessels, terminals, shipping in ice, and piracy. OCIMF has done a lot to improve the safety of tankers and thereby protect the environment. Due to the many members of different geographical and cultural background, OCIMF has been considered to be a slow working organization. At the same time, the broad distribution of members has also been the organization's strength and served as a valuable asset for the development of regulations. The main tools of OCIMF are the Ship Inspection Report (SIRE), the Self-Assessment tool (TMSA), the Offshore Vessel Inspection Database (OVID), and the Marine Terminal Information System (MTIS).

5.2.2 INTERTANKO (International Association of Independent Tanker Owners)

International Association of Independent Tanker Owners (INTERTANKO) is a global association of tanker owners created in 1970. The intention was to form an association representing independent tanker owners and non-oil companies to provide safe shipping of oil and chemicals. INTERTANKO should also be a forum for the development of marine policy. Most independent tanker owners are today INTERTANKO members. The organization had in 2012 235 members with a fleet of 3,380 tankers. The central offices of INTERTANKO are in Oslo and London.

5.2.3 RightShip

RightShip Pty Ltd. is a joint venture company that was created by the fusion of two vetting companies, BHP Billiton Freight Trading and Logistics and Rio Tinto Shipping. The company focuses on marine safety through the organizing and execution of vetting inspections of tankers and bulk carriers, which covers many different aspects of ship operations - including ship structure and cargo handling. The vetting is intended to prevent high-risk vessels from being used in the competitive maritime industry. RightShip provides an online vetting service which can be accessed by members anywhere in the world. The vetting service, SVIS, rates the vessels in five categories where a three, four, or five-star rating suggests that the vessel is acceptable - while when rated one or two stars, further investigations needs to be carried out. In addition to the online vetting service, RightShip also offers vetting specialists that physically inspect vessels and audit management and crew competence.

5.2.4 SIRE (Ship Inspection Report)

SIRE was launched in 1993 by OCIMF to address concerns about the use of sub-standard vessels. SIRE is a risk assessment tool for tankers intended to help charterers, ship operators, terminal operators, and government bodies to deal with ship safety. The SIRE system consists of large databases of updated information on tankers and barges and has received wide acceptance among OCIMF Members and ship operators. Barges and small vessels were included in SIRE in addition to tankers in 2004. SIRE has altogether provided more than 180,000 inspection reports, and at present, about 22,000 reports on 8,000 vessels are provided each year.

5.2.5 CDI (Chemical Distribution Institute)

CDI is a non-profit foundation created by the chemical manufacturing industry in 1994 to inspect and audit the supply chain for transport and storage of bulk and packaged chemicals. CDI serves its chemical company members and provides them with the inspections and audits considered necessary to obtain cost-effective systems for risk assessment. CDI is managed by a seven-member Board of Directors selected by the participating chemical companies. This board establishes the policy and is responsible for the overall affairs of CDI, which include improving the safety, security, and quality performance of marine transportation and storage for the chemical industry.

5.2.6 VIQ (Vessel Inspection Questionnaire)

VIQ is a list of questions used to standardize SIRE inspections. It was introduced during the revision of the SIRE Programme in 1997 and have later been revised several times. In 2000, the Reorganised Vessel Inspection Questionnaire (ROVIQs) was introduced where the VIQ questions were re-organized to follow the order that would normally be taken by an inspector when performing an inspection.

5.2.7 The Officer Matrix

The Officer Matrix is an online system to manage and report the crew situation onboard a vessel. It meets the requirements of OCIMF, and the data can be exported to the OCIMF website. The system allows the ship to keep the officer matrix updated - independent of Internet access. It also serves a compliance check possibility which will alert in case the vessels do not meet the requirements.

5.2.8 Green Award Foundation

Inspections by the Green Award Foundation is performed on oil tankers and paid for by the ship owner. The inspections cover aspects of shipboard operations, including the vessel's shore-based management systems. If the inspection is successful, a Green Award certificate is issued - resulting in discounted harbor fees in the ports that participate in the program. The Green Award Foundation is a non-profit organization, but is, however, not officially recognized by many port state control regimes.

5.2.9 The Vetting Process

CDI inspections are owned and paid for by the ship owner and are primarily performed on chemical tankers. These inspections follow a standardized questionnaire and may cover both statutory and desired requirements. Statutory means under international laws while desired means by wishes from users of the reports. CDI inspection may take 8–10 hours, and focus on cargo operations and competence of the crew.

Vetting inspections by OCIMF are called SIRE inspections. SIRE is booked by cargo owners and are primarily for oil tankers. These inspections are similar to the CDI inspections and focus on cargo operations. The ship owner is allowed to comment on the report before it becomes available to other OCIMF members. An event tree from when the ship operator orders the inspection to when it is completed is illustrated in Figure 5.5.

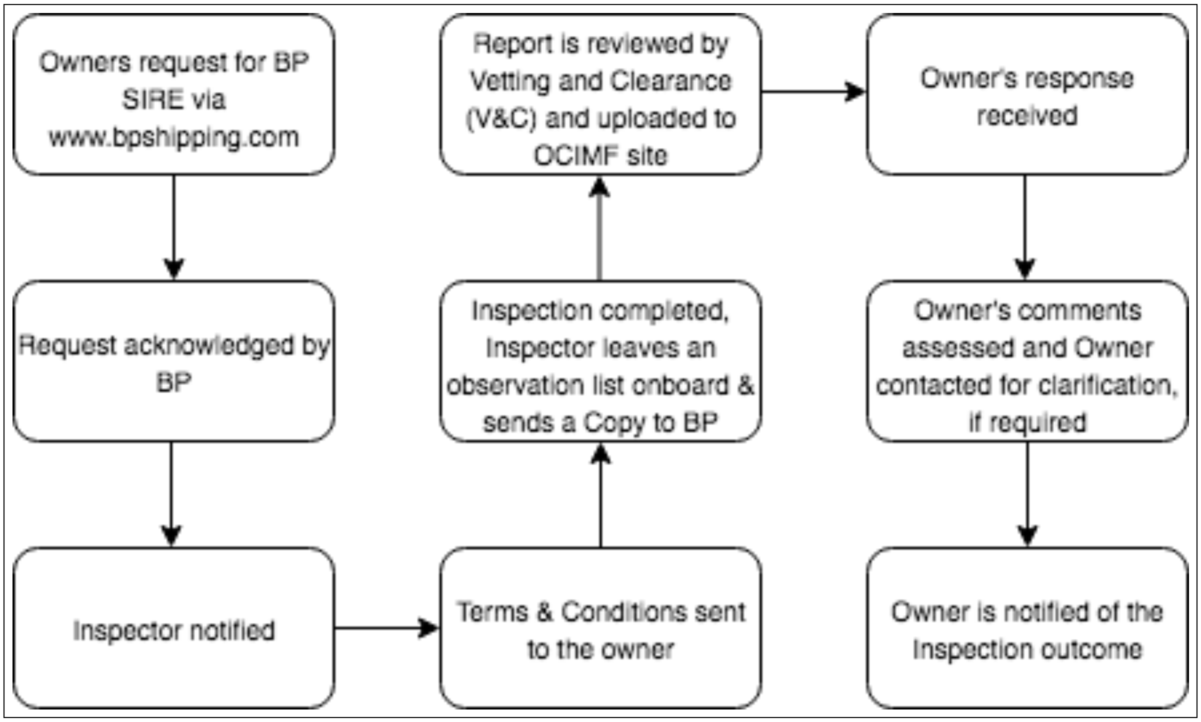

Figure 5.5. A typical SIRE inspection process. BP is used as an example. From INTERTANKO 2017 [10]

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Also, in this case, a standardized questionnaire is used. Oil companies may, however, require the addition of other checkpoints and often perform their own inspections. The SIRE inspections form the basis, and other points are brought up in the inspection but not published in the final SIRE report. Oil majors may also ask a ship owner to participate in the so-called Condition Assessment Program (CAP) for hull or machinery. Classification societies offer CAP on a voluntary basis, and may if successful provide the ship owner with a rating CAP1 - the best of three ratings, CAP1, CAP2, and CAP3. CAS and CAP have many similarities, CAS being a statutory requirement for a flag state, and CAP being voluntary for oil majors. Figure 5.6 shows a decision based flow chart illustrating the many considerations to be made by the charterer before accepting a vessel in a vetting process.

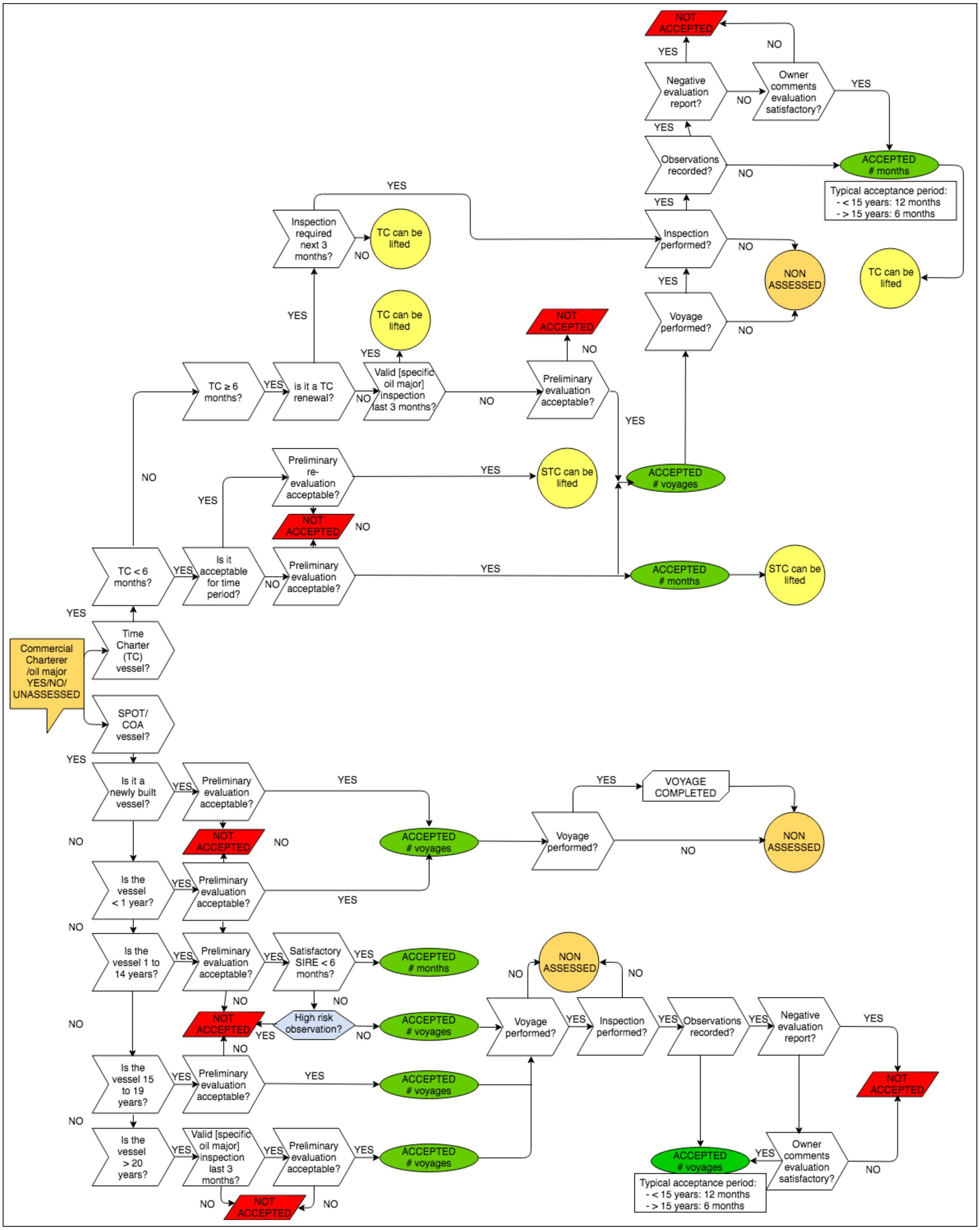

Figure 5.6. A typical decision based vetting flow chart seen from the charterer/oil majors perspective. Modified from INTERTANKO 2017 [10].

5.2.10 Inspections Reduce Accidents

All ship types are inspected by port state control regimes, while tankers are also subject to vetting inspections and dry bulk carriers to inspections from, for instance, RightShip. Quantitative analysis has shown that increasing the number of inspections of ships as well as the enforcement and ratification of conventions are associated with a reduced risk for fatal accidents. Knapp et al. [9] have shown that the probability of fatal accidents decreased with inspections in a high-risk tanker (Figure 5.7). For severe casualties, the probability was found to decrease dramatically with the number of inspections.

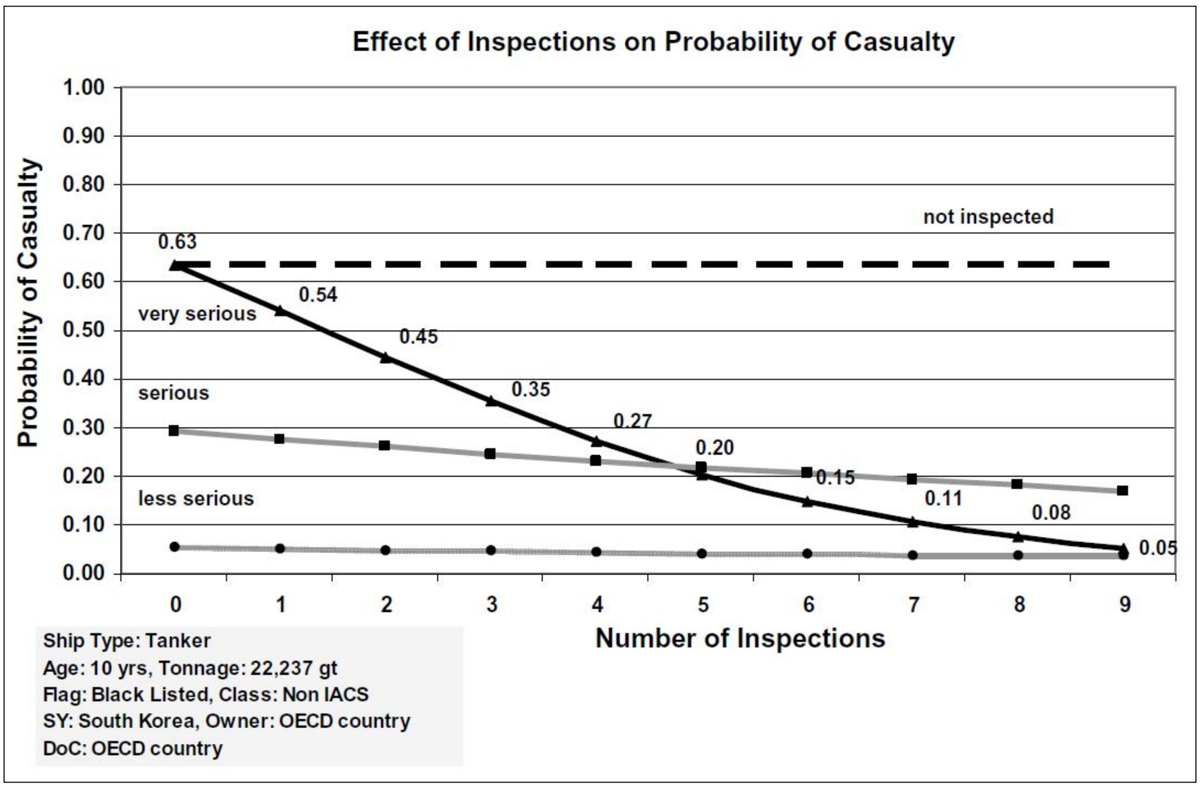

Figure 5.7. Probability of casualties and number of inspections in a high-risk tanker. From Knapp et al. [9].

Container and general cargo vessels that are not vetting inspected as intensively as tankers and dry bulk ships show less effect of inspections while the apparent impact of inspections is more pronounced for tankers and dry bulk vessels (Figure 5.8).

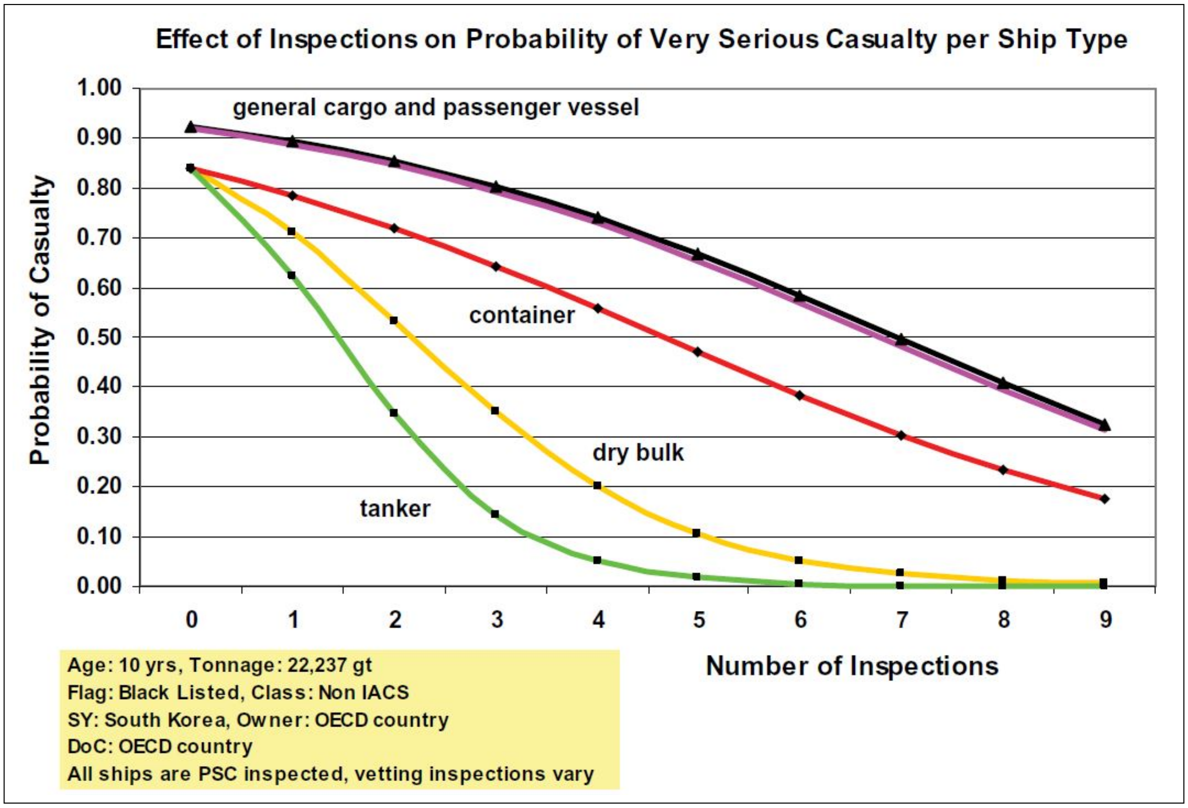

Figure 5.8. Effects of inspections per ship type. From Knapp et al. [9].

The decrease in insurance claims has been estimated to be significantly higher than the inspection costs which suggests that the inspection system overall is thriving on the elimination of substandard vessels (Figure 5.9).

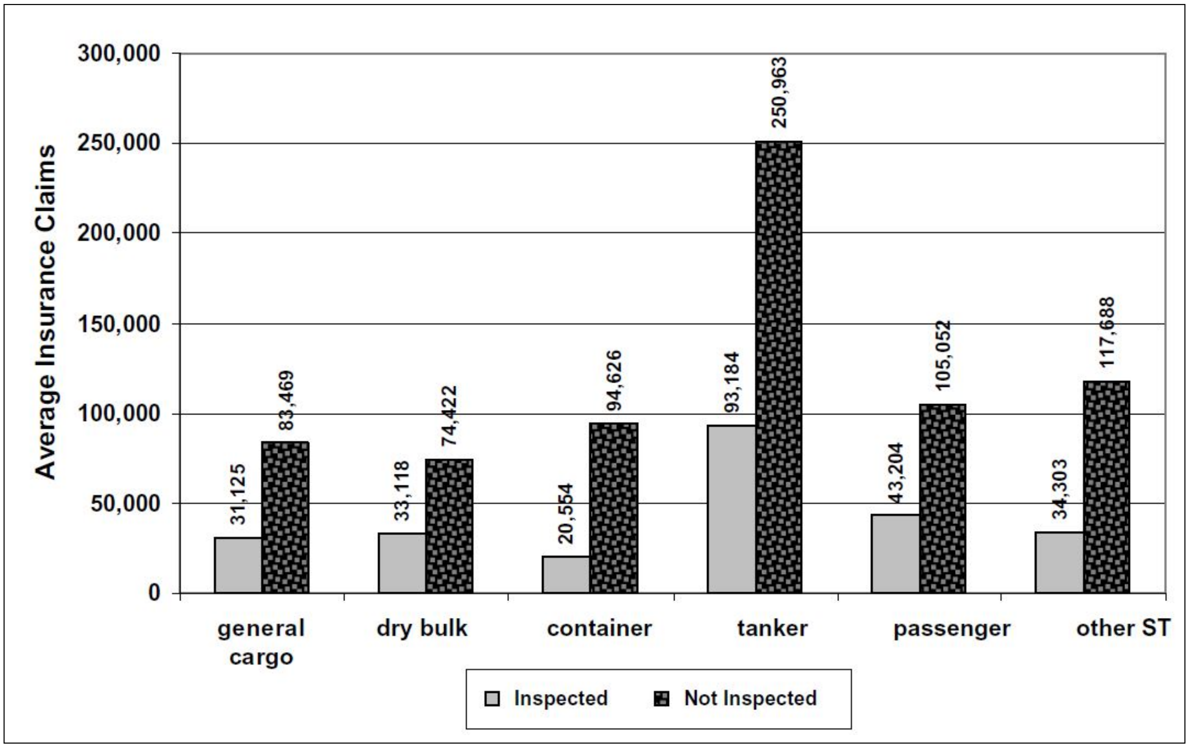

Figure 5.9. Average claims of inspected versus non-inspected vessels per ship type in US $(based on insurance claim data merged with casualty and inspection data from 2000 to 2004). From Knapp et al. [9].

At the same time, it has been argued that the system is far from perfect. Lack of trust in the shipping industry between flag states, port states, classification societies, insurance companies, and cargo owners has caused a lack of collaboration between close business partners - again resulting in expensive systems with parallel and similar inspection regimes.

In 2006, the inspection costs per ship per year were estimated to about US$47,000 for tankers and US$17,000 for other ship types [9]. The number of inspections per year varied for different ship types, with median values around 11 times for tankers and about six times for other ship types where vetting inspections were less frequent.

The areas covered in the many legislative and industry-driven voluntary inspection types showed a significant degree of overlap. The inspections seemed to result in decreased frequency of fatal accidents - but no significant difference was observed for different inspections regimes towards diminishing the probability of casualty.

The many different inspection types and the combination of obligatory legislative inspections and voluntary industry-driven inspections with different requirements may cause confusion related to onboard operations. Demands for reduced time in ports may cause inspections to increase the number of working hours for the ship personnel - thereby increasing fatigue which in turn may decrease the positive effect of the inspections.

According to Knapp et al. [9], most safety regimes have not accepted inspections performed in a different regime or industry-driven vetting inspections - independent of the finding that all inspections seemed to decrease the probability of casualty accidents. An important question was how to improve the functionality of the overall safety regimes, and how the resources allocated to port state control and other inspection types could be used in a more efficient way to eliminate substandard ships.

Attempts have been made in joint meetings between IMO and the flag states to reach an agreement on the harmonization of control activities, but the reported progress had been slow and hampered by mistrust and divergent political opinions.

IMO's GISIS (Global Integrated Ship Information System) is claimed to contain the necessary modules needed to combine data from the different inspections and casualty studies but was mistrusted by the member states and other partners involved. The consequence was that data were not submitted to the database, and different control regimes did not accept inspections performed in other regimes. This lack of collaboration made it difficult to efficiently enforce the rectification of deficiencies since all involved partners would only takes their own data into account.

Although the maritime safety system seemed successful in the identification of substandard ships, there was a large room for improvements through the establishing of systems where data sources could be combined to improve risk profiling. This could also allocate the efforts to ships and regions where inspections are needed the most. It could potentially also open for better collaboration between regulators and companies and remove some of the political barriers in the shipping industry.

In a system where multiple mutually mistrusting entities need to interact, and historical records should be preserved unchanged, blockchain has many of the properties necessary to be a well-suited technology [7].

5.3 Introduction to the Case Study

Knapp et al. [9] stated that the different vetting inspection regimes did not accept inspections from another regime, and that the port state controls did not accept or use data from any vetting inspection in their own system.

Knapp and Franses [239] analyzed data from 183,819 safety inspections on 26 vessels in a paper from 2010 entitled 'Comprehensive Review of the Maritime Safety Regimes: Present Status and Recommendations for Improvements.' Four regional regimes performed the inspections in the period 1999–2004. The data also included casualty data from IMO, Lloyd's Maritime Intelligence Unit and Lloyd's Register Fairplay as well as vetting inspection data from two vetting regimes. Based on these data, they concluded that although a complex framework generated many overlapping inspections, the safety system seemed to be successful in eliminating substandard vessels. Also, the average insurance claim costs were substantially lower for inspected than non-inspected vessels. No significant difference in the probability of casualty was found between industry inspections and port state control inspections. It was further concluded that the system could be made significantly more effective by combining the inspection resources and improvements in the vetting management routines - especially for ship types such as tankers.

'Ships officers, ship owners, and the representative's associations have expressed concerns about the number of inspections carried out on their ships – particularly on oil and chemical tankers.' and 'It is primarily the breakdown in trust that has led to the growth in the number of different inspections.' These are two statements in 'INTERTANKO Guide to the Vetting Process' - a book from INTERTANKO in 2017.

As a consequence of the conclusion of Knapp and Franses [239] and the stated views from INTERTANKO (2017), it was decided to focus the case stduy in the master's work on the ecosystem around vetting to see if the implementation of blockchain technology could improve the vetting management system - allowing a reduced number of vetting inspections. To evaluate this, it was decided to interview relevant stakeholders within the vetting ecosystem to locate pain points and identify common denominators.

Although the ecosystem of vetting consists of a variety of stakeholders (see Figure 5.3), it was decided to focus on interviewing the ship owners/operators and the charters/oil majors considering these as the stakeholders with the most significant involvement in vetting - spending the most money, time and resources.

5.4 Case Results

All participants accepted that the interviews were recorded, and the recordings were helpful to recapitulate the content. This full contents of the interviews are given in a relatively crude form in Appendix B.3, while the views and opinions are summarized and discussed below. Based on the proposal of some of the interviewees, the transcripts in the Appendix have been anonymize by deleting possibly sensitive information.

The goal of the interviews was to address the knowledge, expectations, and challenges in the ecosystem of vetting, and to evaluate the potential for reducing the number of inspections by the implementation of blockchain technology. Through the specific questions asked, it was of interest to learn if the companies had considered the implementation of the technology, and what their expectations were. After looking into the data, there was an opportunity to contact the participants to make sure that the interpretations were formulated correctly. Much of the emphasis was to explore a potential lack of trust between involved partners, and if blockchain technology was considered having the potential to improve this.

5.4.1 Participants in the Study

Since some of the interview objects did not want their name, nor the name of their company to be linked to the information given, it was decided to keep all interviews anonymous, and only state the type of business they represented. The participants came from two different business groups, ship owners/operators and charterers/oil majors. Altogether, representatives of 14 firms were interviewed, nine ship owners/operators and six charterers/oil majors. The interviewees with respective information is listed in Table 5.1.

Table 5.1. Interviewees with respective information.

Case	Company pseudonym	Type of stakeholder	Interview date	Interview length	Interview type
#1	Company A	Ship owner/ operator	11/04-2019	33 min	Telephone
#2	Company B	Ship owner/ operator	11/04-2019	-	Written answers
#3	Company C	Ship owner/ operator	24/04-2019	35 min	Personal meeting
#4	Company D	Ship owner/ operator	24/04-2019	46 min	Telephone
#5	Company E	Charterer/ oil major	25/04-2019 and 29/04-2019	29 min and 10 min	Telephone
#6	Company F	Charterer/ oil major	29/04-2019	-	Written answers
#7	Company G	Charterer/ oil major	29/04-2019	16 min	Skype Video
#8	Company H	Ship owner/ operator	30/04-2019	57 min	Personal meeting
#9	Company I	Ship owner/ operator	06/05-2019	23 min	Personal meeting
#10	Company J	Ship owner/ operator	09/05-2019	42 min	Telephone
#11	Company K	Ship owner/ operator	09/05-2019	21 min	Personal meeting
#12	Company L	Ship owner/ operator	21/05-2019	28 min	Telephone
#13	Company M	Ship owner/ operator	22/05-2019	68 min	Personal meeting
#14	Company N	Charterer/ oil major	23/05-2019	23 min	Skype Video

Braun and Clarke's [12] thematic approach; 'A General Inductive Approach for Analysing Qualitative Evaluation Data' was used to analyze the interview data. This method consists of six steps as shown in Table 5.2.

Table 5.2. Braun and Clarke's six phases of the thematic approach. Modified from Braun and Clarke [12].

STEP	Step Heading
#1	Familiarization with the data
#2	Generating initial codes
#3	Search for themes
#4	Review themes
#5	Define and name themes
#6	Produce report

In the first step, the researcher should familiarize himself with the data, for instance, by listening to the recordings and transcribing the interactions in the interviews. Initial ideas should be noted. This step is fundamental to the analysis. In the second step, the researcher should generate preliminary codes for the data. These codes are more detailed than the themes, which are the topic of the third step. In the fourth step, the themes should be reviewed, to secure that there are clear and distinct boundaries between the themes. In the fifth step, the name of each theme should be determined, and the intention is to capture the essence of each theme. The final and sixth step is to produce the report where the researcher should transform the analysis in a way that convinces the reader of the content and validity of the study. Such a thematic type of analysis is used for the conducting of many other types of qualitative analysis and provides a flexible and useful research tool.

5.4.2 Initial Codes

It was decided to use the individual questions as basis for the creation of initial codes. This is according to step one in Braun and Clarke's approach.

The Interview Guideline and questions can be seen in Appendix B.1. The starting interview questions were the same for all interviews:

1. What is your organization's role in vetting?
2. How is your organization involved in the vetting information flow?
3. Who are your collaborators in the process of vetting?

4. How satisfied are you with your vetting process, and what are the main challenges?
5. What part of the vetting process do you find the most time-, cost-and resource consuming?
6. What would be the most important improvement in today's vetting procedure?
7. Have you considered the implementation of blockchain technology in the vetting process?

These questions were transformed into the following initial codes:

1. Role of organization in vetting.
2. Involvement in vetting information flow.
3. Collaborators in the vetting process.
4. Tools used to manage information flow.
5. Satisfaction with the vetting process.
6. Challenges with the vetting process.
7. Time and cost consumption.
8. Improvement of the vetting procedure.
9. Implementation of blockchain technology.

5.4.3 Summary of Interviews

The analysis started by considering and summarizing the answers to the initial code questions for the ship owners and charterers separately. In this part, the main thoughts of the interviewed parties are summarized. It should, however, be noted that for a more detailed view of all the points that were touched upon in the interviews, the transcripts of the interviews in Appendix B.2 will provide a comprehensive picture of the interviews.

Initial code 1: Role of organization in vetting

Ship operator / owner

Vetting was considered fundamental to the activity of ship owners and take place 3-4 times per year on each ship. The ship operator orders the vetting service from the oil majors who organize the inspections of the ships through OCIMF and their inspectors. The inspectors rotate and may come from Shell, BP, Total, Equinor, Repsol or other oil companies. Earlier, several inspections came on top of each other, but this is different and better organized and planned today - mainly because of OCIMF and that the inspections have been more standardized. There are two inspection regimes, SIRE and CDI. There is a limit of 6 months for the validity of a SIRE report; thus a SIRE inspection may take place every 3-6 months. Some oil majors are stricter with the dates than with the inspection content. Therefore, a vessel may be cleared by one oil company and rejected by another - based on the same report. CDI reports are valid for 12 months, and here the ship owners are freer to choose inspectors. Vetting is related to the ship and the crew, but some of the ship owners arrange pre-vettings to prepare for the formal inspection and prefer to have representatives on-board during the inspection.

Oil major / charterer

Several of the larger oil companies have their own vetting department that considers the vessels to be screened and verified before chartering is performed. The role of the vetting departments is to recommend the ship or warn the company against the vessel being chartered. The information needed is obtained from OCIMF and supplied by data from their own information platforms. Although there is no legal enforcement to perform vetting, it seems that no oil company is willing to charter a vessel before a vetting process has been performed.

Initial code 2: Involvement in vetting information flow

Ship operator / owner

The ship owner starts the vetting process by informing the ship crew about the upcoming inspection and updates the VIQ on ship information, which is uploaded to OCIMF. The VIQ also contains the ship's class certificates and observations. Then they contact the specific oil major where the information flow may differ depending on which oil major is involved. BP has, for instance, their own portal for the ordering of inspections while Shell obtains requests on an Excel-sheet sent by e-mail. ConocoPhillips, Equinor, and others use a platform called SIS3 and Repsol use Q88. The ship owners must, therefore, keep track of who uses which type of platform and transfer the information according to this. A TMSA may also be used by the ship owner to keep track of internal processes. This may include information about previous vettings and different inspectors on what have been their previous focus. An inspection often takes place when the ship enters a port and may take from 6 to 12 hours. After the inspection, the operator receives information about the observations reported by the inspector, which they must comment on to OCIMF within 14 days before the report is published. A ship operator may also perform a search for information regarding the chartering company as well as the vessel owner. Such information can be related to credit risk, reputation, geographical area, and different potential ethical risks.

Oil major / charterer

Several of the larger oil companies may, if updated, have enough data in their information platform to be able to decide on whether to charter the vessel or not. If more information is needed, they may contact the ship operator and ask for more. OCIMF have agreed on a standardized questionnaire that the ship operators must answer to concerning general information related to fixed parameters of the vessels. They also administer a questionnaire of about 400 questions and several inspectors appointed by the different oil companies who enter the ship to perform the formal inspections. All oil companies approve the inspection reports from an inspector of another oil company. How the oil companies interpret the available data may, however, vary between the individual oil companies. OCIMF follows up the inspections and inspectors to update and improve the vetting process.

Other information is not shared between the oil companies - unless they are part of some smaller information-sharing platform, such as SIS3 which consists of 10 oil companies. Some of the oil companies state that the sharing of vetting information between companies has diminished over the last years and that the sharing is now at an all-time low.

Initial code 3: Collaborators in the vetting process

Ship operator / owner

The collaborators for the ship owners are mainly the chartering oil majors and OCIMF. The collaboration with oil majors depends on their location and type of contract. One company could have a contract saying that it should be the next oil major to carry out the next SIRE inspection. Some of the ship owners prefer to work with larger oil majors in a rotating manner, and not use 3rd party vetting companies. Thereby the vetting can be carried out at sea or in port by the oil major inspectors themselves, or by a vetting company on behalf on that oil major. The SIRE vetting reports can only be accessed by the OCIMF members and costs about USD/GBP 40 to download and read.

Oil major / charterer

The oil majors may collect information from OCIMF, the technical operator of the vessel, the Port State control, vetting inspectors, other oil majors or specialized sites such as Fairplay and Equasis. Some oil majors only deal with the technical operator of the ship while others are also interested to know the identity of the real ship owner - being a bank, a person, or a company. Collaboration between oil companies on vetting is restricted to information platforms among some selected companies, but also in these platforms, the amount of shared information is restricted. Vetting information is mainly shared between the specific ship operator and oil company. This exchange of information seems, however, to function well considering that both parties depend on it. Class information is not shared among the oil majors. Some exchange of information between oil companies and classification companies such as DNV GL and Lloyd's also take place, and the oil companies also collaborate with several 3rd party inspection companies operating around the world.

Initial code 4: Tools used to manage information flow

Ship operator / owner

Ship owners report the use of many different internal control systems to manage the information flow when an inspection of a vessel is performed. The reported tools include RightShip, Equasis, Infospectrum, Dun Bradstreet, Credit Risk Monitor, Dow Jones, Power BI, Tradewinds, BIMCO, Social Text, GARD, Official Company Registers, Operator Editor, Particular Editor, Oceanfile, Excel, Oracle Cloud, Google and Q88. Many of the ship operators also use Q88 when communicating with oil companies. A report is made during the inspection and observations made by the inspectors are noted in this report.

Oil major / charterer

The oil companies also use a variety of different tools to manage the flow of information.

Initial code 5: Satisfaction with the vetting process

Ship operator / owner

The general impression is that the ship owners are relatively happy with today's vetting process. They share the view that the situation has improved dramatically in the last years. It is considered a good thing that they can decide themselves which oil major will inspect their ships.

Oil major / charterer

The oil companies are delighted with the activity of OCIMF, and some also with their local platform involving some selected companies. These platforms are considered important fora to suggest and implement new ideas.

Initial code 6: Challenges with the vetting process

Ship operator / owner

Some of the ship owners state that the main challenges with the vetting process are related to some of the individual inspectors - more than with the system itself. The personal opinion of some of the inspectors is sometimes considered to be problematic. One challenge is that part of the information such as ownership and fleet size, may not always be consistent on the different platforms. Another raised issue is related to the so-called Condition of Class (CC). A CC of a ship may lead to rejection of the ship independent of the cause for the CC. Although the cause underlying the CC is repaired, and the classification company states that it is now without consequence, some of the oil majors may still use a seemingly irrelevant CC as the reason for rejecting a vessel.

Oil major / charterer

Language barriers are mentioned as a challenge in the vetting process. Questions regarding system security and login procedures are also considered challenging, as well as the interfaces between external and internal information systems. Being a global type of business, challenges are related to frequent changes in different parts of the world. This also relates to the involvement of several co-workers with different backgrounds. It is reported as a challenge to obtain the necessary information from new players and partners. The classification processes and especially the technology for the transfer of class documentation should be updated with new technology to replace the manual exchange via email.

Initial code 7: Time, cost and resource consumption

Ship operator / owner

Loss of shipment is viewed as the worst case, and the most resource consuming event. It is also considered time-consuming to obtain and collect all the relevant and updated information needed. Some of the ship owners are not satisfied with their managing tools for the inspection data and find it time-consuming - for instance, the use of e-mail to transfer information. Excel is still reported in use to store information instead of databases. It is also reported as time-consuming to prepare the crew for the inspections and make them understand the importance of keeping the ship in the best possible shape. A bad inspection may take the vessel out of work rotation for 3-12 months which may have a severe impact on the company.

OCIMF has determined that there should be at least 30 days between inspections. It may, therefore, take some time before the effect of a bad inspection can be eliminated. This is considered demotivating by some of the ship owners. An inspection is estimated to cost NOK 50,000, including travel and living allowance for the inspectors - this may differ depending on where in the world the inspection will be carried out. The inspection is paid by the ship owner/operator, although organized and carried out by the charterer. One ship operator reports, however, that the oil major covers most of the inspection cost. The ordering of an inspection may take around

2 hours, and then the ship operator must prepare themselves for the inspection. Such preparation may include the collection of information on the specific inspector working with OCIMF and an overview of the inspector's previous reports. These preparations are considered time-consuming.

Oil major / charterer

There is always room for improved IT solutions, but the inspections and communication with the ship operator and the inspection companies are considered the most time and resource consuming. It is also pointed out that the time and resources spent vary immensely from ship to ship. Part of the communication may involve OCIMF-arranged physical visits to operators to get information on the performance of each operator. It is also stated that experience on behalf of the vetting manager is important for the time and resources needed. Some of the companies tend to stick to the same ship operators which may also reduce the time and resources used for vetting. With increased competition in the market, they may have to approach other operators which may increase spent time and resources.

Initial code 8: Improvement of the vetting procedure

Ship operator / owner

Several ship operators state the importance of that the oil majors over recent years have agreed to accept the use of each other's SIRE reports. This has reduced the number of inspections that were needed only a few years ago, and resulted in an important overall improvement of the vetting process efficiency. Much work has been performed by different ship operators to improve their systems for data management. The ship owners consider that further improvements could include easier ways to gather information, perform trend and statistical analysis, and get access to information. Tools to extract, read, and analyze information is also mentioned. It would have been a great improvement to have only one platform where all information related to vetting could be downloaded and managed. It is suggested that this could be organized within OCIMF. It is also stated as a great improvement if the ordering of vetting inspections from the different oil majors could be standardized. The ordering of a CDI is considered easy, and it is wished that it could be as easy to order a SIRE inspection. Today some oil companies have simple procedures for ordering an inspection while others are considered more complex and time-consuming.

Oil major / charterer

One important improvement suggested by the oil companies is an efficient system to track the complete ownership of the different vessels. A ship may have several owner types, and these may not always be easy to identify. Also, an improved system to replace e-mail for the obtaining of class documents is reported as beneficial by the oil companies. Direct access to vessel data in the classification society, such as the vessel Class Status Report, is suggested. In general, more efficient platforms for the managing of digital information are requested. The reliability of the obtained information is also focused on by one oil major. It is stated that there are many examples of shared data not being trustworthy. Thus, a technology that secures the trustworthiness of the shared data was considered an important improvement.

Initial code 9: Implementation of blockchain technology

Ship operator / owner

The majority of the ship owners has not considered the use of blockchain technology in the vetting process because of the many differently involved market players. They consider themselves not having enough influence in the market to initiate such a process. Still, many expresses that they realize the need for new technology and that they are in the process of considering new tools for information extraction and analysis of the inspections as well as trend data. The importance of the data and that information is continuously updated and available is underlined as an important factor for improved efficiency and security. Security related to vessel ownership, insurance and processes related to bill of lading is suggested as relevant for blockchain technology implementation.

Oil major / charterer

As for the ship owners, the interest for new technology, including blockchain, is present, but little concrete has been done so far.

5.4.4 Themes

The topics of the nine initial codes were then summarized into three themes:

1. Status of the vetting process, from Initial codes 1-4.
2. Satisfaction and challenges in the vetting process, from Initial codes 5-7.
3. New technology and future expectations, from Initial codes 8-9.

This condensing of the information from the interviews into three themes will summarize and focus on the most essential information related to the main objective of the study - Will the implementation of blockchain technology in the management of vetting processes reduce the number of necessary vetting inspections? The emerging information in the three themes will then be applied to the framework flow chart by Lo et al. [6] described in Chapter 3.2.3 and Figure 3.3.

Theme 1: Status of the vetting process

Vetting inspections typically takes place 2-6 times per year on each ship depending on the two inspection regimes - SIRE and CDI. SIRE is organized through OCIMF, a non-profit organization run by 112 oil companies. A severe challenge used to be that the lack of a trusted third party resulted in inspections being performed on top of each other. The interviews show, however, that the recently acquired trust in OCIMF and standardization of inspections have resulted in a mutual acceptance of these inspections among oil companies. Vetting is related to both ship and crew, and both ship owners and oil companies put much effort into the vetting process. Larger oil companies have vetting departments to help the company decide whether to charter a vessel or not. The reports from OCIMF are supplied by data from their own information platforms. No oil company is willing to charter a vessel before a vetting process has been performed. The ship owner starts the vetting process by obtaining an update on the ship's information, the VIQ, and uploads this to OCIMF. They then order an inspection from an oil major. The inspection takes place at sea or in port and lasts for 6 to 12 hours. The operator receives information about observations reported by the inspector and must comment to OCIMF within 14 days. Larger oil companies collect data from many sources for the decision of whether to charter the vessel or not. This includes classification companies and 3rd party inspection companies. Such information is not shared between the oil companies. The SIRE vetting reports can be downloaded from OCIMF by all members. Oil majors are also interested to learn the identity of the real ship owner. Class information is not shared among the oil majors. The ship owners and oil companies use a large number of different internal control systems to manage the vetting information flow.

Theme 2: Satisfaction and challenges in the vetting process

Ship owners/operators and oil majors/companies are generally happy with the situation in today's vetting process. They share the opinion that the situation is very much improved compared to 10-20 years ago. The oil companies are especially satisfied with OCIMF and some also with their internal platforms used for information management. Some ship operators point to challenges with some of the individual inspectors more than with the system itself. Another problem is that part of the information obtained from different platforms may not always be consistent, and that class observation may be treated in unexpected ways by the charterers. Language and cultural barriers in a global business ecosystem, system security, and login procedures, as well as interfaces between external and internal information systems, are also considered challenging. This also holds for the transfer of class documentation. The loss of a shipment contract is considered the worst case, and the collection of all relevant and updated information needed is the most time-consuming. Many of the ship operators are not satisfied with their systems for information management and preparation for inspections. It is considered demotivating by some of the ship owners that OCIMF has set a 30 days limit between inspections since it may take some time before a bad inspection can be eliminated. An inspection costs about NOK 50,000 and is generally paid for by the ship owner/operator. Inspections and communication with the ship operator and the inspection companies are the most time and resource consuming for the oil majors. Some of the oil companies tend to keep the same ship operator to save time and resources on vetting. During periods of increased market activity, they may have to approach other operators and thereby obtain increased cost, use of time, and resources.

Theme 3: New technology and future expectations

The oil majors have in recent years agreed to accept SIRE reports organized by OCIMF, including the reports from inspections performed by other oil majors. This has resulted in a drastic reduction in the number of inspections compared to what was needed only a few years ago - resulting in an overall improvement of the vetting process efficiency. For both ship operators and oil majors, the collection and managing of data and information related to the vetting process are time and resource consuming. Further improvements could include more straightforward ways to collect and extract data, perform trends, and do statistical analysis. A vast improvement would be if the ordering of vetting inspections from the different oil majors could be standardized, and if there was only one platform where all information related to vetting could be downloaded and managed. It is suggested that this could, for instance, be organized within OCIMF.

The oil companies would like to have a better and more efficient system to track the ownership of the different vessels as well as an improved system to replace e-mail for the transfer of class documents. In general, more efficient and reliable platforms for the sharing and managing of trustworthy digital information is warranted. Both operators and oil majors express interest in new technology, and what it may contribute to in the vetting process. Some are also well acquainted with the potential of blockchain technology. Security related to vessel ownership, insurance, and procedures related to bill of lading and class documentation is suggested as relevant for blockchain technology.

5.4.5 Analysis and Discussion of the Interview Data

The principal intention of the case study in this master's thesis was to interview parties involved in the vetting process to investigate if the implementation of blockchain technology could reduce the number of unnecessary vetting inspections.

Blockchains are primarily useful in networks of untrusted participants and may be appropriate for some use cases while others would be better off with conventional technologies. Since the technology is relatively new, it is difficult to determine the potential of blockchain for a certain purpose. As described in the method section, Lo et al. [6] have developed an evaluation framework with criteria to be considered in a suitability assessment of blockchain technology for different industrial purposes. The framework includes the answering to seven main questions, as illustrated in Figure 3.3 in the Methods Chapter 2.

When considering the condensed information from the interviews as they are formulated in the three themes, the answers to the seven questions are as follows:

1. Are multiple parties involved?

   The answer is YES. There are many parties involved in the vetting process.

2. Is a trusted authority necessary?

   The answer is NO and YES. In principle, there is no obligatory need for a trustworthy authority to manage the vetting inspections, although such an authority may cause the charterers to trust the results of other inspections than the ones performed by themselves. In this case, a trustworthy authority within the vetting process already exists, namely OCIMF. The background material available during the planning of the master's case study suggested that OCIMF did not live up to its intention and that there was no trust among the charterers of the inspections that were not performed by themselves. This mistrust led to a lot of wasted resources and almost identical inspections being performed by the charterers. Information from the interviews suggests that this has changed over the last decade or so and that the increased trust in the OCIMF managed SIRE inspection reports has led to a reduction in the number of inspections.

   This is a new and exciting finding from the interviews but does not in itself affect the evaluation of whether blockchain technology is suited for implementation in the vetting ecosystem. On the other hand, the finding of a reduced number of inspections will affect the decision of whether blockchain should be implemented, since there already may be a trusted authority, OCIMF, that is performing the task needed to accomplish a reduced number of inspections.

3. Is the application centralized?

The answer is NO. The work is taking place in different companies.

4. Is transparency required?

   The answer is YES and NO. Transparency is warranted for some of the information, while other data and information should not be open to others than the information owner.

5. Is there a need for integrity in the transaction history?

   The answer is YES. There is a need to have the opportunity to go back and verify the transaction history.

6. Is data immutability important?

   The answer is YES. Significant values are at stake, and it is vital that the information and data are secure, that they cannot be tampered with, and that it is the correct version that is available.

7. Is high performance required?

   The answer is NO. This a question on a relative scale, but it is clear that the transaction rate in the vetting system is on a low scale.

Since the answers to question 2 and 4 are YES or NO, it is necessary to answer two follow up questions:
Is trusted authority decentralizable?
The answer is YES. There is no reason that the task of OCIMF cannot be decentralized.
Can data be shared with encryption?
The answer is YES.
The entry of the answers to the seven plus two questions may then be entered into the flow chart, and the result of this is shown in Figure 5.10.

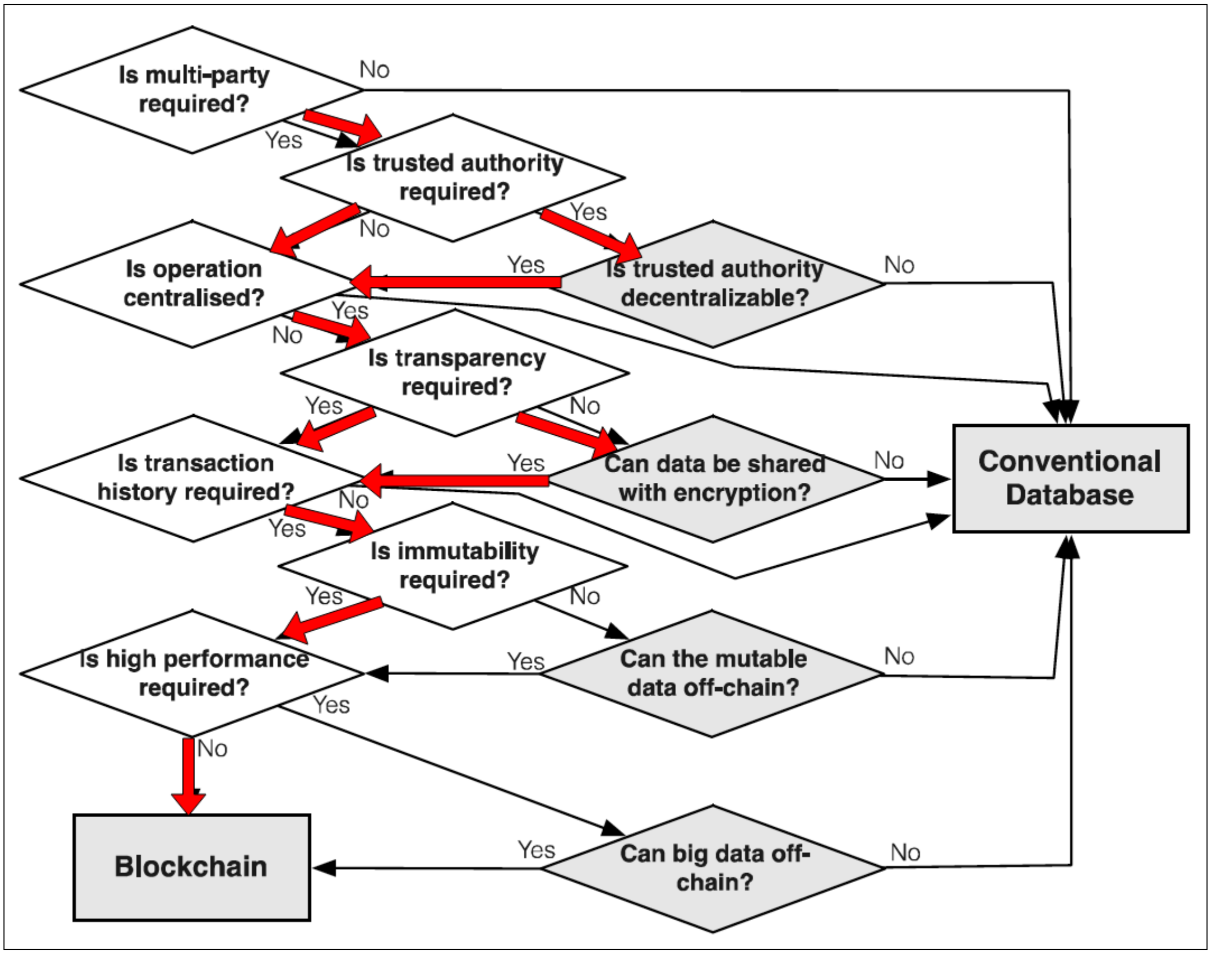

Figure 5.10. Entry answers for vetting use case. Modified from Lo et al. [6].

The results suggest that according to the Lo et al. [6] flow chart framework, the blockchain technology can be implemented into the managing system for the vetting process. This does, on the other hand, not imply unambiguously that blockchain should be applied for reducing the number of vetting inspections, as was the research goal of the case study. As appears from the interviews, the situation has changed over the last years, and OCIMF has lived up to its intention as a trusted central party that is accepted by the other involved stakeholders. It should, therefore, be carefully considered if it would be worthwhile at present to initiate work to implement blockchain.

In this consideration, it should also be paid attention to other requests and wishes that appeared from the interview exercise. This evaluation is, however, outside the scope of this work but is briefly described in the recommendations for further work. If the result of such consideration is that the present processes of the vetting ecosystem is acceptable, and not worth the effort of blockchain implementation, it is still an essential and useful information to have that if the situation changes, and the present trust disappears, then the implementation of a blockchain based platform is a possible option.

Chapter 6

Discussion

Two research questions are presented in the introduction of this master's thesis. They focus on the advantages and challenges of introducing blockchain technology in the shipping business area, and the description of methods that could be used to make the right decision on whether or not to implement blockchain technology.

Blockchain technology has had a tremendous boost in interest since it was first presented in 2008. However, although several applications have been suggested, and even initiated, the use of the technology is still in its early stages, which makes it difficult to find examples and methods that allow a quantitative assessment of the cost and benefit of its use.

Therefore, the conclusions in this thesis are based on results from the literature, and the interviews performed as part of the case study, analyzed on a qualitative scale. It was also found useful to describe the principles underlying what is considered good research, and to shed light on what should be regarded as particularly important in order to obtain reliable conclusions in a field where little work has previously been conducted.

The number of available literature sources dealing with the properties and usefulness of blockchains has dramatically and exponentially increased over the last few years. This information comes in many forms with differential clarity and credibility. The author, therefore, decided that the primary papers from the literature search should be solely peer-reviewed journals. After realizing that quite a lot of interesting information on blockchain technology were also found in other sources, it was decided that if such sources were found to be referenced to in peer reviewed literature, they could also be included - given that they provided relevant information not found elsewhere.

The first part of the thesis is a reflection on various topics on the concept of blockchain technology and its various advantages and challenges. This is a complex area since the technology has been suggested to be implemented in a large variety of different activities. It was not attempted to cover the comprehensiveness of this, but to focus on areas of and in the vicinity of the specifics stated in the research question, 'in maritime supply chains within the shipping ecosystem.' This has from time to time been frustrating, since many of the suggested areas and applications, outside marine activities, has also been very interesting and fascinating.

Blockchain has for many years been synonymous with Bitcoin and other cryptocurrencies related to financial speculation. Over the last years, a substantial number of reports has appeared on projects implementing blockchain in other business areas that the financial industry.

A blockchain may be considered as a chain of time-stamped data that cannot be altered, only appended, which creates the basis for peer-to-peer networks where non-trusting members can interact without the need for a trust-securing authority or intermediary. These blockchain networks could be public, private, or consortium based - sharing the concepts but differing in accessibility and validation procedures.

Internet as we know it was created to move copies of information between users, while in blockchains, the values represented by the transactions are recorded in a shared ledger - secured by verifiable and time-stamped records of the transactions.

This will provide a secure and auditable transfer of information and values through a verification process consistent with consensus rules agreed upon by the members of the network - removing the basis for disagreement since the verified transactions are accessible to the network participants through the distributed ledgers.

Many companies in a variety of sectors are welcoming blockchain technology and its potential to solve real-life challenges. An important issue is, however, lack of understanding of what is required of the specific use case for the implementation of the technology to be beneficial. The introduction of new technology is resource demanding, so being the case for blockchain. To establish such decisions, technical frameworks are needed, and such frameworks are often application specific. If they exist, they can, however, be used to decide whether blockchain technology could be implemented within the specific application, or not. It is still in the early days of framework development for blockchains, but their existence is crucial for businesses to make decisions on the implementation of the technology.

Modern supply chains manage complex processes involving partners of different nationalities, cultures, history, traditions, and regulatory policies who compete to provide the best possible service to their customers. Such supply chains may be poorly performing due to inefficient transactions, fraud, and low trust among business partners - leading to low efficiency and increased costs for those involved.

Blockchain technology has been suggested as a possibly disruptive technology in supply chain management based on decentralized databases for direct and disintermediated transactions between global network partners.

Some recent use cases exemplify these suggestions, such as the TradeLens initiative involving Maersk and IBM and the maritime container management system using blockchain technology. It is too early to conclude on the success or failure of the TradeLens initiative - although the project has been suggested to result in tremendous cost savings through more accurate and trustworthy container bills of lading. Several uncertainties do however remain, for instance, whether a full-scale implementation is possible. This is to be experienced in the years to come.

The main topic of this thesis was to evaluate the potential use of blockchain technology in supply chains and for vetting inspections. Methods or models used as standards to evaluate the performance of supply chains in a cost-benefit perspective are therefore essential. Several models have been used to analyze the efficiency of supply chains. They all have in common that they are general models which later have been updated to serve specific analytic purposes. Two frequently used methods for supply chain evaluation are the TAM and the SCOR models. These models have been updated for many different purposes - but since the interest in the use of blockchain technology in supply chains is relatively new, none of the models have been updated to analyze blockchain-related processes. The author of this paper considers it outside his possibilities to do this as part of this thesis, but hopefully, the models will also be updated for blockchain implementation in supply chains within near future.

The experimental case focused on investigating the opinions from stakeholders in the vetting ecosystem, including knowledge, interest, and perceived belief in the future implementation of new technology such as blockchain in the vetting ecosystem.

As an alternative to non-existing methodologies for quantitative cost-benefit analysis, the author describes published frameworks to be used in decision making of whether to implement blockchain in supply chains or not. It is still in the early days of development for such frameworks, but they are crucial for business decision makers. As of today, these frameworks are limited to scientific literature. Lo et al. [6] published in 2017 a decision-based framework aiming to help a variety of different businesses to assess the suitability of blockchain-enabled applications. The framework describes a process based on answering seven main questions. The answers may again lead to sub-questions. Wüst and Gervais [7] reported on ways to analyze the advantages of different blockchain architectures and offer a framework to identify the suitability of different blockchain platforms.

Although the potential use of blockchain technology has created excitement in many sectors, caution has also been raised about the optimism - underlining that the benefit of the technology must be carefully evaluated in each project before implementation. The technology may be appropriate for some use cases while others may be better off with conventional technologies and traditional databases.

If there is no need for data to be stored, blockchain technology will not provide additional advantages to established technical solutions. With only one writer within a system, a blockchain will not be better than a regular database. Blockchain may, however, be suitable for transactions between trustless sources and when a historical record should be preserved unchanged. Challenges concerning privacy and confidentiality are still considered an issue in public blockchains.

It is important to realize that databases by nature are mutable and entirely dependent on entities that have the authority to add or update the data. The consensus mechanisms in blockchain networks offer multiple writers the ability to modify the database following an authoritative transaction log to which all participants have agreed and have been defined in a consensus protocol. Casino et al. [5] have highlighted the requirements and presented a framework for the evaluation of blockchain-based suitability solutions on a three-level scale: low, medium and high; and the comparison of the property of blockchain with traditional databases in four areas: 'required trust assumptions', 'context requirements', 'performance characteristics' and 'required consensus mechanisms'.

Thus, at least three frameworks are available in the scientific literature as tools for the evaluation of whether a system will benefit from blockchain or not.

Many players are involved in the important topic of marine safety, both concerning mandatory and optional activity. The mandatory inspections are performed according to requirements of port state control regimes and flag state legislation. A classification society may perform the mandatory inspection on behalf of a flag state - the purpose being to provide the ship with necessary certificates for international trade and operations.

Most non-mandatory inspections are carried out on behalf of the cargo owners, so-called vetting inspections. Vetting inspections are performed on most tankers ranging from oil, chemical and gas/liquid tankers as well as combination carriers, ro-ro vessels, bulk carriers, and container vessels.

The many different inspection types and demands for reduced time in ports may cause confusion and fatigue related to onboard operations - which in turn may decrease the positive effect of the inspections. The important question is, therefore, to improve the functionality of the overall safety regimes, and secure that port state control and other inspection types can be used the most efficiently and sustainable to eliminate substandard ships. It could also open for better collaboration between regulators and companies - removing some of the political barriers in the shipping industry.

To evaluate this, it was decided to interview relevant stakeholders within the ecosystem of vetting to locate pain points and identify common denominators among the participants.

All participants accepted that the interviews were recorded. The recordings were helpful to recapitulate the content, and the transcripts are enclosed in Appendix 1. The interviews aimed to evaluate the possibilities of reducing the number of necessary inspections - possibly through the implementation of blockchain technology.

Considering that many of the interview objects did not want their name, nor the name of the company linked to the expressed opinions, it was decided to keep the interviews anonymous, and to only state the type of business they represented. Sensitive information that potentially could lead to identifying the specific interview objects were deleted in the transcripts. Altogether, representatives of 14 businesses were interviewed, nine ship owners/operators and six charterers/oil majors.

Analysis of the data was performed according to Braun and Clark's [12] 'General Inductive Approach for Analysing Qualitative Evaluation Data' where the first step was to become familiar with the information from the interviews. This was done by listening to the recorded interviews and transcribe what was said as accurately as possible. The answers were then categorized into nine "initial code" questions, separately for operators and charterers. This step was useful to get a full picture of the different pieces of information from the interviews. Next, the data was condensed into three themes, which were experienced as a useful way to summarize the information and prepare for the final analysis in the decision framework. This step consisted of answering seven questions with YES/NO and enter the answers into the framework flowsheet. The final result from the data suggested that the implementation of blockchain technology in the vetting ecosystem could be beneficial.

It is, however, important to distinguish between whether the technology could be used, and whether it should be used. One important and unexpected finding from the interviews was that the stakeholders were far more satisfied with the present status of the management of vetting inspections than what was expected from published reports that formed the basis for the present case study. It seemed that the number of vetting inspections had been reduced over the last one or two decades and that this in part resulted from OCIMF living up to its intention as a trusted central party accepted by the involved participants.

It is in this context important to realize that in very few if any, cases should only one study be considered sufficient to provide a final conclusion to a research question, not the least if the result is unexpected. This reflects the view that finding the truth through research is done by the laying of stone by stone - and not by putting all eggs in one basket. This does, on the other hand, not imply that the author does not believe in the results concluded on from the present interviews. The general impression from the interviews was that the views expressed were consistent.

It should be carefully considered whether it is worthwhile at present to implement blockchain technology in the managing system for vetting inspections based solely on the intention of reducing the number of inspections. In such consideration it should also be paid attention to other requests and wishes expressed in the interviews - such as an integrated system to collect, prepare and manage the many types of data and information necessary in the vetting process. This evaluation is, however, outside the scope of this thesis but is briefly described in the recommendations for further work.

If the final decision will be that the existing management systems of the vetting process is acceptable as it is, it is still important and useful to know that if the situation changes, and for instance trust disappears, the implementation of a blockchain based platform could be considered an option.

Chapter 7

Conclusion and Further Work

7.1 Conclusion

The goal of the present master's thesis was to provide reliable information on the properties of blockchain technology and its usability with focus on shipping. The research strategy was to combine literature search for relevant scientific information with a case study and was expressed in the two research questions:

1. *What are the potential advantages and challenges of the implementation of blockchain technology in shipping supply chains?*
2. *Which methodologies exist to provide decision support for the use of blockchain technology?*

To answer the first research question, a systematic search and mapping of relevant peer-reviewed literature were performed. This resulted in a total of 92 peer-reviewed primary papers. It could be concluded that there is an exponential increase over recent years in the number of peer-reviewed publications on blockchain technology in different business and scientific areas. The different advantages and challenges of blockchains have been described with focus on its usability in shipping supply chains.

The conclusion to the first research question is that blockchains represent a complex technology with many interesting and advantageous properties but also several severe challenges. The complex picture is probably central to the tremendous interest that the technology has created.

Concerning the second research question, it is clear that being new and complex, the technology is immature when it comes to applications. Few applications have been in use long enough to be able to conclude on their benefit, and few models for the analysis of applications such as in supply chains have been updated to allow a quantitative analysis of its applicability. Some frameworks are, however, available in the scientific literature and can be used to perform a qualitative analysis to assist in decision making. Such a framework was used to analyze data from the case interviews related to vetting inspections. The conclusion from the case study was that blockchain technology is applicable for vetting information management, but that a thorough cost-benefit analysis should be performed before the implementation.

7.2 Further Work

There are many reasons to assume that the blockchain technology will be an important part of data and information management systems of supply chains in the not very far future. One reason to assume this is the exponential growth of published literature on blockchain properties and the many suggested and initiated applications, in particular, some of the applications launched by important players - such as the TradeLens system by IBM and Maersk for the managing of container supply chains.

This thesis has shown that the potential for the use of blockchain in supply chains is large, but that analysis tools for the implementation are few or lacking. Being a complex technology with several challenges, it is important that these questions, in addition to the development of analysis tools, are dealt with by the scientific community.

The case interview study gave several interesting conclusions, including: 1) Blockchain technology is applicable for the managing of information and data in the vetting ecosystem, 2) The stakeholders are more satisfied than expected with how the vetting inspections are organized, and 3) Several stakeholders have a strong wish for a more integrated management system where all data and information needed for the vetting process can be collected, analyzed and managed.

Concerning conclusion 3), there is a good reason to believe that such an integrated system for vetting could be an interesting topic and that this could be a system where blockchain would be a central part. However, that is for future work.

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Appendix A

List of Acronyms

AI Artificial Intelligence

API Application Programming Interface

APICS American Production and Inventory Control Society

APICS SCC APICS Supply-Chain Council

BOL Bill Of Lading

BTF Byzantine Fault Tolerance

CAP Condition assessment Program

CAS Condition Assessment Scheme

CDI Chemical Distribution Institute

COA Contracts Of Affreightment

DLT Distributed Ledger Technology

EHR Electronic Health Records

ESP Enhanced Survey Program

EU European Union

GISIS Global Integrated Ship Information System

GPS Global Positions System

HACCP Hazard Analysis and Critical Control Points

ICO Initial Coin Offering

ICT Information and Communications Technology

ILO International Labour Organization

IMO International Maritime Organization

INTERTANKO International Association of Independent Tanker Owners

IoT Internet of Things

IT Information Technology

LNG Liquefied Natural Gas

LPG Liquefied Petroleum Gas

MARPOL International Convention for the Prevention of Pollution from Ships

MoU Memorandum of Understanding

MTIS Marine Terminal Information System

NTNU Norwegian University of Science and Technology

OCIMF Oil Companies International Marine Forum

OPA 90 Oil Pollution Act 90

OVID Offshore Vessel Inspection Database

PBFT Practical Byzantine Fault Tolerance

PEOU Perceived ease-of-use

PoW Proof-of-Work

PoS Proof-of-Stake

PU Perceived Usefulnes

RFID Radio Frequency IDentification

ROVIQ Reorganised Vessel Inspection Questionnaire

TC Time Charter

SCC Supply-Chain Council

SCM Supply Chain Management

SCOR Supply Chain operations Reference

SIRE Ship Inspection Report Programme

SOLAS International Convention for the Safety of Life at Sea

SVIS Ship Vetting Information System

STC Said to Contain

TAM Technology Acceptance Model

TMSA Tanker Management Self Assessment

TRA Theories of Reasoned Action

tsp transactions per second

UN United Nations

UTAUT Unified Theory of Acceptance and Use of Technology

VIQ Vessel Particular Questionnaire

VC Vetting and Clearance

Appendix B

Additional Information

B.1 Interview Guideline

Appendix
Interview Guideline

Prior to the interview, it was asked if it was ok to record the conversation. The respondent was informed that he/she could deny the recording, but still move forward with the interview. It was explained that the recordings would only be used as support when writing the report, and then deleted. It was also informed about the possibility that the company name and the name of the respondent could, if required, be omitted from the report.

An introduction to the project and its research questions was given together with a short presentation of the author. Following the introduction, the respondent was given the opportunity to ask questions before the interview started.

The interview questions as well as their order had been prepared prior to the interview. Considering that the methodology used in the interview process is semi-structured, the questions could be changed, and new questions added, depending on the situation and the background of the respondent.

The aim of the interview is to identify perceived pain points in the ecosystem of vetting.

Interview Questions

1) What is your organization's role in vetting?
2) How is your organization involved in the vetting information flow?
3) Who are your collaborators in the process of vetting?
4) What tools do you use to manage the information flow in vetting?
5) How satisfied are you with your vetting process, and what are the main challenges?
6) What part of the vetting process do you find the most time-, cost- and resource consuming?
7) What would be the most important improvement in today's vetting procedure?
8) Have you considered the implementation of blockchain technology in vetting process?

B.2 Interview Transcripts

B.2.1 Company A

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Ship operator/owner

Interview Questions

1) What is your organization's role in vetting?

Charterers, ship operators. Inspections carried out on their ships.

2) How is your organization involved in the vetting information flow?

Get requests on our ships for vetting inspection. When it comes to the number of inspections carried out on our ships this was a concern 4 years ago - but not anymore. By law you cannot have more than one inspection every 30 days. Today a ship normally has an average of 3 vetting inspections per year.

3) Who are your collaborators in the process of vetting?

Oil majors.

4) What tools do you use to manage the information flow in vetting?

A similar software to Oceanfile. We also use Q88 for certificates, but Q88 is not usually for vetting itself.

5) How satisfied are you with your vetting process, and what are the main challenges?

Required to have 3 expedition each year. It is acceptable.

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

Main challengers: making sure that everything is up to speed, that everything goes easy. Preparation is the most time consuming. Not the inspection itself. Inspection cost is USD 4-6K. The expensive part is getting the person on-board the vessel using a helicopter on-board.

7) What would be the most important improvement in today's vetting procedure?

Biggest improvement: consistency with the vetting inspectors. Very individually different results. Consistency. 3 different inspectors give different results depending on the person and the type of day that person has. Can go either way. The most improving part would be that you manually have to look through the data which takes 2 hours every time. If this was to be collected from a database you would not need to use this amount of time. Sharing the information is a potential because you will not need the time used to carry out the checking of 2 hours if it is already there [inside a database].

8) Have you considered the implementation of blockchain technology in the vetting process?

No. Not sure it could be useful for the ship owner, but for charterer or oil major I believe it will.

B.2.2 Company B

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Ship operator/owner

Interview Questions

1) What is your organization's role in vetting?

[Stakeholder company] is vetting vessels, owners and charterers prior fixing. (We also have a due diligence process on Bunker Suppliers, Brokers, Agents, etc.)

2) How is your organization involved in the vetting information flow?

As an operator, we charter vessels in (and out) for single trips or longer period. Prior to the fixture we will perform our due diligence which contents the following:

- Jurisdiction where the counterparty is incorporated and operates, including, but not limited to sanction risk;
- Available financial information concerning the counterparty, i.e. credit risk;
- The counterparty's corporate structure and place in the value chain
- The counterparty's track record and reputation in the market, generally, and also in [Stakeholder company] prior or ongoing experience with the counterparty;
- The size of the transaction involved;
- [Stakeholder company] existing exposure to the counterpart and/or trade;
- Whether [Stakeholder company] is chartering the vessel from another ship owner or chartering the vessel to another entity
- The geographic areas involved in the trade, which is to say whether the vessel/cargo in question will be trading to ports considered to present a risk;
- Potential regulatory risks, e.g. sanction, competition, corruption and money laundering risks; and
- Potential ethical risks, e.g. political, and supply chain risks.
- The vessel condition: If any red flags are raised during the vessel check, next steps recommended steps can be one or all of the following:
  - – Ask Owners for latest set of statements of facts to check if the vessel performed as it should;
  - – Ask Owners for proof that deficiencies have been rectified (be critical/wary of the "proof"..)
  - – Check with last Charterers of the vessel how she performed/if they had any issues with the vessel
  - – Make sure to arrange for full on-hire survey

3) Who are your collaborators in the process of vetting?

Mainly the charter manager responsible for the fixture and the Counterpart Risk Team will assist. Externally we use Rightship and Equasis, along with surveyors.

4) What tools do you use to manage the information flow in vetting?

Rightship
Equasis
Infospectrum
Dun & Bradstreet
Credit Risk Monitor
Dow Jones
Power BI
Tradewinds
BIMCO
Social Text
GARD
Official Company Registers
Google

5) How satisfied are you with your vetting process, and what are the main challenges?

In my opinion, the biggest challenges are:
- Often only limited and/or dated information available
- Time consuming to collect sufficient info and store it
- The information is not always consistent on the different platforms (ownership structure, date of registry, fleet size, etc)

[redacted]

- Rightship lost the contract with Paris MoU. That requires us to manually vet the vessel to obtain the latest info

Maybe not a huge challenge, but some charterers include wordings in the CP that they only accept 3-star rated vessels or better for their shipments.

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

Checking, saving docs and crosschecking info from all the different sources.

7) What would be the most important improvement in today's vetting procedure?

Have one platform where the search would be run through all our existing platforms and deliver a list of hits. That would save time of logging in to every source and run a search. Be able to download, share and store the relevant documentation in a tidy way.

8) Have you considered the implementation of blockchain technology in the vetting process?

Yes. If the vessel and company profile were updated and available at all times, there would be less clicking and emails externally and internally. The chartering managers wouldn't need to ask the Counterpart Risk Team for assistance on checking the vessel. They would also not need to go back and forth with the brokers, disponent owners, head owners, Rightship, etc to rectify outstanding deficiencies, exchange SoF, etc.

B.2.3 Company C

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Ship operator/owner

Interview Questions

1) What is your organization's role in vetting?

Vetting is our ticket to trade. It is something we need to do. We buy services from the oil majors who carry out the inspections on our ships. This is done through OCIMF and their inspectors. They rotate on the inspectors from each of the oil majors. Sometimes these can be Shell, BP, Total, Equinor, Repsol etc.

Earlier there used to be done several inspections on top of each other. This is not the case today. Today we have to start planning an inspection four months in advance in order to be able to be sure we do not exceed the limit of 6 months for a SIRE report. Often some oil majors look at the date of the inspection and not the content of it which makes this date very important.

2) How is your organization involved in the vetting information flow?

This is different from oil major to oil major. BP have their own portal where one can enter and order an inspection. Shell have their own sheet of paper where one can order through an Excel-sheet. This is done manually via email. ConocoPhillips, Equinor etc. uses a platform called SIS3. Repsol uses Q88. [Stakeholder company] uses our own internal scheme to see who uses what and sends the information needed from here.

[Stakeholder company] also uses CDI. This is only for LPG and not LNG. These reports are valid for 12 months. In these reports, we stand freer to choose inspectors etc. Chemical and LPG-tankers are here in focus.

A TMSA is also done in our offices to check what we are doing internally. This is only done with the oil majors only people and no externals.

3) Who are your collaborators in the process of vetting?

Only the oil major we are chartering for. This is based on our gut feeling and where in the world they are located but also depends on which contracts they have. An example would be that Shell could have an internal contract with us saying that Shell should be next oil major to carry out the next SIRE inspection. We try to use the larger oil majors such as Shell, BP, Total, Exxon etc. in a rotating manner. [Stakeholder company] does not use 3rd party vetting companies. This is something that the oil majors do. The vettings can therefore be carried out by the oil major themselves or using a 3rd party vetting company on behalf on that oil major. Total only carry out these inspections themselves. Fairbridge is such a 3rd party vetting company working with Shell. They then use Shell's vetting sheet to fill out the inspection. This report can only be accessed by the OCIMF members and costs about USD/GBP 40 to download and read. [Stakeholder company] does not do any vettings on their own ships. They do other regimes as internal audit which are statutory from the ISM-code. When we are on-board our own vessels, we also do internal inspections where we use the VIQ as a benchmark to do analysis and measurement.

4) What tools do you use to manage the information flow in vetting?

We use an internal control system which is used when we get an inspection on one of our vessels. A report is then made during the inspection. If we receive an observation we link it to this report. We then have 14 days to comment on the report.

5) How satisfied are you with your vetting process, and what are the main challenges?

It works ok. Our biggest challenge is that the person inspecting the vessel have opinions which differ from the legislation. The personal opinions could be problematic.

Another issue is related to Condition of Class. If we receive a CC on one of our vessels this could potentially lead to a rejection of the vessel independent on what the cause for the CC is. Even though [Stakeholder company] and class look at a CC as a good thing, many see it as a problem that this is pointed out. This could be a CC that is no problem if it is regularly checked and fixed when the vessel is docked in the future. The scary thing here is that some ship operators try to hold these issues hidden from the inspectors, causing this practise to fail because something that should be reported does not get reported. Many of the oil majors should look at a CC from a different angle and not reject a vessel only because it has a CC. This especially hold if we have class on our side (Lloyd's, DNV GL etc.).

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

The most resource consuming is if we lose a shipment. It will take a lot of time to regain the trust and this should not happen. If our vessel follows our procedures this should not happened. OCIMF states that there should be no less than 30 days between inspections in order for operators not being able to push a bad inspection back in line as well as putting less pressure on the crew when you pay someone a lot of money to point out what you are doing wrong. This can be very demotivating.

An inspection easily costs NOK 50 000. Shell, BP etc. uses subcontractors to avoid flying their own vetting inspectors around the world. They use a lot of money on this. They therefore use local inspectors. The total cost is still sent to [Stakeholder company] – everything from hotel, airplane ticket and access to the terminal (safety regime). [Stakeholder company] do prepare themselves in advance if they know the inspector coming on-board [have some record on him] to be able to know what he considers the most important aspects of the inspection. If an oil major like Shell are having an upcoming inspection, we usually send the previous inspection reports to our vessel in order to prepare. Ordering an inspection usually takes around 2 hours. Internal in our system we can search for the specific inspector working with OCIMF. We then get a total overview of the previous reports done by this inspector. We also use Q88 to order inspections. This will be done with Repsol as they use Q88. We then fill out that we need an inspection from Repsol in Q88 and we also add the inspections, results etc. into Q88. This is only time consuming when something goes wrong.

We do not know which part of the vetting process that is the most cost consuming, but we pay everything around USD 4-6K for each inspection, anyway. This is independent on the location of the inspection. [Stakeholder company] pays the oil major who then again pays the inspector. It does not say what the inspection consists of (hotel, travel etc.) - only that one inspection is to be carried out.

7) What would be the most important improvement in today's vetting procedure?

An easier way to gather information, do trends, do statistics, get access to information. This is to be able to predict the future and the tools for this. Extract information, read and analyse the information.

8) Have you considered the implementation of blockchain technology in the vetting process?

No. We do not stand free to choose this because there are so many market players. We have no influence in the market. We use tools such as Power BI trying to analyse the data better. To extract information from text is very hard (the inspections) and analysing this. We need references to make trends easier and I believe there will be a change to the system soon.

B.2.4 Company D

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Ship operator/owner

Interview Questions

1) What is your organization's role in vetting?

Today we have two types of vetting regimes. SIRE and CDI. The inspections for these are pretty similar, but there are some different principles/weightings. There are some rules for the ones who enter a vessel as an inspector. These have questionnaires with them. The person then inspects the vessel with the usage of this questionnaire and eventual observations.

[Stakeholder company] vessels are inspected approx. 3-4 times a year. There has been more order in the chaos in the past years after they used around 20 years to standardise the inspections. Before, the oil majors had their own instruction boxes. This was hard to relate to, but today only the SIRE and CDI reports are used. Today, these are very standardised, but how each oil major decides to evaluate the results from each report differs. They have different perspectives on what they consider important. The frequency of the SIRE inspections does vary some. Mostly, these are to be done every six months, but some are playing around with decreasing this to three months.

Often, if a vessel has a minor issue, such as a small injury in the hull which is seen as an observation, this can be enough to not approve the vessel for chartering – even though it is said that this is to be fixed during the next docking.

The vetting process is very important and is the ticket to trade. One vessel can be approved by some oil majors, but not by others because of their internal policy for clearance. How they decide to interpret the results are different even though the results in the same report are the same. [Stakeholder company] is not an opponent of such inspections – but at the same time it seems a bit off that each oil major values the same inspection differently. [redacted] If a vessel has an observation, it is not chosen either way – it does not matter about the content of the observation, just that it is an observation. [redacted] The vessels are voted down from their possibility to charter goods, and not voted upwards.

Criteria to be evaluated whether a ship is applicable of chartering goods are the vessels age, history, owner etc. If a ship operator has many observations on a vessel over a short amount of time an oil major can conclude that they will not use the specific ship operator's vessels for a longer period such as six months.

A CDI report should be no more that 12 months. A SIRE should be no more than 6 months. Sometimes one needs to have an inspection close to each other because of the deadline that must be reached in order to trade. A vessel is exposed to inspections regularly, but these are not only from vetting, but also from flag, port etc. Usually a CDI is done every 11 moths, while a SIRE inspection is done approx. every 3-4 months to make sure they are within the legal frames. We have an average of three inspections on each vessel yearly.

2) How is your organization involved in the vetting information flow?

The role of [Stakeholder company] starts approx. 3 moths ahead of the nomination of an inspection. When this nomination takes place, a lot of time is spent on prepping the vessel beforehand. We make sure there are no class observations etc. When then ship then enters a port, an inspector visits the vessel and spends everything from 6-12 hours on the inspection. During this time, he walks around the vessel and asks questions. Especially the SIRE inspection, the VIQ 7, have started to focus much more around the human aspects in the past – meaning the understanding from the crew. Both the SIRE and the CDI reports the inspector will submit a hand-written word-document on-board the vessel on comments what he inspected during the inspection. After a couple of days, SIRE of CDI sends out and official report on the specific vessel. [Stakeholder company] then has a period of 14 days to comment on this report before it is closed and saved within the database. Customers who uses these reports to vett their vessels, open the report in the database and reads the report to evaluate whether the vessel is approved for chartering their goods.

All ship operators have different tools to treat these findings. [Stakeholder company] uses Q88 as a tool. After the inspector has published the report, [Stakeholder company] logs into the database and uploads their comments on the report.

3) Who are your collaborators in the process of vetting?

Customers, oil majors.

4) What tools do you use to manage the information flow in vetting?

Q88. The reason why we use Q88 are because of the dynamic data. Q88 use their results to plan and one can also trace the name of the inspector. This is acceptable. We also use internal systems to treat these data for statistics and trends on our own vessel. One can also use Power BI for this.

We use a TMSA like many other operators to evaluate ourselves prior to an inspection. An oil major could then send a request for a TMSA where they visit our offices and observes the operations inside their offices for a period of 2-3 days inspecting their procedures internally. The results of these inspections can vary a lot from oil major to oil major. An example could be that one oil major was very please, but another was a bit more sceptical.

5) How satisfied are you with your vetting process, and what are the main challenges?

We are pretty happy with the inspections themselves. The inspectors from each oil major have different principles on how they decide whether a ship is good or not. This can be a bit frustrating. This is not on a personal level. In an inspection done through this VIQ one can as an example get five observations. How [Stakeholder company] answers to these inspections are of extreme importance to how they are interpreted in the report. Even though we get some observations, one can be able to answer these in a correct manner so that the ship will be seen as acceptable. An oil major can often focus on the number of observations instead of the content. This can sometimes seem meaningless. It is often the market that decides this. As an example, if one can choose between three vessels, and two of them have two observations and one has five, the last is easily removed. One can also choose to have a specific inspection with one inspector, but also decide not to if it is a specific inspector.

6) What part of the vetting process do you find the most time-, cost- and resource consuming?

A lot. That our ships welcome the inspectors in a good manner and preforms the inspection in a good way. What is resource consuming being to have the vessels up to date at all times. Making the crew on-board understand the importance of this also takes time and resources. This is extremely important that they understand and take seriously. If an oil major chooses not to use one of our vessels, this has a very negative effect on us – economically. The consequences are enormous and this happens. The constant work around this is very important and needs to be seen as a hygiene factor. It is rare that a vessel is not approved based on one specific inspection, but this can happen via mistakes. Then it is very resource demanding to get the vessel back on track as an approved vessel. This can sometimes seem odd because there is nothing wrong with the vessel itself, but it can be the crew on-board. Still, this is not accounted for – even though the crew is changing ship, it is the specific vessel and its name that gets the negative reputation. An example can be that we have 2-3 vessels each year that is not approved (2018). This is based on a fleet of 50-55 vessels (2018). When this happens, the vessel is taken out of rotation for a period of 3-12 months. That the whole fleet is blacklisted happens extremely rarely. It will then cost a lot of money and is extremely resource demanding and has not happened to [Stakeholder company] in recent times.

7) What would be the most important improvement in today's vetting procedure?

Vetting a vessel related to geographical challenges is not a problem. Getting hand of an inspector is not a problem. The process from getting the list of observation which are to be answered and map these can be a challenge. We in [Stakeholder company] ourselves believe we are ahead of other when it comes to KPI factors data wise. This is when it comes to the internal storage of data in our systems. We are now working on developing a more dedicated big data model to follow vessels and trends in a more complex way by running trends and statistics on each vessel. This way we can track each vessel and follow up what each one needs and how much. One can then more easily understand mistakes we make and their locations.

We do use a lot of time on processing data internally and develop systems for this. Everything from operational to crew data are used to map this. These data are gathered in their own database and used to map internal reports etc.

8) Have you considered the implementation of blockchain technology in the vetting

process?

No, not in vetting. Only together with bill of lading. 70% of the processes in shipping are still where we were 200 years ago. Securities related to ownership is very relevant for blockchain. These data are extremely important. Shipping has a long way to go here. I also believe that blockchain have a big potential within insurance and when it comes to information that needs to be stored on-board the ships themselves.

B.2.5 Company E

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Oil major/charterer

Interview Questions

1) What is your organization's role in vetting?

We have our own vetting department internally. This department goes through all the vessels that are to be screened and verified before the vessel is used. Further information on this can be found in SIS3 under [Stakeholder company].

[Vetting Manager]: The organizations role is for vetting of tankers. The process is a quality assurance process for tonnage intake. Our role is to recommend/not recommend the vessel for chartering.

2) How is your organization involved in the vetting information flow?

Each ship operator enters SIS3 and updates the information related to their fleet in the system. When we internally get a request for a vessel, we already have the main information from this database. If we need more information, we go back and ask for more information from the ship operator.

OCIMF consists of approx. 112 oil majors who together have standardised a questionnaire that the ship operators have to answer (length, width etc.). They have also conducted a questionnaire consisting of approx. 400 questions. OCIMF has a set of standardized inspectors who enters vessels for inspection. If an inspector from [redacted] inspects a ship, all the other oil majors must approve the report performed by this inspector. How they interpret these data are up to each of the oil majors inside OCIMF. Every oil major uses reports between each other. OCIMF follows up all the inspections and inspectors who continuously are improved to make sure everything is up-to-date and relevant from OCIMFs perspective.

When it comes to sharing information between oil majors, this is not done. The ship owner gains something because they can upload information to SIS3 and not to all 10 oil majors separately. There also exist a help desk where they can call for information. An important principle within SIS3 is that nobody makes money on this and that there is a cost sharing policy. This is important, such as it is in OCIMF. The main focus in SIS3 has been on shipping traffic.

The trend when it comes to information sharing is that it has become less and less sharing over the past years. Today we have arrived at the bottom where there is no sharing of information. This is on the legal side of it. What can be shared, is if a vessel is trusted into a terminal. To save time, it can be applicable to share this information to see which vessel that are able to enter the terminal. There exists a separate process from the vetting process looking into this focusing on loading and unloading. But this is different from the vetting process.

3) Who are your collaborators in the process of vetting?

The other oil majors and ship operators involved in SIS3. We only share information related to the vessels length, width and general basic information among the participants in the system. Information related to vetting is only shared among the specific ship operator and the specific oil major. Information from class is not shared among the oil majors. This could be a challenge for the ship operators because they can be asked to send the information back and forth between the different oil majors, but this is just the way it is. We get what we want and the ship operators are happy to provide us the information we need. Information is not shared among the participants in SIS3.

In order to be a member of SIS3, one would need to be similar to the existing members and have a relation to OCIMF. The ship operators upload the information they want on SIS3 so that this can be shared among the oil majors. [redacted]

Otherwise we use Lloyd's Intelligence as well as others. We also cooperate with between 8-10 3rd party inspection companies operating around the world. Naturally, we work closely with OCIMF and CITCO on the gas side. We also work closely with PSC and class. This depends from partner to partner in SIS3 who they cooperate with.

4) What tools do you use to manage the information flow in vetting?

We use SIS3 and the infrastructure on Oracle Cloud. Generally standard software.

5) How satisfied are you with your vetting process, and what are the main challenges?

One of our main challenges are related to language barriers such as Spanish and mandarin but also Portuguese. There are also challenges related to the vetting system and the oil major's internal system. We use traditional solutions with standard APIs to log in. We also continuously work with security where we use software's such as Cloudflare.

OCIMF is doing a great job.

Internally the involved in SIS3 have a lot of great ideas. We do use some time to slow down and evaluate whether the ideas should be implemented, but once they are implemented, every function is used.

Another main challenge is the continuous change within the business one will have to adapt to. A challenge within the SIS3 cooperation is that when one thing is happening in one part of the world (ex. South America), another thing happens another place. Generally, changes externally outside the organisations that we need to stay updated on.

[Vetting Manager]: We are happy with the systems that we use. A challenge is to synchronize the variety of co-workers. SIS3 is a good system when it comes to overview of what has been done, who did it and the status. The processes with class and sending of class documentation should be modernized with new technology do that it is no more done manually via email. It is not very time consuming, but it has a lot of potential.

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

Not much money is spent to develop IT solutions. Internally, the standard processes work ok. I assume that the largest consumption is when it comes to inspecting vessels and in terminals. We use a lot of time to follow up the ship operator. Not the vessels themselves, but the specific operator. OCIMF has a TMSA where one can enter each ship operator and have a physical visit at the operator. It is used a lot of time to map how each operator operates. This information is uploaded in SIS3 and we also have similar for operations of the same types as offshore activity being diving activity and checking equipment. This stay documented within the SIS3 system.

[Vetting Manager]: We have not scientifically documented this. Nothing specifically that I can think of here. Thing goes as they should and we get the information we need.

7) What would be the most important improvement in today's vetting procedure?

Being able to track the operator and who is responsible for the vessels in forms of ownership. As a rule of thumb every vessel has 6 owners (technical owner, beneficial owner, technical manger etc.). We are usually able to figure this out, but this takes a lot of time to figure out. Tracking the ownership structure would therefore be an important improvement.

We do not spend much time to process the data as we get what we need from the ship operators. Still, we have a feeling that the operators spend a lot of time on this.

We can use some time to get hold of class documents as this is done manually via email today.

[Vetting Manager]: We do not use a lot of time to gather and process data. We get this the old way from the ship operator. An algorithm might be able to make this more effective, but it has not been done anything academically to prove this.

We have our own inspectors internally and with other agencies around the world. Our internal inspector will have to go through a minimum of 6 inspections of a given type per year to maintain their competence as an inspector. This is seen as a cost to make sure that the inspector is up to date at each time and is practically done with optimization. Globally we have 6 contracts with land based agencies who have a total of 120 inspectors around the globe. These can do this in a short amount of time or we can do it ourselves. This is a process where the optimization aspect is used.

8) Have you considered the implementation of blockchain technology in the vetting process?

No, but we would still consider the usage of blockchain technology in the future.

B.2.6 Company F

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Oil major/charterer

Interview Questions

1) What is your organization's role in vetting?

The vetting department evaluates the risk associated with the use of a tanker offered for service to our Company and decides if a particular vessel is suitable for use or not. The assessment process is done by use of all relevant information available for that ship.

2) How is your organization involved in the vetting information flow?

The request for vetting a particular vessel comes from internal clients within our Company, through a dedicated system internet based. These clients are the chartering department, commercial department or regional offices around the globe. The request comes through the system, the analysis is done by the vetting analyst within the system and the answer is forwarded to the requestor via the system.

3) Who are your collaborators in the process of vetting?

We can say that any organization providing information about a vessel is a collaborator in the vetting process. These, among others, could be:

- The Technical Operator of the vessel;
- The Classification Society;
- The Oil Companies International Marine Forum - OCIMF - SIRE and TMSA programmes;
- Port State Controls and USCG;
- Other Oil Majors;
- Vetting Inspectors;
- Specialized sites such as Fairplay and Equasis.

4) What tools do you use to manage the information flow in vetting?

We use an electronic web based system developed by Equinor (Ex-Statoil) named Ship Information System - SIS.

5) How satisfied are you with your vetting process, and what are the main challenges?

We are quite satisfied with our vetting process.

6) What part of the vetting process do you find the most time-, cost- and resource consuming?

Communication with inspection companies, inspectors and vessel Technical Operators in the process of inspections scheduling.

7) What would be the most important improvement in today's vetting procedure?

Having direct access to vessel data in the Classification Society files, such as the vessel Class

Status Report.

8) Have you considered the implementation of blockchain technology in the vetting process?

No, we have not.

B.2.7 Company G

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Oil major/charterer

Interview Questions

1) What is your organization's role in vetting?

Our role is to vett customers in relation to performance of a ship.

2) How is your organization involved in the vetting information flow?

We check references on earlier charterers on a vessel. We check the history of the vessel, operation related to ship operators, whether they pay in time, check with ports or yards whether they have been in dry dock for the past six months. We also talk to broker and customer to check whether everything is OK. These are the possibilities we have.

3) Who are your collaborators in the process of vetting?

We use 3rd parties in cities like London. They also check references for us which are services vi we to pay for.

4) What tools do you use to manage the information flow in vetting?

Rightship, brokers and customers.

5) How satisfied are you with your vetting process, and what are the main challenges?

It can be hard to map new players and where they come from in terms of ownership and names. Especially when business is good new payers emerge. When business is bad, figuring out the needs and what payers are capable of paying for. As an example, we do not make any money if we spend two days on a job like this – which makes the business go away. Also, when using other 3rd party vetting actors, we lose some of the profit.

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

We usually do business with actors we know from before and have a good relation to. A problem here is that when business is good, new payers enter the market and disappear in bad times. Figuring out things around this is a never-ending story.

7) What would be the most important improvement in today's vetting procedure?

Being able to have a system where we would be able to check who owns what and finding correct information in one place would be absolutely fantastic.

8) Have you considered the implementation of blockchain technology in the vetting process?

[Stakeholder company] have looked at the technology in two areas. One: the distribution of bills of lading with banks and customers. We have tested this out in practice and it works. [redacted] Two: automatic booking in an ideal world to get confirmation. We believe that blockchain technology can be used in a variety of ways. We also see that there could be a potential for using the technology when it comes to vetting when it comes to owners, charterers etc. One could here use a track-record to avoid a 3rd party.

B.2.8 Company H

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Ship operator/owner

Interview Questions

1) What is your organization's role in vetting?

We have a small department working on vetting. With ships at the moment and some new ones coming up. I both order the vettings and join inspections, answer to observations etc. It is also the commercial side of it who gives an incentive that a ship needs to be vetted. My role is to make sure that the quality of the fleet is growing.

A vetting is done through OCIMF and their inspectors. We prepare ourselves ahead as well as the vessel to be inspected and are also present during the inspections. This is due to the importance of the inspections and to be able to have the ticket to trade which is the approved inspection.

[redacted] I have the role of observing what is going on at the inspections and how the crew reacts to the inspections which makes it much easier for me to the actual information from the inspection back to the office. That is why we are present at the inspections.

I personally believe in pre-inspections and that philosophy because I believe we can prepare ourselves better. I have sailed myself and became a captain. I travel a lot and these trips are hard to plan which makes it hard to plan the family life as well.

2) How is your organization involved in the vetting information flow?

We have weekly physical meetings internally between technical, commercial, the owner, chartering and operation. The rest is joined by via email. We discuss which ships that should be vetted for inspections, which has had inspections and how the previous inspections went.

3) Who are your collaborators in the process of vetting?

We cooperate with OCIMF through the TMSA where they come to inspect our routines at the office physically. We also cooperate with oil customers. In a couple of weeks, we have a TMSA coming up where they go full audit on out offices. In order to prepare ourselves for this we hire in consultants.

The commercial side of the organization uses Q88 which is more related to customers. Otherwise everything inside OCIMF is used. We also use XML-files which are sent between us and the vessels and uploading these to the OCIMF system. CDI works in the same way as this.

4) What tools do you use to manage the information flow in vetting?

We use Excel to be able to track each vessel and what status related to the vetting process they are currently in. Previous status, planning etc. We also use RighShip and OCIMF to see the status of vessels to be inspected and their status. In OCIMF we use Particular Editor. For CDI we use Operator Editor. The Particular Editor can be used on-board while the Operator Editor cannot. In Operator Editor one need to go into CDIs database, get the data out, work with it and then send the data back in. This is harder than it is in OCIMF. These are the two we use to hold the data for our vessels updated. Crew matrix is taken from each vessel by sending it to them and then let them fill it out. Q88 has this type of tool to be used for the crew matrix. Now I have started to take the data direct from a crew agency who has a great software who makes it possible to take the data directly into OCIMF.

5) How satisfied are you with your vetting process, and what are the main challenges?

The system itself is ok as it is in OCIMF. The most challenging part is to extract data to be able to make statistics from it. Today we have to do this manually by extracting it to Excel and do statistics from there which I am an opponent of. But everyone has their own Excel sheets. It would be much easier to take data directly from OCIMF and plug it into ex. Power BI to give statistical data in a presentable way. It is important to track data and see where the problem is. [redacted] A lot of the questions in the CDI systems gives us a NO in the system which is seen as an observation from the charterers perspective. We only use this on the SIRE inspections. OCIMF gives a certain statistic, but it is hard to use this tool. Therefore, we use our internal statistics because this is of high importance.

[Commercial]: On the commercial side, it is the exposure related to approval of the vessel. As long as the vessel is approved, we are happy. The transparency around this. In commercial we gain access to the vetting results and why we are not approved. But for a regular operator it is different. Let’s say we charter in a ship and he fails, it is very little transparency on why this vessel failed. An example is a case now were we are in conversations with an oil major, related to why the vessel was not approved. But it is still unclear why the vessel was not approved. RightShip, on the other hand went from having pretty good transparency (meaning we were able to have a long list of variables with each variable having a scale) where each variable indicating the meaning of each variable (one flag is concerned with this, and another with this). Then this is summed up to be one grade but we could not see the specific problems causing this grade. Today everything is going into a black box and nobody knows what is going on. You cannot take any proactive actions to meet these variables. It is not transparent anymore. As an operator such as we are, where we have a close dialogue between commercial and technical, we should be able to be proactive, but this is missed due to the non-transparent environment.

[Commercial]: We also have challenges related to cycle. Vetting is primarily set up to be used within tanking where you have a lot of shipments and cargoes. This means that if one oil major fails out, we have others to go to (If BP fails, we have Shell and Chevron to go to [redacted] Re-inspection has a very long time until the next inspection can be done and also a cycle up to 6 months which makes it impossible for us to optimize this. [redacted]

6) What part of the vetting process do you find the most time-, cost- and resource consuming?

When it comes to time, it is the sending of emails back and forth for an inspection. First it is an email that needs to be sent for a request, then we get an approval, then the contract is coming which is to be scanned, signed and sent back, who is going to pay etc. We therefore have to keep track of what has been done in this process ourselves which can cause a bit of a hassle to keep track of. This is done in Excel. If this is not structured, it is hard to keep track of each different vessel and so on.

Most of the costs related to the inspections are fixed considering it is the oil majors who are requesting the inspections. We take some of the cost which are around USD 5K and they take the rest. CDI is a bit different considering it is the inspector him/herself who is billing. Then it can be USD 10-12K. We also have to pay for our own inspectors who is traveling to the respective inspection where we have to pay the flight, hotel, traveling etc. which costs us around USD 5-7K. This means that it does cost a lot for this. It is still good that the oil majors pay for the rest of the inspection itself and that this ends up at around USD 5K. Righship is a bit different, but not that much. In the end, it sounds like a lot, but in the whole picture it is not that huge of a cost.

If there is coming new operators in the market we use time to find out what their specific requirements are. For the ones who are members of OCIMF this is ok, but for the others this can be hard considering we do not know their requirements in the SIRE-inspections. Often these go to businesses who go to OCIMF and ask them to screen the vessel for them.

[Commercial]: We are not that much included in this process. If a vessel is confirmed, we are happy.

7) What would be the most important improvement in today's vetting procedure?

Make us able to do everything inside OCIMF not needing to extract data back and forth to do statistics. Another problem is that every oil major has their own regimes. The INTERTANKO's Guide to the Vetting System is helpful but if one could be able to order and do everything through OCIMF's pages it would be much easier for us. What is hard by this is that every oil major has their own way of ordering an inspection such as Shell, Exxon etc. The questionnaires are the same, but they have different ways of ordering the inspections. The CDIs are ordered through CDI. Then they go out and fix this for us. It would be nice of SIRE would do the same.

What is written in the end of the book from INTERTANKO about each oil majors having a different inspection questionnaire is not the same today. It is more coordinated today so you do not have the same amounts of inspections as you had ten years ago when it could be one inspection every month. Before you were needed to have one inspection from each (Shell, Total, BP etc.), which is not the case today. Today they have each other reports of which they can use and this is usually ok so we do not need to have as much inspections as we had before. At the same time, every oil major's inspectors have their different areas they focus on. [redacted] But it has become a lot better recently considering the oil majors can look at each other inspections.

If there existed a platform with the relevant and reliable information at all times we would use this. Specially to see the focusing area of each oil major and have a greater overview of this. Also having a more transparent average observation form each country (India, China etc.) to send this to our vessels when they are arriving upon a destination in order for them to know what is of importance when arriving at that specific destination to prepare themselves.

[Commercial]: The operations related to no transparency in Righship is hopeless in relation to what one is able to understand can be improved. The thing that everything goes into a black bock with no understanding of the result what so ever. I wish there would be more transparency here. Today it feels like we are behind everything here and cannot improve.

8) Have you considered the implementation of blockchain technology in the vetting process?

Not that I have thought about, no.

B.2.9 Company I

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Ship operator/owner

Interview Questions

1) What is your organization's role in vetting?

A good vetting is a ticket to trade. We request vettings from the oil majors to be carried out on our ships.

2) How is your organization involved in the vetting information flow?

All observations are distributed among all our vessels with root of cause, corrective action and preventive action. This happens quarterly. On board crew discusses this to make "suggestions of improvement" and communicates with the other vessels within the fleet. Nothing goes externally.

3) Who are your collaborators in the process of vetting?

Nobody except the oil majors. [redacted]

4) What tools do you use to manage the information flow in vetting?

Oceanfile for vetting. Also, internally software systems for maintenance.

5) How satisfied are you with your vetting process, and what are the main challenges?

Vetting improves the quality. No doubt. Challenges can be whether an inspector has a good or a bad day. The first impression and their personal opinion means a lot. Otherwise there are no challenges.

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

We have vetting meetings internally between 5-6 people being the fleet manager, inspector, crew manager (cost control manager), safety manager and marine superintendent. We use approx. 0,5 hours on this which equals 2,5 hours together. Afterwards some of us sits down and goes through the observations to decide how to answer each observation – the more observations, the more work.

7) What would be the most important improvement in today's vetting procedure?

They should follow the CDI regime. This would make things much easier – considering we now have to follow each respective oil major's own regime. We then talk about OCIMF.

8) Have you considered the implementation of blockchain technology in the vetting process?

No. I have no idea what this is.

B.2.10 Company J

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Oil major/charterer

Interview Questions

1) What is your organization's role in vetting?

Using all available information to make a decision on something. Any marine vessels of terminals that we use in business whether it is FOB, TC etc. needs to be vetted. We look at all available information and make a decision whether that piece of item will be safe to operate. The company cannot use any piece of marine asset if it is not vetted.

2) How is your organization involved in the vetting information flow?

We have a global marine assurance group and vetting is a part of that marine assurance group. Marine insurance processes include specific audits of technical operators - people that are responsible for operating of the assets. We also do investigations on various levels such as supporting terminals with safety functions etc.

3) Who are your collaborators in the process of vetting?

A typical low-level vetting would be a tanker coming into one of our terminals and we would request various documentation from the technical operator only. We do not deal with the owner, the owner could be a bank, person, company etc. but they are not the ones operating the vessel. The technical operator has a contract with the owner, so even if the owner was to call me I could not provide him with information because that would violate the contract the technical operator has with him. We would ask the technical operator for special reports, audits, PSC, incidents, crew, training, insurance etc. We view it, and this is reviewed with experienced people. We have to have certain levels of experience to sit in this chair and take these decisions versus passing an inspection report with YES/NO's through a computer and deciding by counts whether it is a high risk or not.

4) What tools do you use to manage the information flow in vetting?

We are engaging in some new software partly trying to identify untrusty relationships between owners, operators, commercial operators, respondent owners, financials etc. – all kinds of things that is primarily based around sanctions. This is not vetting. Just information imported into vetting. Yes, vetting is based a lot on trust. We trust class to do their job, technical operators, etc. but you don't do deals only based on trust. Interactions are based on networks and experience. I still struggle with how you can replace technology with experience.

In this company, we do not use an automated system to screen inspection reports. We generally use 3rd party auditors for operating offices as well. We also use a shared database with other oil majors. That is a place to store information. We do have feeds into the system. It is a pretty sophisticated piece of software with active feeds. We can feed into it from class, OCIMF, inspection reports can be responded to with attachments and they see directly towards the system as well etc. It is mainly a place to store information. Operators can only access parts of the system. There is a way to get data out, ex. if we organize an inspection etc. That's about the only out we have in it.

5) How satisfied are you with your vetting process, and what are the main challenges?

On a scale of 1-10 related to the tools we use, I'm a 7. The tools could of course always be better. The biggest challenge is experience. We end up on a various reason of times, and not only in this company, in a position where people do not have the level of experience to judge the level of risk that we are getting into. So, while it's an experience based system, we struggle to get experience. Is there a way to make it less experience based? I don't know. I personally don't think so. Someone being an accountant can do half of what I do, but the other half they can't – and that's why they are paying me for my experience. My theory is this: would you fly a plane that has no pilots in it? The technology is there, but would you fly it? Someone young would trust this technology, but me, as an older person would not because of on my risk based experience – you can't base technology on every possible situation that could go wrong. So, you have the ability to use technology to take off and land, but when things go bad, what happens? On the other side, is experience perfect? Absolutely not, I must have read about a thousand incident reports on ships you can honestly say that at least 80% comes out of human factor - if not more. So, I don't have an answer to whether we need more of less technology. So, this comes back to the level of trust and the trust in the technology. And how we remove the experience factor from vetting in marine industry and still rely only on technology – I don't know. Some oil majors do use an automated, I wouldn't say vetting system, but a large part of their vetting process is automated – so if a SIRE report comes in, the computer programme bases on the observations and they give each respective question a risk evaluating factor – meaning if it comes up as a NO, and is evaluated a high risk, as a 3 or 4, it does not evaluate the report as someone reading the report saying "you know what, based on the actual comments on that actual NO, it's not as low/high as it should be". This means that the human part is removed from it. I struggle with that. Even though you could have one finding, it could be a really risk high finding, or you could have several, which would not result in a safety issue at all. You remove some of that human interface and experience and you lose a little trust right there. So, the challenge is not the data, the data is there, it's the people reviewing the data – and their experience. When you start to rely more and more on data, people just assume you do not need the experience to process that data.

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

I think that's a tough question. If you look at actual vessel vetting's, that's the core of vetting. There's a lot of things around it – relationships, level of business (FOB, TC etc.) etc. But in vetting some vessels are very easy with access to data and everything is in order, and then you have other vessels, ex. an on- or offshore vessel where you have a lot of different types of information. The trust factor is not really the highest on the tanker side because tanker side have been doing the very similar process for the past 40 years. The trust has been built up, the process has been built up and it runs very smoothly. The offshore structure is very different. On average a tanker could take an hour, while an offshore vessel could take weeks – and only that is getting access to the data. So, I would find it very hard to justify what takes the most time and cost and resource consuming as I consider it all my job.

I'm thinking about the latest period where we have been getting more calls from one of our offices abroad. That's because people there are not as experienced as I am and I constantly have to assist them. They spend too much time discussing. This is a problem since we have constructional time requirements, ships waiting, lay days – all this builds up and it becomes a problem down your chain because this one vessel is loading very slowly. Things were going back and forth because of the unexperienced people – I did one sister ship afterwards, and it was very simple. This is based on the experience. The answer is either yes or now, we don't have to go back and forth and make the process wordy and drag it out and be nice about it – that is not what we should be doing considering that this is very time consuming. I find this both time, cost and resource consuming. Vetting is a position where you have to make a position, and if you're not able to make that decision it takes more time, cost us more money and uses our resources. This again goes back to the people who don't have the experience and try to make decisions, which they are not qualified to do, it becomes very difficult.

7) What would be the most important improvement in today's vetting procedure?

[redacted]

I guess the important thing for you would be data reliability. We used to have a feed in for Lloyd's and from someone else – but the data from them was not reliable, it was wrong at the time. If it is not reliable, then it is no point in paying for it. The big thing for us is whether the data is reliable or not, so this Lloyd's List Intelligence fixes a lot of things. As an example, we had a vessel that popped up on an older sanction checks software that we used. It was the first time in eight years that a vessel actually popped up on it. With just a five-minute dive into it, it was discovered that the vessel, not the operator or the owner, but the vessel, was on a DOJ list – of course a big red flag. The operator claims he is not responsible, because he just bought the ship, but my opinion is: go fix it. It is not our job to do this. We should not take the risk of you [operator] sending us your ownership documentation and we get false information. After a while it was decided that they needed to go and fix their problem – it wasn't our problem. So, with this new Lloyd's List Intelligence, they are not only looking for the vessel or the operator, they look at the owner, commercial operator, the beneficial owner, technical manager, 3rd party operators – they are looking at a much bigger nest. In relation to sanctions, Iran is sanctioned by everybody. Therefore, Iran will change the name of their vessels, technical operator, ownership – they change documents like we change our socks – only in attempt to get through the system. This is therefore a lot more reliable source of data – it appears to be much more trustworthy than what we had before and it casts a much bigger net. So, the main answer to the question would be: the more trustworthy data that we can feed into the system, the better decisions we make. So, there is a technology element to what we do, but unfortunately we have to make decisions based on that technology and that's where it needs to be reliable. Therefore, I do not think it removes the human factor aspect from it related to the risk ranking of it. If the information is not trustworthy or its not correct most of the time, then we can make a false decision. If you can improve the technology, not so much how its delivered, but the technology itself, that would be a big improvement.

8) Have you considered the implementation of blockchain technology in the vetting process?

My general response to this is related to my knowledge to Bitcoin and when you take a digital currency having been worked in several places – that's where the security comes in. I don't know a lot about it, so I can't put it together with the vetting process. Maybe for security features on how we handle the information, but at the same time I really don't understand what blockchain technology is.

If the initial data of input is not accurate – even if the security of the data is, there, the data is no good, there is no point. The data we use is only temporary data – it is only good in the moment it is written, it could change in a minute. So, if I want to class status report of an operator, I can only rely on that information when its given to me – because in the process of sending the data to me, it could happen a catastrophic failure, that's not on the data, meaning that the data is pretty momentary. We can't use the same data the next time – it could be the next day or year later – so its temporary data. And we really hold on to the data and archive it for an audit trail. Let's say we approve something, we use the data and it gets recorded and the vessel goes ground, you can imagine the legal hold and legal actions that starts running around immediately – so, we can turn around and say: "well, this is the information that we based our position on". And that's the only reason why we store and capture the data. I personally think that its companies that provide data, such as Lloyd's who might have a better role of blockchain since they are the ones who are providing the data, we are just using the data.

B.2.11 Company K

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Ship operator/owner

Interview Questions

1) What is your organization's role in vetting?

We arrange the vettings our self. It is my task to invite the oil majors to go on-board our ships and preform the inspections. Afterwards we follow up and answer the observations to OCIMF in terms of root cause, corrective action and preventive action. This can be done with writings and also with photos to show what we type of work that has been carried out for improvement. We also board out ships and do pre-inspections. Sometimes it also helps to be on-board when an inspection is carried out, even though we initially do not have the right to influence an inspection. It is the ship and its crew that gets vetted specifically and not me as the vetting manager.

2) How is your organization involved in the vetting information flow?

I first start to inform the ship and the technical inspector that in about 14 days there is an inspection coming up – and please prepare for this by going through our checklists on-board. Also, they are to update the ship information, VIQ, where they send a file back to me which I then again upload to OCIMF. This is the last update in terms of the ships certificates such as class etc. Some of this information frequently change, while generic information such as the dimensions of the ship etc. stays the same. After this has been done I contact the specific oil major that I have decided to carry out the inspection approx. one week ahead of the inspection itself. This could be decided by chartering or operation that the customer wants the inspection to be carried out by a specific oil major, but otherwise I decide this for myself. We try to do the inspections every five months. We are allowed to have one specific oil major once a year, but not two times after each other (every 6 moths). I do base my decision on who we chose to do the inspection based on where the inspection is to be carried out as this depends on the inspector. This is in general the information flow until the inspection takes place. We also look at who the respective inspector is prior to an inspection and we can track this specific person in our system for types of observations that person pays attention to. We also have a record on what the caption on our ship says about how he was to handle on-board as an inspector.

Afterwards, when the inspection is carried out, the ship sends me the inspection list with observations where I ask the ship to provide comments on each observation (root cause, proactive and preventive action). Usually I have to go in and change how this has been written to make it more presentable. If I do not agree with the observation, I contact the oil major and have a dialog with them. My primary goal here is to delete the observation, but either way I have to make clear that I do not agree with the inspector's observation. After this, out comments are uploaded to each observation in OCIMFs web-page (which is done within 14 days after an inspection).

3) Who are your collaborators in the process of vetting?

OCIMF and oil majors.

4) What tools do you use to manage the information flow in vetting?

Internal systems where we upload the inspector's personals (with name, his observations, captain statement etc.) which is done by the business system Oracle. Inspection details and observations are also put into a part of Oracle. Communication wise we use emails. We rarely communicate via phone.

5) How satisfied are you with your vetting process, and what are the main challenges?

We are very happy that we can still decide who is going to inspect our ships. Once we get imposed by a customer or a charterer who this shall be it gets tricky because this means we lose some of the control on who is coming on-board to inspect the ship. I feel that this is an important part of the result from an inspection. We are in general very happy with how it is today. [redacted] With more vettings the chance of failing increases as well as the average score.

A challenge is to have a good enough ship that looks good enough. Also, that the crew on-board is good and takes this task seriously. In addition to vetting inspections we have PSC, which we have no control over. We also have flag state controls once every year – which we have full control over. We also have terminal inspections, but these are all irrelevant to SIRE inspections.

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

Sometimes one will have to take inspections more frequently in order to get a better record on OCIMFs pages over the past inspections. A charterer will always look at the last inspection carried out. Sometimes you would like to take an inspection fast after a bad one in order to push it behind in the line. This can give an additional cost. Also, some oil majors are more expensive than other. As an example, an inspection cost depends on where in the world you are located, even though it is the same inspector. This then depends on which oil major is using that inspector. We also spend money to keep our vessels up to standard such as repair parts, paints, etc. The cost of having an inspection at a location where there are no inspectors also cost money to fly that inspector to that specific location (if this is in west Africa etc.).

7) What would be the most important improvement in today's vetting procedure?

It is very easy to order an inspection. This only takes about ten minutes and is done via email. When you have done this a number of times it is easy. But there are some oil majors who have questionnaires that are to be filled out if the ship is to be evaluated for a charter such as SIS3. This can be hard to use, and even several hours to figure out. The first times this is done you could use half a day. [redacted]

8) Have you considered the implementation of blockchain technology in the vetting process?

No, we have not. Most of the business is conservative but I do not find it very hard.

B.2.12 Company L

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Ship operator/owner

Interview Questions

1) What is your organization's role in vetting?

Vetting is something that we need to do to our ships in order to trade. We have both CDI and SIRE inspections and get the services from the oil majors who themselves carry out the inspections.

2) How is your organization involved in the vetting information flow?

We need to make sure that our ships are ready to be inspected. When ordering inspections, this is done through email with each of the companies in their respective different systems where we send emails back and forth during the process.

3) Who are your collaborators in the process of vetting?

For us, we have the ship superintendent, the technical superintendent, being responsible for the management of the ship, the master of the ship itself, and the oil majors and chemical customers. There are many of these customers who do vettings of the ships. Mostly it is a request to get information from us. They want to find the latest information updated – like the class documents etc. Our customers provide us with questions and our work is to clear the ship and provide them with the information they need.

4) What tools do you use to manage the information flow in vetting?

Internally we use a central mailbox, email. We all have access to the same central mailbox internally and we individually pick our own vessels that are in our fleet and answer those messages from that mailbox. Here we use Outlook mailbox. Secondly, we keep the data on a server. We have folders where we keep records of important information.

Outside of our company, separately, there are other records likes the technical review of the ship. There is generic information about the ship which is the length, width etc. There are also other main databases such as the SIRE, CDI, Q88 etc. Q88 holds questions and creates questionnaires for individual customers, help with crew matrix etc.

5) How satisfied are you with your vetting process, and what are the main challenges?

The main challenge for a ship owner is the screening process required in order to win the cargo. The ship has to pass this vetting in order to conclude the deal. The vetting's are done on a cargo-by-cargo deal meaning they do the vetting process over and over again each time cargo is to be shipped. Sometimes a lack of information can be the cause of a rejection. Also, the inspectors' opinion on something can be highly evaluated. It is therefore hard to know if your ship will be accepted or not. We have a general idea, but sometimes is becomes a matter of timing. We don't have access to our customers database and we do not whether a ship is accepted or not. This is very frustrating.

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

It's difficult to say. You are always dealing with emails – that's for sure. That's probably the most time consuming. You also spend time on arranging the inspections. That's usually a full day. If you have an incident etc. then you also spend time on this. It is a lot of back and forth with the questions when you have accidents.

Mostly the dealing with communication is generally the most consuming part.

7) What would be the most important improvement in today's vetting procedure?

It's quite costly to have all these different systems out there – CDI, SIRE etc. If there was just one place, or one interface that everyone could agree to use. As a company, we spend millions of dollars on these inspections and the industry spend multimillions of dollars on this. I do not think anyone is very satisfied with it. It would be better if we had one central place that everyone could use to share and store their information – but that is very difficult. People have made their own investments in their systems and it is hard to change this. They are not willing to change.

8) Have you considered the implementation of blockchain technology in the vetting process?

No, we do not have blockchain in out vetting process today. We have our own system which we have invested a lot in where we store information. That's what we use today and I don't see us changing this system any time soon.

B.2.13 Company M

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Oil major/charterer

Interview Questions

1) What is your organization's role in vetting?

We as an oil major use a number of ships for our business. It may be for shipping the oil. In any business we assist the ship, namely vetting. We are actively involved in the vetting process for managing our maritime risk.

2) How is your organization involved in the vetting information flow?

[redacted] [Company name] deals with a large number of ships. We are one of the leaders in oil transportation and because of that we have to be proactive in vetting. What we do, is we keen the ships ready for business. When keeping the ships ready for business, we get a request and manually process the information to make sure the ship is ready for shipment. So, the vetting works in a way that a commercial entity from [Stakeholder company] will put up a request for a clearance of a ship. This is where the process starts. We have an internal system called [redacted]. So, information is submitted through the system. [Internal system] is used globally in [Stakeholder Company]. So, when a clearance is submitted, there is a large number of verifications internally and if everything gets passed, the clearance is approved – instantaneously. If not, the system will indicate which things needs to be approved before the ship can be cleared. The process involved in vetting can be to look at the SIRE reports which are carried out by the ship operator through OCIMF. Then we look at the PSC reports provided by various PSC agencies. It may be dependent on basic information of the ship, length, width, projected area of the ship etc. – many factors are involved. So, we cover the inspection, and the compatible team look at the crew matrix of the vessel and verify these etc. Then, we verify the incident history of the ship – collision, grounding, etc. It comes through OCIMF sometimes or through Lloyd's Fairplay. Lloyd's Fairplay is the ones supporting most of the information related to incidents. Then we review the incidents. If there are previous incidents, we review it to see if the ship safely can be used. Also, the structural aspects of the ship and previous outstanding's in general. Most if done proactively. It is a risk based approach.

3) Who are your collaborators in the process of vetting?

We collaborate with OCIMF, CDI, RightShip, ship managers and terminals.

4) What tools do you use to manage the information flow in vetting?

We use [Internal system] – an internal system. It is purely used by [Stakeholder Company] for our own use. Vetting management clearance goes through the system. The feeds come automatically into the system from various sources like OCIMF, Lloyd's Fairplay etc. Then it gets automatically processed, but also manually.

5) How satisfied are you with your vetting process, and what are the main challenges?
Our internal system was introduced only a couple of years back. Before that we had more manual processes providing a lot of manual work. But the new internal system has reduced this – but still, it is not totally automatic. We need to do manual interventions also. We have a large team working on this. Of course, it needs improvements, but it greatly reduces our workload related to vetting.

The operators send us information if it is requested. This is done via email and the size can be around 100-150 megabyte. Normally this works alright.

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

The PSC report has in recent times become more time consuming because we need to do it manually ourselves. The structural review is also done manually - which takes time. Another issue is compatibility. This is between the various stakeholders and is where we need to reduce the time.

7) What would be the most important improvement in today's vetting procedure?

Now a larger amount of the information is processed automatically. When much of the information is processed manually, there is a larger chance of getting errors. When automated, the chance for error is reduced and the system will tell you the areas that needs to be verified.

8) Have you considered the implementation of blockchain technology in the vetting process?

No, I have not heard about this technology before. But the technology sounds interesting. I think blockchain technology could potentially be used in vetting.

B.2.14 Company N

Candidate(s): [Interviewee name(s) – Working position(s) – Stakeholder Company]
Stakeholder: Ship operator/owner

Interview Questions

1) What is your organization's role in vetting?

We charter our vessels between various actors. We need to make sure our vessels do not sail empty to optimize the process. This is to get the most return. The vessel must satisfy a set of claims to make sure the quality is up to our standards. A large amount of our fleet is chartered in. This is partly to solve short term shipments, but also in order to have flexibility related to the market economy. Many factors play into this. In this process, vetting is a factor. [redacted] We do not have an industry standard as others do because of our business. The flag state claims, IMO etc. must be under control. One thing is the technical quality of the ship, and another is the quality of the operating company. A lot of the international claims relate a lot to the operating company as well as the technical aspects of that ship. Especially inside OCIMF, they care a lot about the technical aspects. This differ from our business meaning that the charterer market has another dynamic to it.

Basically, you charter for someone you know. [redacted]

We have our own regime to vett our own ships based on internal revisions on-board or externally by third party vetting companies based on standards. We also have a vetting related to the flag state standards. This history if public for all ships. PSC is the background for the information used. We try to identify potential issues before we have a PSC. For our sake, this is the most critical part. [redacted]

2) How is your organization involved in the vetting information flow?

The process is very qualitative. What usually happens, is that one gets in touch with a broker saying that one needs help getting tonnage. The broker then enters his portfolio and finds a potential candidate. Then, we ask ourselves internally: have we used this vessel before?

3) Who are your collaborators in the process of vetting?

We are collaborating with third party vetting companies. We have contracts with these and they perform the inspections on our behalf. Before, we did it ourselves in-house. It was hard to do this in-house because these people had to travel around the world to inspect the vessels. It was also expensive. So, today we get the reports from the third parties, and make an evaluation on these, but we also do inspections on our own vessels - both announced and unannounced. This happens a couple of times a year internally from our team. It is to evaluate if we agree with the vetting company's evaluation in order to be able to understand whether what they do is acceptable from our perspective. This could go both ways –both over- and under reporting.

4) What tools do you use to manage the information flow in vetting?

We use the databases from the flag states and the classification societies. We use a lot of tools from [Classification society] as we collaborate with these. This is to register findings related to regular procedures. The contracts used in chartering are usually standardized. When we are on-board we also use a lot of Excel as well as photos for verification.

5) How satisfied are you with your vetting process, and what are the main challenges?

Considering that it is a niche market with a number of known actors much of the decisions are based on qualitative information. In general, the transactions happening are ok, but a charterers opinion can vary. Due to that this is qualitative, it opens for possible errors. Another challenge is related to the port state regime where specific opinions not necessarily are the same. This means how the information is interpreted. Discussing this information with port state can be challenging. Opinions, cultures etc. do mean something here. Corruption is also related to this.

It is also different from vetting company to vetting company – who are the ones to find the claims and having one standard with one structure related to this would be helpful. This is partly due to that this is qualitative.

6) What part of the vetting process do you find the most time-, cost-and resource consuming?

Rectification related to port state inspections. A lot of this has to do with the maintenance of the vessels making sure it is well maintained to minimize the risk of the vessel becoming detained by a port state regime. We spend a lot of time to follow up the ship managers related to this. The problem is if the technical operator is not doing his job to make sure the vessel is up to its standards. This problem is often solved by collaborating with stakeholder you have an experience with from before and know who are.

7) What would be the most important improvement in today's vetting procedure?

Personally, I'm a supporter of regulation and standardization. I believe that the future market will be in need of a higher degree of standardization because more of the actors will be digital. If you look at the supply chain in shipping as a whole it is very old fashioned - but also extremely modern. On land, one has local legislations, while this is not the case in international waters. This makes it hard when it comes to rules and regulations as these can vary between actors depending on their respective geographical location. There are also issues related to corruption and actors not interested in transparency. Much of this is again due to that the information is logged as qualitative information. I believe that a lot of this will be automated in the future and that shipping might not look the same in ten years as it does today.

8) Have you considered the implementation of blockchain technology in the vetting process?

No, this is due to todays practice being qualitative. But we want to be able to look into this in the future.

B.3 Primary Papers from the Literature Search

Research conducted 12/03-2019

blockchain AND technology AND systematic review

ScienceDirect	
A systematic literature review of blockchain cyber security	2019
A systematic literature review of blockchain-based applications: Current status, classification and open issues	2019
Digital business ecosystem: Literature review and a framework for future research	2019
Blockchain in healthcare applications: Research challenges and opportunities	2019
Blockchain technology in the energy sector: A systematic review of challenges and opportunities	2019
Understanding digital transformation: A review and a research agenda	2019
Event processing in supply chain management – The status quo and research outlook	2019
Blockchain authentication of network applications: Taxonomy, classification, capabilities, open challenges, motivations, recommendations and future directions	2019
Smart contract applications within blockchain technology: A systematic mapping study	2019
A survey on privacy protection in blockchain system	2019
Blockchain's adoption in IoT: The challenges, and a way forward	2019
A survey on control theory applications to operational systems, supply chain management, and Industry 4.0	2018
Decentralized privacy preserving services for Online Social Networks	2018
Digital image integrity - A survey of protection and verification techniques	2017

Taylor & Francis	
A blockchain-based service composition architecture in cloud manufacturing	2019
Understanding the Blockchain technology adoption in supply chains-Indian context	2019
Blockchain: a potential guide to developing business, law, and technology solutions	2019
Information systems for supply chain management: a systematic litterature analysis	2019
Bibliometrics-based evaluation of the Blockchain research trend: 2008 – March 2017	2018
How blockchain technology can change medicine	2018
A systematic perspective on the applications of big data analytics in healthcare management	2018
The impact of digital technology and Industry 4.0 on the ripple efect and supply chain risk analytics	2018
Industry 4.0: state of the art and future trends	2018
Modelling the contracts of the future	2018
Blockchain technology and its relationships to sustainable supply chain management	2018
Digital disruption of the AEC industry: technology-oriented scenarios for possible future development paths	2018
Resource deployment system implications of migrating the firm into a digital value creation paradigm	2018
On the Fintech Revolution: Interpreting the Forces of Innovation, Disruption, and Transformation in Financial Services	2018
A review on supply chain contracting with information considerations: information updating and information asymmetry	2018
The battle for trust: institutions versus strangers: Who can you trust? How technology brought us together and why it could drive us apart	2018
Risk based framework for assessing resilience in a complex multi-actor supply chain domain	2018
Defining and assessing industry 4.0 maturity levels – case of the defence sector	2018
Supply chain risk management and artificial intelligence: state of the art and future research directions	2018
Creating a competitive advantage in the global flight catering supply chain: a case study using SCOR model	2018
Contract law 2.0 'Smart' contracts as the beginning of the end of classic contract law	2017
ISO 9001:2015 - a questionable reform. What should the implementing organisations understand and do?	2017
Towards an optimal investment strategy considering fashionable IT innovations: a dynamic optimisation model	2017
Performance analysis and design of competitive business models	2017

WebOfScience	
Blockchain for Cities-A Systematic Literature Review	2018
A TISM modeling of critical success factors of blockchain based cloud services	2018
A Systematic Review of the Use of Blockchain in Healthcare	2018
A Survey on Security and Privacy Issues of Bitcoin	2018
How Digital Identity on Blockchain can contribute in a smart city environment	2017
A Review of Researches on Blockchain	2017
Where Is Current Research on Blockchain Technology?-A Systematic Review	2016
Blockchain for the Internet of Things: a Systematic Literature Review	2016

SpringerLink	
Modified cyber kill chain model for multimedia service environments	2019
The Data Sharing Economy: On the Emergence of New Intermediaries	2019
The Promise of Blockchain Technology for Global Securities and Derivatives Markets: The New Financial Ecosystem and the Holy Grail of Systemic Risk Containment	2019
Managing lifelong learning records through blockchain	2019
Daniel Drescher: Blockchain basics: a non-technical introduction in 25 steps	2018
On legal contracts, imperative and declarative smart contracts, and blockchain systems	2018
System architecture for high-performance permissioned blockchains	2018
How to Exploit the Digitalization Potential of Business Processes	2018
Developing the Creative Abilities and Competencies of Future Digital Professionals	2018
An empirical study of architecting for continuous delivery and deployment	2018
Mapping the values of IoT	2018
Effects of transparency: analyzing social biases on trader performance in social trading	2018
Electronic Markets on big data services	2017
Regulation of Big Data: Perspectives on strategy, policy, law and privacy	2017
A Blockchain Research Framework	2017
Blockchain Technology in Business and Information Systems Research	2017
blockchain AND supply chain AND shipping	
ScienceDirect	
Making sense of blockchain technology: How will it transform supply chains?	2019
Creating markets in no-trust environments: The law and economics of smart contracts	2019
Blockchain technology for enhancing supply chain resilience	2019
Blockchain technology for security issues and challenges in IoT	2018
Blockchain's roles in meeting key supply chain management objectives	2018
Blockchain adoption: A value driver perspective	2018
On blockchain and its integration with IoT. Challenges and opportunities	2018
Toward a supply chain finance (SCF) ecosystem - Proposing a framework and agenda for future research	2018
IoT security: Review, blockchain solutions, and open challenges	2018
Intellectual property law and practice in the blockchain realm	2018
Blockchain's roles in strengthening cybersecurity and protecting privacy	2017
Taylor & Francis	
WebOfScience	
How Blockchain Could Be Implemented for Exchanging Documentation in the Shipping Industry	2018
Applications of Blockchain Technology to Logistics Management in Integrated Casinos and Entertainment	2018
SpringerLink	
Gigantism in container shipping, ports and global logistics: a time-lapse into the future	2019
Analysis of coordination mechanism of supply chain management information system from the perspective of block chain	2019
Regulatory Fitness: Fintech, Funny Money, and Smart Contracts	2019
A conceptual perspective on collaborative consumption	2018
Analysis of Blockchain technology: pros, cons and SWOT	2018
Containership cargo profiles, cargo systems, and stowage capacity: key performance indicators	2018
Digital transformation in maritime ports: analysis and a game theoretic framework	2017
Design of a software architecture supporting business-to-government information sharing to improve public safety and security	2017
supply chain AND methodology AND analysis and blockchain	
ScienceDirect	
Review of blockchain-based distributed energy: Implications for institutional development	2019
Survey on blockchain for Internet of Things	2018
Taylor & Francis	
Braving Bitcoin: A technology acceptance model (TAM) analysis	2017
WebOfScience	
The impact of the blockchain on the supply chain: a theory-based research framework and a call for action	2019

SpringerLink	
An IoT-based E-business model of intelligent vegetable greenhouses and its key operations management issues	2019
Internet of Things: information security challenges and solutions	2018
Electronic Markets and current general research	2018
Quantifying the Cost of Distrust: Comparing Blockchain and Cloud Services for Business Process Execution	2018
Supply chains and electronic markets - impulses for value co-creation across the disciplines	2017