The Application of Blockchain Technology in the Maritime Industry

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Abstract The maritime industry is one of the most polluting in the world. In this paper we present fresh insights related to the application of the novel blockchain technology in reducing pollutions. We analyse recent literature on blockchain technology and propose ways of the utilization of blockchain technology in the maritime industry. Special interest for maritime industry specialists represents the perspectives of the utilization of the blockchain technology in improving the environmental efficiency of the maritime industry. The technology has a broad range of applicability, allowing connecting the supply chain more efficiently, providing the exchange and visibility of time-stamped proofed data, decreasing the industry operational costs with intermediaries and increasing security. It also allows full visibility for all parties involved with proof of work, facilitating Class Societies inspections, Port State Control and audits compliance. The results of the study also show that cases on blockchain application in other fields increase the industry willingness to its application on the maritime industry. While having blockchain implementation specialized third parties would increase the implementation possibility and the industry willingness due to reduced costs and friction. The study will be interesting for scholars, policy-makers and practitioners from the maritime industry.

Keywords Blockchain technology · Maritime industry · Green supply chain Green IT

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1 Introduction

The steadily growing volumes of industrial production, growing population in the world and growing traffic exhaust lead to the contamination of environment. These issues concern policy-makers, scholars and practitioners around the globe. The IT sector cannot stay apart of the global trends and concerns and has much to offer in order to reduce the volume of pollution and thus save the environment [1–6]. One of such radical IT technologies that emerged ten years ago is the blockchain technology [7, 8]. The blockchain technology is the general-purpose technology [9] and can be applied in many industries. The blockchain technology is defined as "a distributed database of records or public ledger of all transactions or digital events that have been executed and shared among participating parties" [8, p. 7]. The system is secure—the records are verified by public ledgers and can never be erased in the future. The main benefits of the blockchain technology are transparency and cost-efficiency [10]. In the present, transactions between firms are made through intermediaries (i.e. banks) that charge significant amounts of money for their operations and currency conversion. The blockchain technology allows firms to make transactions directly between each other and is made in a very secure manner. The transaction costs that firms can save on bank operations can be used in the development of green technologies. Another advantage of the blockchain technology is the possibility to execute "smart contracts". Smart contracts are computer programs that can automatically execute contracts' conditions [8]. The amount of paper utilized for contracts and other paperwork would be significantly reduced.

The seaborne transport is one of the cheapest means of transportation in terms of the price per tonne of the cargo transported. However, the maritime transport is extremely polluting. For example, one ship produces as much CO_2 and NO_x exhaust as 70,000 cars. Different measures are approved by policy-makers in order to make the maritime transportation environment-friendly. For example, the new legislation specifies that exhaust-free vessels can come into European ports after 2020 (i.e. for example, the level of sulphur oxides, should not exceed 0.5% mm). Practitioners from shipbuilding and the shipping industry are concerned with the development of new vessel types, driven by electricity, hydrogen or hybrid [11]. Practitioners and policy-makers also search for other ways to reduce pollution in the industry. Without any doubts, digitalization opens new possibilities to save the environment and to provide sustainable development in the industry.

The research on the blockchain technology is quickly developing nowadays. However, two areas within the blockchain technology are barely researched yet. One of them is an application of blockchain in the development and support of green technologies. There are a few articles published in 2017 that shed light on how the blockchain technology assists in green innovation support [12, 13]. As mentioned above, the blockchain technology is a universal general-purpose instrument that can be applied in different areas. Thus, one of the most priority areas of sustainable development is the most important area of the blockchain

application. This study intends to cover this gap and contribute to the emerging green blockchain stream of research.

The blockchain research is an interesting area for researchers and practitioners. Several special issues on the blockchain technology recently appeared in different ICT, technology and innovation journals. The topic is also popular in different conferences. The articles shed light on the application of the blockchain technology in different industries and areas, such as the energy sector [10], healthcare [14], finance [8, 15], government services [16] and others. The interest in the green IT technology in the maritime industry is steadily growing [17, 18]. However, there was still limited research on the application of the blockchain technology in the maritime sector [19]. Without any doubt, the highly international maritime business is one of the industries where the blockchain technology perspectives are quite interesting and thus more research attention is needed. Our paper intends to cover this gap in this knowledge and shed light on barriers on the dissemination of the blockchain technology in the maritime industry.

This research aims presenting the possibility of Blockchain technology applications within the offshore maritime industry. This chapter focuses on Scandinavian shipping companies. The Norwegian and Scandinavian maritime sector is highly innovative. It can be named as an innovation leader in the world maritime business. Norway and other Scandinavian countries are high-cost countries and practitioners constantly seek ways to reduce costs of operations in order to stay competitive in this highly volatile and cyclical market [20]. The research question that guides this study is: Why should firms in the maritime business implement the blockchain technology in order to preserve the environment? We have carried out interviews with the operators and suppliers of the Norwegian offshore shipping industry to answer the research question.

This paper is organized as follows. In the next section, we present the theoretical background of the study related to the blockchain technology. In Sect. 3, we explain the specifics of the maritime business, its need of the green IT technology and propose ways on how to utilize the blockchain technology to cover this need. The chapter terminates with the conclusions and implications for theory and practice.

2 The Blockchain Technology

In 2008, Satoshi Nakamoto (an alias for a person or group of people who has never had its identity publicly confirmed) developed Bitcoin, which is a peer-to-peer electronic cash system that allows two parties to perform payments directly, excluding the need for a trusted third party or intermediary, in financial transactions. Bitcoin is essentially a chain connecting several digital signatures, verified by a timestamp server [7]. Nakamoto developed a cryptocurrency to enhance trust among peers and to allow direct transactions, overcoming the need for intermediaries in financial transactions, thus reducing costs. He created a digital foundation, a

technology to allow such transactions, which is now known as blockchain. Although blockchain was firstly created with Bitcoin together, the technology evolved to apply for several uses and businesses and the concept should not be confused with the concept of Bitcoin.

2.1 Development of Blockchain Technology

Since Bitcoin's start and popularization, several technology companies have begun working with blockchain, popularizing the technology within the "*fintech*" industry, as it is known. While most of these companies are still in their start-up phase, many of increasing interest over the technology. The biggest company to invest in blockchain so far has been IBM, which states that they expect blockchain to revolutionize transactions the same way the Internet has done for communications, allowing increased trust and efficiency for low or zero costs [21]. The company has started a big blockchain project, investing in academia and professional training, while tailoring solutions for other companies interested in applying the technology. According to IBM, blockchain is:

> …a shared, distributed ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible — a house, a car, cash, land — or intangible like intellectual property, such as patents, copyrights, or branding. It can also be used to help companies manage the flow of goods and related payments, or enable manufacturers to share production logs with original equipment manufacturers (OEMs) and regulators to reduce product recalls. Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved. [22, p. 5].

Blockchain is public, meaning that anyone can participate and contribute in the chain. It works based on Proof-of-Work system, in which each block contains a *hash*, a unique identifier or digital fingerprint of the data contained in the block (e.g. 000000rt5687ai85 in Block 456), the hash from the previous block (0000hj87yuki98 in Block 456), along with batches of time-stamped recent valid transactions, which also have their own hash (e.g. 0987hynjyf45lk87 in Block 456). The timestamp server publishes the previous blocks' hashes, proving that the data must have existed at the time (since it has a hash), also including the previous timestamp in the hash, thus forming a chain reinforced by each additional timestamp (n), shown on Fig. 1 in the sequence. The proof-of-work system allows the timestamp server's implementation on P2P basis by scanning for a value that when encrypted, the hash will begin with a number of zero bits. For this, it was added a nonce in the block, a number or key that needs to match exactly to the nonce created when the block/hash was created, therefore signed, until a value is found that gives the block's hash the required zero bits [7].

These replications mean that each node acts as both a publisher and a sub-them have already developed and have begun incorporating others, showing the scriber of the ledger; being allowed to send or receive transactions to and from other nodes; while the data is synchronized across the network as the transactions occurs [22].

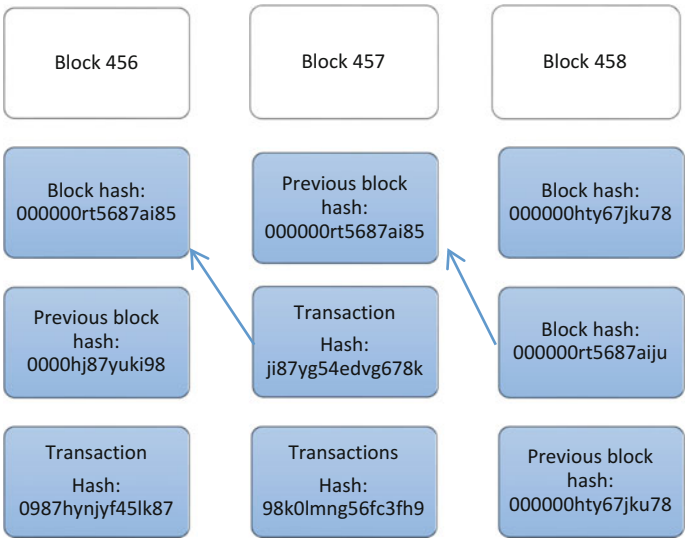

Fig. 1 Principle of the blockchain technology

The timestamp server, the ledger distribution, along with the proof-of-work concept constitutes the consensus model, which is blockchain's validation system [7], assuring that all transactions are authenticated, secure and verifiable [23]. Because of its characteristics, a blockchain network enforces trust within the chain for all the users [24].

2.2 Types of Blockchain

There are three types of blockchains, being Public (Bitcoin, Ethereum, Litecoin, etc.), Federated or Consortium (R3, B3I, EWF) and Private (company internal). The first one is the public and anonymous created technology, which is permission-less, meaning that there is no requirement for software, allowing anyone to participate, thus, completely decentralized. This public chain uses a Proof-of-Work consensus system to validate and maintain the nodes, while the other two are types are also decentralized within their users, or in other words, centralized to the permitted users to access the network, and require a solution provider to develop the chain. Their consensus system is similar to the one developed by Nakamoto [7], but they differ in accessibility. Table 1 shows their differences and particularities.

Permission-Less Blockchain
This Blockchain is public, meaning that anyone can participate and contribute in the chain. It works based on Proof-of-Work system, in which each block contains a *hash*, a unique identifier or digital fingerprint of the data contained in the block, the

Table 1 Types of blockchain and their characteristics

	Public	Consortium	Private
Participants	Without permission • Anonymous • Could be malicious	Permissioned • Identified • Trusted	Permissioned • Identified •Trusted
Consensus mechanisms	Proof of work, proof of stake, etc. • Large energy consumption • No finality • 51% attack	Voting or multi-party consensus algorithm • Lighter • Faster • Low energy consumption • Enable finality	Voting or multi-party consensus algorithm • Lighter • Faster • Low energy consumption • Enable finality
Transaction approval freq.	Long Bitcoin: 10 min or more	Short 100× ms	Short 100× ms

hash from the previous block, along with batches of time stamped recent valid transactions, which also have their own hash. The timestamp server publishes the previous blocks' hashes, proving that the data must have existed at the time (since it has a hash), also including the previous timestamp in the hash, thus forming a chain reinforced by each additional timestamp [7]. The proof-of-work system allows the timestamp server's implementation on P2P basis by scanning for a value that when encrypted, the hash will begin with a number of zero bits. For this, it was added a nonce in the block, a number or key that needs to match exactly to the nonce created when the block/hash was created, therefore signed, until a value is found that gives the block's hash the required zero bits [7].

The hash created shows the previous' block hash as well. If any alteration is attempted in the chain, the connection to the previous block will be broken, which will then cause the whole chain to break. So, the longer the chain, the stronger it is, requiring all previous blocks to be changed to match the new information. However, a process allows searching for the nonce number for the altered block, called "*mining*". Once any block in the chain is mined, it receives a new hash and nonce, while all the blocks in that ledger are now broken [7]. What makes this system work is that every node (user) in the chain has a copy of the chain, being the distributed characteristics of Blockchain (decentralization). Hence, if one block or more were mined to accept the alteration, the last block will have its hash altered and consequently, different from the other records from other users in the distributed chain. Therefore, the greater amount of identical hashes in the last blocks "wins" the distributed chain, keeping the immutable characteristics [7]. The mining concept also works as an incentive for keeping the Blockchain un-hackable. To discover the nonce number, several calculations are required, which demand very high processing capacities from a computer and/or server. Every time a "miner" can actually mine a nonce, it is paid a Bitcoin and the calculations become harder.

Permissioned Blockchains

In the permissioned blockchain, the users have a special permission to access the chain, working as a guarantee that only the allowed users can access the chain or specific parts of it, based on their assigned roles. It is also a distributed ledger; however, users may or may not be anonymous. Even though it also uses a consensus-base data validation, it does not apply the public blockchain Proof-of-Work, since the mining process explained before takes longer to process and requires advanced and high computing power, becoming expensive for private use. Thus, the permissioned types apply the concept of "Smart Contracts", which is:

> an agreement or set of rules that govern a business transaction; it's stored on the blockchain and is executed automatically as part of a transaction. Smart contracts may have many contractual clauses that could be made partially or fully self-executing, self-enforcing, or both. Their purpose is to provide security superior to traditional contract law while reducing the costs and delays associated with traditional contracts. [21, p. 17]

In this system, a private key distributed from a public key, which together form a "signature share", then creating a signature. If anyone can manage to discover the public key, this person will not be able to breach in, as there will be a private key to open the block [25].

All Blockchain types maintain the other characteristics mentioned before, with the permissioned ones returning to the same characteristics after the signature authentication. The main advantage from decentralization is the facility to identify and correct problems within the chain since it is easy to isolate a problematic node to investigate the matter further, then discovering if it is malfunctioning or showing signs of tampering, without losing the behaving nodes, which can continue to be available in the system [26]. Buterin [27] explains that there are three other main reasons for decentralization, being: fault tolerance, attack resistance and collusion resistance. The first explores Norton's [26] concept a little further, explaining that decentralized systems are less likely to fail by accident due to their reliance on separated and non-relational components. The system also becomes attack resistance due to its lack of sensitive central points, becoming more difficult to attack, destroy or manipulate; while becoming collusion resistant due to the difficulty of having most or all participants to conspire in favor of themselves over the other parts [27].

It is important to discover how to choose the correct type of blockchain to the required application. To do such, IBM suggests businesses to ask themselves a few questions to perform an analysis, such as:

- "Do you require a permissioned network?
- Do you need to know the identities in your business network? For example, to adhere to regulations such as anti-money laundering or know your customer?
- Do you have frequent exchanges with others that could be automated and pre-programmed, freeing up valuable time and resource?
- Would you benefit from transaction resolution in minutes rather than days or weeks?" [22].

Table 2 Blockchain implementation solutions

Approach	How it is done	Examples
IT services	Build on request	ConsenSys
Blockchain first	Develop using the tools provided by the blockchain	Ethereum, Bitcoin
Development platforms	Tools for IT professionals	ERIS, Tendermint, Hyperledger
Vertical solutions	Industry specific	Axoni, Chain, R3, itBit, clearmatics
Specials APIs and overlays	DIY building blocks	Blockstack, Factom, Open Assets, Tierion

Blockchain Storage and Implementation Solutions

The blockchain, disregarding which type, keeps the last block recorded in all the chain's nodes, thus saving disk space requirements. Yet, it is necessary to build the chain somewhere. When it is decided which type of blockchain will be implemented, it is necessary to choose the solution required to it. There are several providers in several possibilities as software and software as a service (SaaS); cloud based and Blockchain as a service (BaaS). Table 2 details some providers and solutions. The main players so far are Amazon, with AWS BaaS, Microsoft with Azure BaaS and IBM with their BlueMix BaaS [22]. However, the main Blockchain solution is the Hyperledger, an open-source Linux Foundation Project launched in 2015 alongside with 17 other companies to collaborate for the technology's development and advance into the cross-business use. There are other open-source platforms with the same purpose, such as Iroha, a C++ Blockchain platform, and Cello, a rapid cloud platform Blockchain deployment [21]. This way, developers have a single-click cloud-based environment for Blockchain deployment providing rapid smart contracts development [22].

3 The Blockchain Technology in Maritime Industry

As a result, the technology has several possible applications within other industries than finance, public sector, retail, manufacturing [28]. Even though not all companies might need the technology in their own operations, they might participate in other networks to facilitate and enhance businesses, comply with regulations and other requirements, among other examples, with a few applications on the maritime industry.

3.1 Industrial Specifics

The maritime industry has established itself as a key supply chain stakeholder over the years, either by its sub-industries or by supporting businesses and allowing their growth. Shipping itself has also become a differentiator among enterprises and an advantage for them in enlarging their market reach [29]. However, the industry faces some old known obstacles along the way, such as shipping cycles [30], along with crucial challenges and choices that can mean a company's survival in the industry. "The marine industry is undergoing a transformation. As well as managing today's rising operational costs and achieving cost-effective environmental compliance, ship operators are faced with tomorrow's "big decisions". Decisions about fuels, technology and whether it is possible to "future-proof" their fleet and assets" [31].

Maritime industry is one of the most affected industries by new stricter rules and legislations [32] mostly enforced by the International Maritime Organization (IMO) and the European Union (EU), as well as other global treaties. How to deal with such challenges call for diverse solutions and can be a good opportunity for innovative technologies. The industry has already conducted several studies, prototypes and other innovations, such as un-manned vessels prototypes, technologic control and engine rooms, artificial intelligence for learning and training, "green" fuels and batteries, etc. Environmental compliance fleet to allow local and global trade has been a great challenge for the marine industry as the legislation keeps updating constantly to new and higher standards [33].

Data is the focus of shipping digitalization, mainly driven by the offshore and containerized shipping, as poor information management can account for up to 20% of an operational budget [34]. A typical supply chain manages a data inflow of an average of 100 gigabytes per day [35], which is expected to reach 35 zeta bytes by 2020 [36]. Jan Wilhelmsson, shipping vice president of Eniram, a Wartsila systems developing company, lead a research for the company to develop their new fleet performance monitoring system to discover how the maritime industry is spread by digitalization. His findings showed that the cruise industry is on track to real digital transformation being visibly ahead of the others, while the cargo segment is mixed, being mostly advanced on shore. He divided the industry into digital evolution categories to understand the differences. The first category includes companies with management engaged to technology and innovation to support the business. The second, the ones that tried but are still struggling, with either methodology, data, results, etc.; while the third group comprises the ones that think their operations are too complex for any solution, therefore, faded to be out of the competition soon.

In an interview in the first quarter of 2017, Dr. Martin Stopford states that digitalizing shipping is the only solution for the industry. He argues that three methods would change the business model running through shipping cycles, allowing the digitalization that the industry requires: smart ships, smart fleet and smart global logistics. However, he adds that a great cultural change is needed in order to allow such changes, aligned with Wilhelmsson's findings. Stopford argues

that "*having the technology is a first step, but the data needs to be used in order to show performance improvement*" [37]. One example is the concept of digital oil fields, in which information technology tools are applied to constantly collect data, providing big data for posterior decision-making and solving possible lack of qualified labour in the future [38]. The maritime transport and logistics has been applying data-driven technologies application for some time, with several examples, including the first blockchain application by Maersk. One more innovation comes from a start-up called Xeneta, which has begun collecting data from container-liners and tracking over 60,000 routes globally, allowing shippers to receive real pricing information for benchmarking, rather than past static data; thus, providing pricing transparency and supporting contracts negotiations [39]. Radio Frequency Identification (RFID) systems integration through Internet of Things (IoT) in order to create value for the chain based on data is another example driven by business needs [40, 41]. The use of RFID tags is estimated to increase to 209 billion units by 2021 [42], as the sensor-based technology could reduce operational costs by 10–25% [43]. IoT most current application in the industry is GPS tagging of shipping containers to assist managing their flow through transit nodes [44]. This also enables real time tracking of goods and vessels and delivers extra customer service as it provides real time information about one or more specific container. Another example is port operations. As shipping companies and other logistics modals compete fiercely for port space and resources, the collected data is not shared among the peers. This makes it extra difficult for a system to analyse and redistribute data from the port to its stakeholders, in order to optimize the use of available supply logistics; thus, turning ports in bottlenecks of everyday operations, as volumes keep increasing. The port of Hamburg estimates that the number of containers passing the port will increase from 9 million in 2013 to 25 million in 2025, and solved its data-sharing problem by requiring all parties to connect in a single data system [44]. The innovation scenario in the maritime industry seems to be evolving and growing rapidly. DNV-GL has already started providing cloud solutions and digital offerings, such as data analysis and value creation form it. Its main software is providing integration with machine learning and between historical data analysis and future forecast, with the goal of fully integrating to the IoT in the future. Such applications will allow data-smart operations and asset management, through another technology called "Digital Twin", which is basically an asset's digital model representing its deep profile characteristics, such as systems, software, behaviour, needs, demands and so on, providing analysis, perception and diagnostics while completely integrated with all stages/stakeholders [34]. With companies such as DNV GL, Kongsberg Maritime, etc. and several star-ups, Norway already has an established presence into the maritime and innovation development. In March 2017, it was announced a collaboration to test pilotless vehicles in the Fjord of Trondheim, among the Norwegian University of Science and Technology (NTNU) and industrial players as Kongsberg Seatex, Marintek, Maritime Robotics and Rolls-Royce Marine, becoming the world's first test location for self-directed vehicles such as unmanned ships and underwater drones.

Other countries also entered the digitalization race by fostering innovation. The Maritime and Port Authority of Singapore (MPA) launched the Smart Port Challenge 2017 to encourage start-up and organizations collaboration, pushing digital transformation into the industry, harnessing technologies to add value to the maritime logistics chain, also collaborating with the Port of Rotterdam in the same kind of endeavour. The start-ups are gaining space into the industry as entrepreneurs discovered its financial and size potentials, already claiming attention due to their innovative concepts. One start-up called Onboard, based in Rotterdam, is bringing the Internet of Things to the maritime industry by providing an open platform with full integration with other applications and customer's internal systems, providing full insight of vessels and operations [45]. Another start-up, Care4C's, is focusing on bringing the telemedicine into the vessels, monitoring and collecting data about cardio vascular and sleep patterns, providing predictive analysis and proactive risk management [46]. While Care4C's is digging into a needed and underdeveloped field, most of the start-ups are focusing on data analytics and artificial intelligence to reduce fuel consumption, CO_2 and other emissions, route optimization and integration with other technologies and trends, such as drones use and the afore mentioned unmanned vessels. However, data and analytics software, IoT applications, etc. require intermediaries in the chain to be accessible, which adds extra steps, resources and costs to it, as they require extra labour, training, systems integration, etc. Yet, all these examples show that there is willingness within the industry to pursue more innovations and innovative behaviour, developing the cultural aspects pointed by Stopford. Alongside, Blockchain technology could be a solution to support most of the ongoing and needed innovations, as it is a decentralized, application, building an encrypted and immutable ledger accessible and confirmed by all participants of the chain or only those who have access to it.

3.2 Blockchain Application in Maritime Industry

While still not completely diffused within the industry, the technology has been gaining space into discussions and possible applications. One good example is the Marine Transport International Limited (MTI) freight forwarder. In 2016, MTI announced that was using a public blockchain ledger called TrustMe™ to comply with the new verified gross mass (VGM) requirements of packed containers, implemented from July of 2016 by the Contracting Governments to the International Maritime Organization's SOLAS treaty (International Convention for the Safety of Life at Sea). The new regulation transferred to the shipper the responsibility of ensuring that the right VGM is provided to the terminal or carrier prior to being loaded to the vessel. The company then began using Blockchain through TrustMe™ in order to provide a permanent and visible record to port officials, shippers and cargo owners; thus eliminating the need for data intermediaries, private databases, logs and spreadsheets [19].

The technology has also been applied to enable single energy trade within commodities markets. A renewable energy trader, Volt Markets, implemented a public blockchain to provide assurance of trade and absolute tracking for renewable energy certificates, while in January 2017, another trading house, Mercuria, carried out the technology on a large oil trade within ING and Société Générale banks [47].

Several other uses are possible within the maritime industry, mainly in order to solve regulation compliance, documentation issues and origin assurance as well as to support communication and automation. Blockchain could solve the digitalization of the Bill of Lading (BoL), essential document within shipping, providing an immutable chain accessible by all parts required within 10 min of its creation. The BoL is a contract of carriage and an ownership/receipt document, and by the Maritime Law, the original version of the document is required to be produced by the consignee to allow cargo delivery. This document is frequently delayed due to banks and other issues, which leads to the cargo usually arriving at ports before the original BoL creation or to BoL fraud. Such includes the document being produced and signed before the actual loading of the vessel or being altered after cargo delivery; with forged signatures, bank guarantees and wrong description of cargo [48].

The blockchain application to support BoL was one of the first researched applications within maritime industry and is probably one of the most advanced ones, alongside with containerized shipping, already having adoption frameworks and models. An Israeli start-up called Wave is focusing on creating a paperless trade for shipping trade by applying Blockchain to create and track BoL's, Letters of Credit and the whole chain. Its main competition, Skuchain, located in California, USA; believes in the evolution of the "collaborative commerce", being the integration of all parts of all supply chains involved in commerce, exchanging information and collaborating towards commerce.

In order to find out whether Norwegian maritime companies are ready to adopt the blockchain technology, we carried out interviews with the representatives of shipping companies. There were seven interviews performed in total, being four with Offshore operators and three with suppliers, which were divided by these two categories and given numbers from 1 to 4, for Offshore operators players, and 1 to 3 for Offshore support players. Table 3 and Fig. 2 show the interviewees perception on how much shipping companies are willing to invest into blockchain innovation in general and divided by their own companies and in the offshore. The results from analyzing the interviews shows that there is need to innovate in the form of blockchain technology in the maritime industry and consensus regarding such need, however, with many limitations and uncertainties. There is also a consensus that costs are the main enabler and barrier to technological implementation, as well as secondary costs derived by it, such as reliance on consultants and third parties, need for training, need for specific personal and other possible requirements, such as software integrations. The willingness for innovation is directly connected to these factors, as well as what can be expected from the innovation. Again, the great measurement for success is cost, being cost reduction the biggest motivation for innovation.

Table 3 Perception to adopt blockchain innovation

	Company willingness		Industry willingness	
	Coding coverage (%)	Coding references	Coding coverage (%)	Coding references
Operator 1	5.79	6	6.23	6
Operator 2	8.18	6	0	0
Operator 3	2.63	3	1.66	1
Operator 4	5.28	3	8.42	6
Support player 1	7.66	6	1.45	1
Support player 2	5.10	7	4.02	6
Support player 3	7.56	9	4.07	4

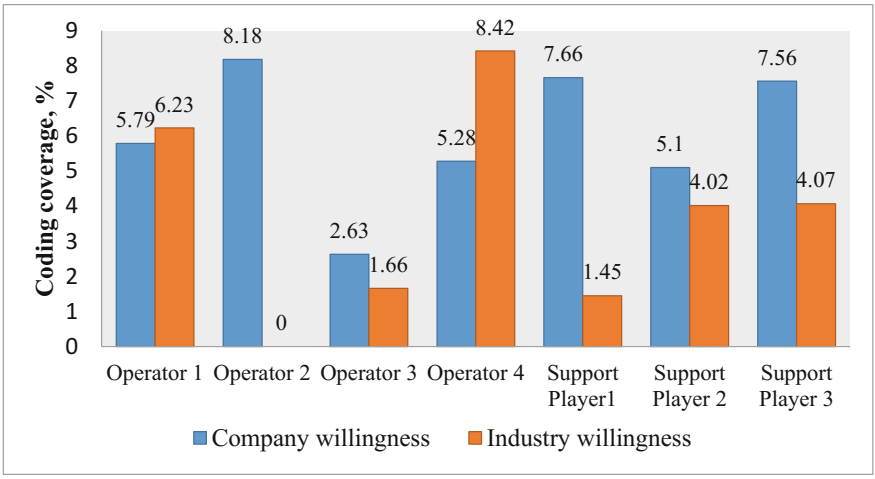

Fig. 2 Company and industry willingness to adopt blockchain technology: expert evaluations

4 Conclusions

Maritime industry is quite complex industry [49–51] that is characterized by high costs and the high level of pollutions. This study explored the possibility of blockchain utilization with the aim of pollution prevention within the maritime industry and other non-financial uses. We have identified the literature and its gaps related to the subject. The lack of academic literature about blockchain and its utilization in green innovations, especially in the maritime industry, was the key driver to this research. In a literature review of blockchain academic research, Yli-Huumo et al. [52] has not detected any study of its application within the maritime area.

Blockchain's applicability to architecture allows companies to keep an encrypted, immutable ledger of transactions, which can be shared trustfully within the selected network due to the peer-to-peer (P2P) proof of work concept, eliminating the third parties involved, thus saving money through reducing costs.

This study came from the perception that the industry lacks digital innovation in its operations and green supply chain [53], being one of the late adopters regarding new technology. The main research question driving this study attempted to foster an academic research of the topic. The answer to this question—Why should firms in maritime business implement the blockchain technology in order to preserve the environment—is quite simple. The industry needs to reduce costs to be able to remain lucrative and overcome the obstacles presented by global energy supply and demand, turning them into opportunities, while complying with the legislation requirements enforced by the responsible global regulation bodies. IT tools are excellent instruments that allow cost savings [54]. Maritime industry needs also an enhanced action against cybercrimes and piracy. Thus, the technology presents itself as a solution for such and opens many more opportunities within the industry.

Still, the industry needs a push towards the digital revolution it requires—external motivation. Based on the literature review and the results, it is clear that the industry is motivated by costs and by the need of implementing something based on legal requirements. Just as in the case of the Port of Rotterdam, if required by the Port Authority, Classification Societies, IMO or other similar bureaus, the industry rushes to adapt itself in an attempt to "future proof" its assets, which could be a main enabler for innovation and technological implementation. It is clear that the industry's lack of knowledge of blockchain's possibilities is the principal reason for its still rather slow adoption rate, which should change in the near future, based on the success of the pioneer's adoption.

The technology has a broad range of applicability, allowing connecting the supply chain more efficiently, providing the exchange and visibility of time-stamped proofed data, decreasing the industry operational costs with intermediaries and increasing security. It also allows full visibility for all parties involved with proof of work, facilitating Class Societies inspections, Port State Control and audits compliance. However, it is not enough to solve the operations need for innovation. It is important to differentiate the technology in order to engage with it, highlighting that it is not data analytics software, a data storage provider nor server. Yet, it does best on what it promises—creates and provides decentralized public or controlled access to a ledger, which is immutable, secure and time-stamped verified by proof of work hash-system that allows the elimination of third parties and the costs associated to it. However, the lack of knowledge about the technology and the industry's cultural barrier to innovation act against innovation and new technology application, even though the results showed a consensus on the industry's need for enhancements for both. Nevertheless, the results also showed that studies and cases on blockchain application in other fields increase the industry willingness to its application on the maritime industry, while having blockchain implementation specialized third parties would increase the implementation possibility and the industry willingness due to reduced costs and friction.

Costs present as the key driver to allow innovation, as both enabler and barrier, being the factor that can boost the industry's willingness of blockchain application, especially regarding operations, in addition to the industry's need for technological innovations.

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