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Blockchain Capabilities to Improve the Productivity of Maritime Logistics Processes: Review, Taxonomy, Open Challenges and Future Trends

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Abstract

This paper surveys recent publications on maritime logistics with a focus on blockchain capabilities. Maritime logistics plays an important role in global trade and an important part of the global economy depends on it. The growth of world trade has led to the creation of various systems that are prone to error and fraud, the current supply chain needs to connect and trust many intermediaries which not only increase abuse and errors but also it will increase cost and time in the chain. Hence, transparency and stability are highly demanded. On the other hand, with the onset of the fourth industrial revolution, a new approach called "blockchain" was introduced which can have very important applications in maritime logistics. As this novel technology is in its early stages of development, its applications in maritime logistics have not been specifically investigated. So, this paper takes a deep dive into blockchain technology capabilities for maritime logistics by reviewing relevant scientific journal papers since 2014. The paper also discusses and challenges the current operational paradigms and by categorizing efforts, provides a taxonomy of research topics in maritime

logistics. Finally, the paper in addition to presenting challenges, identifies new avenues for academic research based on current trends and development.

Keywords: Maritime logistics, Blockchain technology, Systematic review, Open challenges, Future trends.

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Introduction

Logistics is not a typical industry or process that people sometimes deal with. Logistics and transportation have a special place in our daily lives, and their impact is undeniable. In today's world, all organizations and companies use logistics on different scales. Logistics refers to a set of processes involved in moving raw material and finished goods throughout the supply chain, from the manufacturer to the final consumer. Logistics consists of some interconnected elements, including receiving, warehousing, inventory management, cargo planning, packaging, transportation management, and order fulfillment (Lee, Nam, & Song, 2012). As logistics is a prominent factor in all organizations, inadequate logistics can cripple a business and cause production delays that impact delivery times and ultimately reduce sales. Meanwhile, successful logistics strategies enhance efficiencies, cut costs, and help businesses gain control across the supply chain, and ensure that the products are delivered to the proper location at the right time to meet delivery deadlines and customer expectations. Unfortunately, involving too many intermediaries in the process of logistics will reduce trust among stakeholders because the documents and information are shared physically or through an intermediary in the traditional type of supply chain and logistics, which may cause information fraud and manipulation. Arguably, this type of logistics is costly and ineffective for the whole industry or company. Concurrently, the fourth industrial revolution is taking place, and one of the most effective technologies to deal with such problems is blockchain. Blockchain helps us to digitize logistics and keep information intact by eliminating intermediaries. It, also, allows optimization, productivity, visibility, and coordination between all stakeholders in the end-to-end supply chain and logistics. There are different types of logistics, including inbound logistics, outbound logistics, third party logistics, military logistics, reverse logistics, and so on (Sarkar, 2017). Logistics generally contains five types (as shown in Fig. 1). The integration of logistics and supply chain triggers the cooperation of stakeholders on managing a set of functions to control the flow of raw material into an organization to prepare the end products through a number of processes and deliver them to

the customers through fine transportation. Blockchain can greatly contribute to improving these processes.

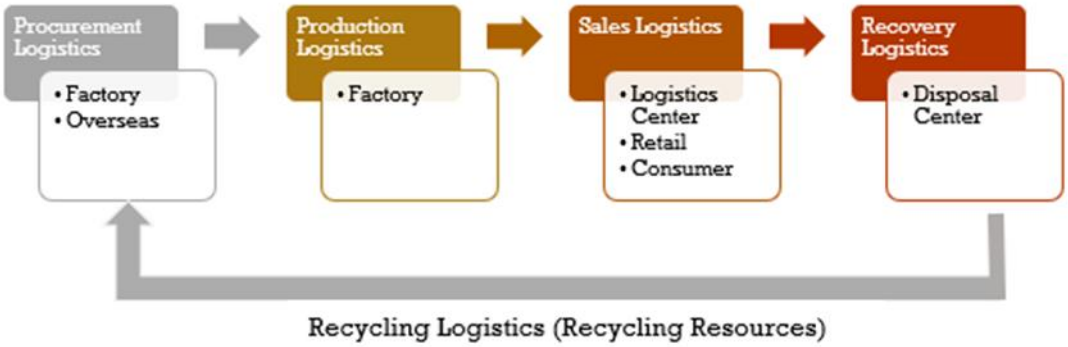


Figure 1. Logistics processes in general

Transportation in logistics includes various modes including road, rail, air, pipeline, and maritime shipment. Obviously, customer satisfaction is important. Thus, management should choose the right sort of transportation for the distribution of goods depending on several factors. Low cost and high efficiency have made maritime logistics the primary mode of transportation in world trade. Consequently, this study aims to discuss maritime shipping, operations in the field of sea transportation, its importance in global business, and how practitioners can make it more transparent and efficient.

Shipping – which transports about 90% of worldwide trade – is, statistically, the least environmentally damaging mode of transport when its productive value is taken into consideration (Hoseini, Omran, Márquez, & Makui, 2018). For instance, the large amount of grains required to supply the world's daily bread could not be transported by any other means than ships. Moreover, set against land-based industry, shipping is, overall, a comparatively minor contributor to marine pollution from human activities according to the international maritime organization (IMO) (Torkian, Hoseini, & Askarpoor, 2020). To an inexperienced person, the maritime logistics and the shipping industry may seem similar. But, when you are involved in these industries, you will find out that these industries have diverse instructions, assets, activities, experience, expertise, and attitudes as presented in Table 1. Maritime logistics is a crucial part of world businesses. However, a small service malfunction or insufficient capacity anywhere in the chain could result in delivery delays, increased costs, or wrong shipments. The obvious goal of implementing new technology should be increasing the efficiency of maritime logistics processes. For this reason, blockchain, which is emerging nowadays, contributes to increasing security and speeding transactions and data exchange (Wagner & Wiśnicki, 2019). Many industries are associated with blockchain, e.g., medicine, food, equipment, marketing, and much more. Maritime logistics is a high-throughput, low-cost, and efficient transportation method that faces many uncertainties. However, the need for

sustainable methods to alleviate the environmental impacts of marine logistics has attracted much attention for future research (P. Andersson & Ivehammar, 2017).

Table 1. Maritime transportation vs maritime logistics

	Maritime shipping	Maritime logistics
Theory/Conception	The process of transportation of goods and cargo through the sea or ocean. Moreover, the process is focused on transportation individually.	The process of scheduling, warehousing, implementing, and managing of transmission of products and is the emphasis on an efficient logistic system.
Activities/Operations	Contracting, shipping, movement of cargos, and loading/unloading	Contracting, shipping, movement of cargo, and loading/unloading. In addition, warehousing, packaging, distribution, communication of ports, and quality control.

The modern world is showing an interest in digitalization, and industry 4.0 technologies (the internet of things (IoT), circular economy, cloud computing, machine learning (ML), and blockchain) are a way to help industries to get to that destination. In addition, maritime logistics and sea shipping need to change their structure to achieve productivity and more efficiency. To achieve this aim, blockchain is a tool that can be used to transform the old maritime transport structure and paperwork and digitize and improve maritime logistics processes. Furthermore, blockchain can add numerous features to all industries, especially maritime logistics, including eliminating intermediaries and brokers through its decentralized structure, resulting in trust between actors. Security and privacy are other leading advantages enabled by blockchain within an unalterable history of transactions. Blockchain also reduces costs and increases the efficiency of an organization. This paper will comprehensively discuss the capabilities of this emerging technology.

A review was conducted on blockchain technology approaches to maritime logistics in the literature, and it was found that the application of those approaches in maritime logistics has been triggered in a few surveys. The approaches proposed in each survey are presented in Table 2. For example, Issaoui et al. (2019, 2020) investigated smart logistics as a part of the fourth industrial revolution to present blockchain trends by classifying the applications of blockchain according to four clusters. They compared works based on two key parameters (or areas of interest) of trust and smart contracts. However, other key parameters, like transparency, were not undertaken in this work. Other studies have focused on other parameters, but none has been comprehensive. Table 2 contains a few untouched parameters. On the other hand, these studies have not focused on maritime logistics performance. That is, in addition to studying blockchain technology in such fields as the food industry and healthcare, they have also dealt with maritime logistics. In this regard, the present study is the first work that has collected 43 related articles and conducted with the aim of identification, taxonomic classification, and systematic comparison of the existing researches. Table 2 also presents some studies reviewing maritime logistics. The characterization taxonomy is

composed of three groups, including areas of interest, case study, and the sector of maritime logistics they are applied to. At this stage, an in-depth review of previous research on blockchain technology in maritime logistics is essential for various groups including researchers, shipping companies, and stakeholders who are planning to integrate blockchain into maritime logistics or carry out further research. Not only does this paper review the research on the application of blockchain in maritime logistics to evaluate and identify the gaps in studies, different trends, and specifically future dimensions of blockchain in maritime logistics but it also discusses how much progress has been made in maritime logistics so far as well as how this cutting-edge technology can affect maritime industry performance from both academicians and practitioners' point of view.

The paper is organized as follows. Section 2 shows the background of logistics, maritime logistics, blockchain, and metrics definition. The research methodology followed in this study is described in Section 3. Section 4 discusses the selected blockchain applications in maritime logistics in two categories. Open issues and challenges, as well as potential future trends of blockchain in maritime logistics, are highlighted in Section 5. Finally, the paper is concluded with a conclusion in Section 6.

Research background and literature review

This section explains the concept and structure of logistics, maritime logistics, and blockchain.

Logistics

There is a difference between supply chain and logistics. The transformation of raw material into end products and their delivery customers are referred to as supply chain whereas logistics refers to the movement of raw materials, services, money, and information within a supply chain (Dutta, Choi, Somani, & Butala, 2020). The logistics also includes moving inside an organization and monitoring the entry and exit of cargo and goods and the flow of information. The logistics includes the integration of information, transportation, inventory, handling of goods and packaging, and, in cases, security. Logistics is a part of the supply chain that adds time and place value (Lee et al., 2012). According to the definition of the World Trade Organization, logistics is a part of the supply chain management process that includes planning, effective utilization, and the control of the flow and storage of goods, services, and information related to it during production, distribution, and delivery from primary suppliers to end customers. The logistics system is an interconnected process for managing and optimizing activities to ensure the proper and rapid transportation of goods between the point of origin and points of consumption to meet customer requirements. The efficiency of a logistics system reduces the overall costs of logistics, thereby providing the related industries with a competitive advantage (Tseng, Yue, & Taylor, 2005).

The process of logistics cycles contains multiple actions including serving customers, product selection, quantification, inventory management, and logistics management information system. Since customers are the most important asset of a firm, firms must have a clear understanding of the customer demand to meet their expectations. Therefore, firms need to have a continuous strategy for achieving this goal. Hence, some steps to develop the desired strategy should be made including visioning, which is the most important step, strategic analysis, planning, and change management. Some of the logistics goals to meet producer and customer demands are minimum inventory, rapid response capability, minimum variance, product life cycle support, consolidated shipments, and production of high-quality products. Several factors impact logistics efficiency, which can be divided into internal and external factors:

- Internal factors: warehouse capacity, shipping time, order accuracy, on-time delivery, transportation cost, damaged products and inventory turnover ratio.

- External factors: globalization, technology, workplace, environmental concerns.

Maritime logistics

Maritime logistics as the primary type of transportation has become the heart of worldwide trade. The industrialization of the world has increased the importance of sea transport. The standard of living has been improved by sea transportation of all kinds of products to people. Nowadays, the maritime industry has gained more importance than ever because the livelihoods of many people depend on it. A wide range of actors is involved in the maritime industry, including suppliers, shipowner companies, seafarers, port authorities, tugboat companies, customs, customers, insurance companies, and banks involved in sea transportation. Each of these actors has a different role in the process of sea transportation and must do their job in an integrated manner to provide an efficient, effective, accurate, and sustainable shipment through the sea. Maritime logistics generally depends on the cooperation of many actors for optimal performance in the supply chain. Interaction between active members of the supply chain is a necessity for effective navigation. Maritime logistics entails processes such as planning, implementing, and managing transportation from one point to another. This industry includes many operations, as was already mentioned, including transportation, inventory management, order processing, storage, customer services, handling, packaging, labeling, information management, returned product management, and site/location selection (Aylin & Yucel, 2016). Maritime logistics is a part of a complex and compact maritime supply chain that consists of a series of interconnected but globally distributed organizations. One of the most promising fields of innovation in this area is digitalization (Weernink, van den Engh, Fransisconi, & Thorborg, 2017). As was already mentioned, maritime logistics has various functions, so it is important to discuss major operations of maritime logistics.

- Transportation management: Transportation in a maritime logistics system is the main operation. Therefore, due to the basic importance of this activity, managers pay special attention to it to reduce costs. Maritime transportation can be categorized into three types including industrial, tramp, and linear shipping. Also, routing and traffic management is a part of logistics transportation and depends on shipping type.

- Inventory management: In managing inventory, the main concern is to keep inventory levels and expenses as low as they can be. At the same time, managers can predict the market by holding information about customers and create coordination with inventory because inventory planning has an important role to play in providing services to customers.

- Demand prediction: The forecast can be defined as what product will be sold where and when. The forecast is the most important factor for planning. Sustainability in the logistics process depends on the effective and accurate prediction of demand. In marine logistics, different departments are involved, each requiring a different prediction.

- Cargo handling: Cargo handling involves numerous services including receiving, storing, assembly, and product loading/unloading from ships. On a large scale, there are two groups of cargo, i.e., general and bulk cargoes. Moreover, each of these groups needs special facilities and tools. To be mentioned, effective cargo handling results in minimizing transportation costs.

- Packaging: Another marine logistics activity is the packaging of products for transportation. There are three main objectives in product packaging, including identifying the product, protecting the product, and helping product handling. Additionally, controlling and care instructions should be considered in packaging.

- Port logistics: The global trade trend is aimed at greater market focus on loading and ports operations because there is competition among the ports. A port consists of several terminals. In addition, ports play an important role in economic progress in all countries as a gateway to global trade. The principal operations of ports are pilotage, towage, and cargo handling.

Table 2. List of contributions from previous surveys on blockchain in maritime logistics.

Study	Publication year	Reviewed maritime papers	Contribution	Goal	Areas of interest					
					Digitalization	Traceability	Smart Contracts	Security and Safety	Transparency	Trust
(de la Peña Zarzuelo, Soeane, & Bermúdez, 2020)	2020	16	Industry 4.0 Maritime logistics	Implementing industry 4.0 technologies in order to optimization	✓	x	x	x	x	x
(Issaoui et al., 2019, 2020)	2019 2020	8 8	Finance Management	Classifying the applications according to four clusters and evaluate the key functions of smart logistics	x	x	✓	x	x	✓
(Anwar, Henesey, & Casalicchio, 2019)	2019	11	Industry 4.0	Clear insight about how can we improve port logistics and develop digital ports via industry 4.0 technologies	✓	✓	x	✓	x	✓
(Marija Jović, Filipović, Tijan, & Jardas, 2019)	2019	18	Maritime logistics	Explain the characteristics of blockchain and emerging trends in the marine industry	x	✓	✓	x	✓	x

Table 2. List of contributions from previous surveys on blockchain in maritime logistics. (continued)

Study	Publication year	Reviewed maritime papers	Contribution	Goal	Areas of interest					
					Digitalization	Traceability	Smart Contracts	Security and Safety	Transparency	Trust
(N. Andersson & Leander, 2019)	2019	10	Maritime logistics	Review basic challenges of maritime logistics and purpose some solution	x	x	x	x	✓	✓
(Liu, Zhang, & Zhen, 2021)	2021	18	Maritime supply chain	Guidelines for Implementing Blockchain in Logistics and Expressing Problems in Marine Logistics	✓	✓	x	x	✓	✓
(Marija Jović, Tijan, Žgaljić, & Aksentijević, 2020)	2020 2019	24 12	Supply chain Maritime logistics	Brings up challenges and barriers of blockchain technology and the impact of blockchain-based information exchange and sustainability	✓	x	x	x	x	✓
Our Study	2022	43	Maritime logistics	Our research shows the existing literature review of blockchain in maritime logistics and discussing the gaps and suggests future directions	✓	✓	✓	✓	✓	✓

Blockchain

Blockchain has been used much earlier than "Bitcoin". For the first time, it was used in "Merkle Tree". However, the most important application of Blockchain was discovered in 2008 when a person or group called "Satoshi Nakamoto" used the distributed ledger technology (DLT) to do digital transactions (Nakamoto & Bitcoin, 2008). In 2009, they explained specifics about how the technology was used to increase digital trust by recording every transaction and established a decentralized network as all information was not controlled by one person. A blockchain is a distributed data structure on interconnected computer systems in which components (or blocks) of the data structure are not linked based on the memory address. There is a new concept of connection in blockchain. Each block is replicated in its previous blocks, as well as throughout the blocks so that if a block fails, it will recover well. All businesses, based on accurate and reliable information, can integrate blockchain into their structures (Crosby, Pattanayak, Verma, & Kalyanaraman, 2016). For this reason, the blockchain network is a suitable solution to receive such information because it provides network members with information securely, transparently, and fast. This information is only accessible to allowed members. A blockchain network can track payments, accounts, orders, productions, and many other things virtually (Aggarwal & Kumar, 2021). There are a number of key elements in the empowerment of blockchain, including distributed ledger technology, immutable records, and smart contracts. When a transaction occurs, it is stored in a block. These deals show tangible (a product) or intangible (intellectual) movement. Each new block that is recorded is connected to the block before and after itself. These blocks are formed whenever a transaction occurs and stored in an irreversible chain that is non-manipulative. Each new block that is added strengthens the previous block and thus the whole blockchain. There are four types of blockchain based on their authentication and control mechanism, which are shown in Table 3 (Bamakan, Faregh, & ZareRavasan, 2021).

Table 3. Different types of blockchain

	Public	**Private**	**Hybrid**	**Consortium**
Advantages	Independence Transparency	Access Control Performance	Access Control Performance Scalability	Access Control Scalability Security
Disadvantages	Performance Scalability Security	Trust Auditability	Transparency	Transparency
Use Cases	Cryptocurrency	Supply chain	Medical Records	Banking

Processes in the industry usually have problems. In this situation, the presence of middlemen may reduce the trust in information, as this data is subject to change. In addition, information recording systems can be vulnerable to fraud and cyber-attacks. Low transparency also causes a delay in information verification and a waste of time and expense (Hou, 2017). All these defects slow down business and result in lagging behind the

competitive world. It means that we need a better way for implementation and "blockchain" provides us with such a way because this fresh technology brings lots of benefits to businesses as follows:

- Greater trust: With blockchain, you can ensure that data is provided to you at the right time and accurately and that your data is shared only with members who have access to the network.
- Greater security: Each transaction is approved by the agreement of the majority of network members, so consensus on the accuracy of the data is required for all network members because transactions could not be deleted or changed after registration.
- More efficiency: By using smart contracts, which is a set of automated rules, transparency and speed of transactions through the network increase. It also cuts costs and paperwork, thereby leading to more efficiency and productivity.

Materials and Methods

A deeper understanding of the application of blockchain in maritime logistics requires a systematic review that follows an exact sequence of methodological stages to research the literature. A systematic review depends on several items in which search strategy, sources of data, and research questions play an important role in achieving goals. These items contribute significantly to documenting and analyzing the results. Hence, this section gives a brief description of each.

Research questions

Research questions specify the scope of the research, and the process of answering the research questions determines the rest of the research path. Five research questions are defined that clarify the basis for obtaining the strategy of the search for extracting the literature, as outlined in Table 4.

Search strategy

To answer the research questions, steps have been taken to collect and analyze data. To make sure there is no similar work, we surfed the Google Scholar with the following keywords:

(*maritime logistics*) [AND]
(*blockchain*) [AND]
(*survey* <OR> *review* <OR> *overview* <OR> *challenges* <OR> *trends* <OR> *issues* <OR>*study*)

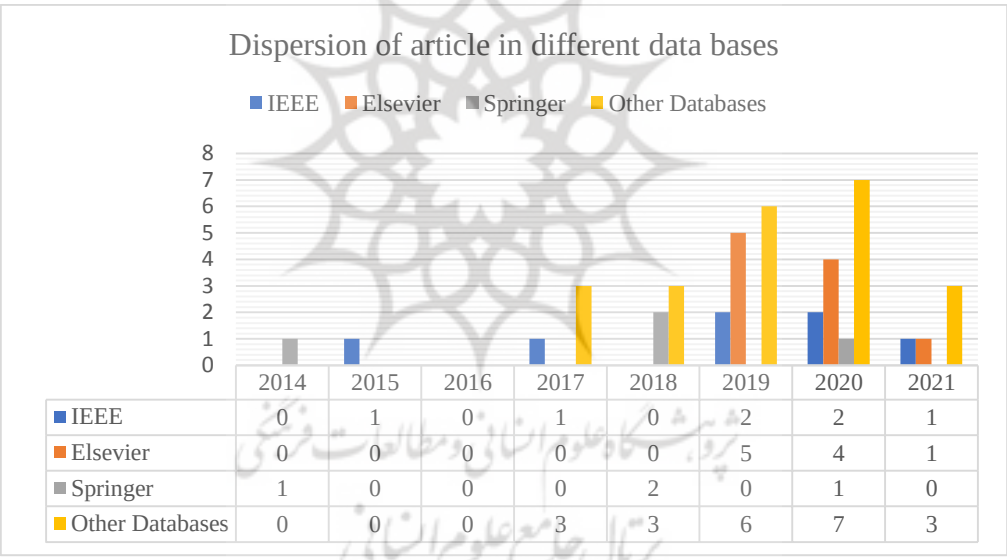
Table 4. Research questions

RQ1	How much progress is maritime logistics based on blockchain?
RQ2	What is the difference between using blockchain and traditional methods?
RQ3	How to implement blockchain for performance improvement of maritime logistics?
RQ4	Which research gap is still unaddressed in blockchain application in maritime logistics?
RQ5	What are the open issues, future trends, and challenges of blockchain in maritime logistics?

As stated in Section 1, no focused research was found. Therefore, due to the importance of blockchain technology in maritime logistics, the aggregation of available evidence was considered. It was observed that basic research into the blockchain issue in maritime logistics started in 2014. So, the search window was selected within the period from 2014 to August 2021.

Sources of data

To access previous articles, we selected some credible academic databases and search engines that included all electronic platforms. For this purpose, reputed scientific databases including ACM Digital Library, IEEE Xplore, Scopus, Springer, Web of Science, etc., and many useful and relevant papers were inspected. Fig. 2 succinctly describes the distribution of articles across the reviewed years. As illustrated in Fig. 2, exponential growth in research is significantly observed from 2019 to August 2021. Besides, the majority of these papers are published in Elsevier.



	2014	2015	2016	2017	2018	2019	2020	2021
IEEE	0	1	0	1	0	2	2	1
Elsevier	0	0	0	0	0	5	4	1
Springer	1	0	0	0	2	0	1	0
Other Databases	0	0	0	3	3	6	7	3

Figure 2. Year-wise collected research papers

Classification of the selected studies

The maritime logistics system, today, needs to improve efficiency in managing its processes. Also, a safe and secure flow is required for the distribution of goods. In logistics, real-time access, visibility, and integration are very important for the occurrence of processes at the right time. Especially, this information is highly important in ports. "Digital ports" are referred to as ports where all information to monitor and guide goods to their final destination is shared among members in an online platform. In this regard, blockchain can have a great impact. As such, it causes economic and social changes. Consequently, due to the increasing need for technologies of the fourth industrial revolution and to shift away from the old structures, different technologies of industry 4.0 have been used in each industry, each of

which is suitable for a specific sector and may not be the solution to problems for another industry. Since blockchain applications are the main purpose of our study and blockchain has many advantages for global business because of its capabilities, such as decentralized and distributed features, whereas global trade has a wide range of scope, so the use of blockchain is not limited to marine logistics. Therefore, this section is grouped into three clusters categorized based on areas of interest, case studies, and the parts that studies have focused on.

Areas of interest

The classification of articles in this section is based on the features listed in Table 2 to identify how blockchain can add benefits to different parts of maritime logistics operations.

Digitalization

When ships enter and leave ports, vital information must be exchanged with various entities. However, the way the information is shared is crucial, so digitalization is the key. It not only reduces errors but also improves information quality. In a study by Hossain (2017), details of blockchain features were analyzed based on the transformation of digital businesses in sea shipping, and different platforms of blockchain and the integration of blockchain with the IoT were introduced. In 2020, Philipp (2020a) carried out a study bases on collected qualitative and quantitative data, which was used by applying the Business Model Canvas and presented a case study to show the advantages of digitalizing maritime operations and control emissions. A study was conducted by Yoon (2020) to identify the most suitable features of blockchain for the development of maritime industry digitalization and the adoption of blockchain technology in port logistics by using the analytic hierarchy process (AHP). At the same time, to understand the main drivers and barriers of digital innovation, Gausdal et al. (2018) conducted a case study to demonstrate the possibility of digital transformation. Wang et al. (2020) also proposed a framework based on digital models to improve the efficiency of ships in ports, in which all information shared in the platform is stored in blockchain and plays an important role in the moorings. Moreover, a decentralized data network was introduced by Perera and Czachorowski (2019). They demonstrated that blockchain-based digital models can be used to operate a bit of ship and navigation conditions. Further, some researchers have investigated the readiness of digital transformation and digital innovations in port logistics. In a study by Philipp (2020b), port performance was measured via a maturity model. As is known, the concept of the Bill of Lading (BoL) is a prominent factor in the maritime industry. So, Henesey et al. (2019) assessed blockchain feasibility in BoL digitalization.

Traceability

Traceability can be defined differently in various industries, but in our study, traceability can be defined as monitoring and following cargo and ships' movement to catch real-time information and make maritime more efficient. Product tracing and tracking are two of the main challenges of maritime logistics, so an investigation was conducted by Alkhoori et al. (2021) in which IoT was used to increase underlying transportation tracking and visibility and

monitor cargo using a test Ethereum blockchain platform and cloud services. In addition, considering blockchain as a tool for data recording, possible applications of distributed ledger technology for the management of overboard discharge were examined by Vujicic et al. (2020). As transactions in blockchain distributed ledger are illustrated to all actors of the network, tracing of goods and shipment is merit for maritime logistics. Thus, Loklindt et al. (2018) carried out semi-structured interviews to document exchange. Consequently, Bagloee et al. (2019) worked on tracking and found traceability as an enabler of blockchain platforms by eradicating third parties and eliminating the need for a central authority. Cruz et al. (2020; 2021) proposed the Ethereum blockchain platform to track the fishery value chain from the beginning to the consumption point. Some experts have proven the effect of blockchain implementation on understanding the source of the products in the maritime industry within a pilot program. This was investigated by Behnke and Jensen (2020).

Smart contracts

Essentially, a smart contract is a self-executing type of computer principals intended to facilitate and verify maritime transactions automatically in a faster and safer way to conduct negotiations without the need for intermediaries. In the shipping industry, smart contracts can save expenses by wiping out traditional paperwork, increasing security as data are immutable in a blockchain platform, and enhancing accuracy because all operations are automatic. In a paper by Peronja et al. (2020), smart contracts are a suitable way to decentralized maritime operations, especially in the BoL, which is considered one of the most important assets in the maritime industry. Moreover, Philipp et al. (2019) discuss how blockchain smart contracting can facilitate the implementation of collaborative logistics infrastructure and presents a case study based on expert opinions. According to Kamolov and Park (2018), smart contracts must replace traditional structures by applying IoT in ports to achieve a smart transition. Another research in the field of smart contracts has been done by Han et al. (2020), which presents a global platform to achieve effective transactions. Tsiulin et al. (2020) worked on blockchain and smart contracts to understand and compare the existing innovative concepts of document handling function in the maritime shipping and digital industry.

Security and safety

By implementing blockchain technology, information exchanged between port authorities and shipowners is important for the security, safety, and environmental protection of crews, passengers, and more. The blockchain has recently been used in the BoL for maritime operations, and it has helped to reduce fraud and increase the speed of transactions. However, in order to use the technology in autonomous maritime transportation, which is based on communications, the security of data is essential so, Petkovic and Vujovic (2019) explain the use of blockchain to enhance autonomous shipping security. Additionally, in a paper by Mamoona Humayun et al. (2020), a four-layer framework is proposed for the sake of interconnected massive vehicles with the integration of IoT and blockchain. The research presents two real-life case studies to show that IoT alone is not secure and it needs

blockchain. According to Tsiulin and Reinau (2021), digitalization of ports has constantly been one of the main efficiency drivers of the economy, so a case study presented within smart contracts to measure the feasibility of blockchain to upgrade security and long-term development strategies. Additionally, a paper with the subject of the feasibility of blockchain applications to enhance transparency and security based on the Hyperledger Sawtooth framework is introduced by Ashraf Shirani (2018).

Transparency

Lack of visibility and accountability comes from an absence of transparency, as it is a critical factor in the maritime industry. Transparency adds numerous benefits to the shipping industry including eliminating corruption, increasing sustainability, and helping decision-makers to make the right decision at the right time. The digital solutions for the automation of smart ports with the help of artificial intelligence for transparency result in maximum service, so these concepts have been examined by Igor Ilin et al. (2019). A case study with Rhenus Logistics, which is one of the international leading third-party logistics providers, has been presented by Ewald et al. (2021), in which digital handling, smart contracts, and traceability for the sake of more transparency and efficiency in maritime operations are described. Since efficient tracking shipment is essential for global trade, Hasan et al. (2019) have researched that blockchain can improve efficiency and tracking by the means of smart contracts to monitor the interaction between manufacturer and consumer to remove intermediaries. According to Jović et al. (2019), due to increasing cargo volumes and information, it is necessary to develop port community systems. They also reported a case study in which smart contracts and IoT are used to make ports smarter.

Trust

Without trust, a business cannot hope to survive. In this regard, the goals and motivation of stakeholders should be clear in a network to convince other actors to share their information. A recent study by Zyskind and Nathan (2015) has illustrated the use of blockchain protocols for automated access control. They implemented a standard cryptographic structure combining off-blockchain and blockchain recording encrypted data while logging pointers on blockchain. Besides, a decentralized blockchain platform allows users and stakeholders to make better decisions for their organizations, as a digital ledger provides immutable records of data and store them permanently, so Boison and Antwi-Boampong (2019) have worked on this subject. The focus of Nguyen et al. (2020) has been on the potential operational risks of the blockchain-integrated container shipping systems, as well as strengthening security and improving efficiency by the means of blockchain. Unfortunately, corruption is one of the most important social challenges that today's business world deals with. It is, therefore, essential to establish a secure network to reduce uncertainties among users, which has been investigated by Sarker et al. (2021). Similarly, a study by Berman et al. (2020) based on the Robonomics platform provides encrypted decentralized technologies based on distributed ledger tools and market mechanisms for managing the work of diverse multi-vendor cyber-

physical systems to build trust. Lately, the physical internet has attracted the attention of many researchers because of the goal of a paradigm shift towards economic, environmental, and social logistics. In this regard, an article by Meyer et al. (2019) presents a framework for dealing with the concerns of physical internet and physical properties in the logistics network and decentralized management. It argues that blockchain can solve the issues by establishing trust.

Case study and focus of the papers based on blockchain

Simply, a case study is a method that uses more information sources to systematically examine individuals, groups, organizations, or events. Case studies are used when we need to understand or explain a phenomenon. They have several advantages, including mass information processing. You can also find more resources in case studies. Besides, the documents and evidence provided by this type of research improve the importance and accuracy of the research. In this section, case-study papers are classified based on the continents or countries where they have been conducted, their aim of applying blockchain technology, and their method (Table 5). Also, the marine logistics processes addressed by these case studies are described. These case studies or frameworks have been implemented on a portion of marine logistics. In a nutshell, a five-layer framework based on blockchain-IoT is proposed by Komathy (2018) to interconnect various trade activities through shipping including banking, finance, and supply chain. As blockchain technology is still immature, and in its earlier stage of development, some works are conducted to measure the feasibility of blockchain adoption in maritime logistics. For instance, Di Gregorio et al. (2017) assessed blockchain likelihood by the means of technology adoption in the supply chain (TASC) model. Yang (2019) also examined the effect of blockchain technology on the development and improvement of maritime logistics, in which data were collected with a questionnaire. In (Francisconi, 2017), based on a CANVAS framework, the impact of blockchain on the ports business model is evaluated. Briefly, this research has categorized four blockchain business cases and evaluated their relative impact on port logistics. Since pollution of the sea by leaking fuel from ships poses many problems for the environment and humans, such as cancer and asthma, the blockchain-based platform suggested a framework to track and trace fuel conditions by recording them in a ledger in order to check the transfer of fuel at the terminal and final combustion ("Blockchain Technology and Maritime Shipping: An Exploration of Use Cases in the U.S. Maritime Transportation Sector," 2020). Cost reduction and a high level of strict regulation in maritime industry are purpose of applying blockchain technology in marine industry. According to Gausdal et al. (2018), a three-dimension cluster is presented based on Jaccard's coefficient to examine the sources by coding similarity. A case study was adopted by a qualitative approach to figure out blockchain merits and demerits. According to Boison and Antwi-Boampong (2019), blockchain technology in port logistics can control users' access and assets' distribution by the tamper-proof record of data, thereby boosting the transparency and traceability in the network. It can also provide a platform to facilitate

payments for products. In a study by Hasan et al. (2019), a framework and solutions are provided using Ethereum blockchain by the means of smart contracts to wipe out the need for trusted third parties. Also, a single echelon supply chain contract is implemented and designed between contract correspondents. Through a paper by Bagloee et al. (2019), inspired by the opinion of using smart contracts and blockchain, Bagloee et al. (2019) proposed a scenario in transportation and traffic management, which allows traffic authorities to issue a limited number of mobility permits, distributed equally among all users. They demonstrate that tradable mobility permits (TMP) can mitigate traffic congestion. Table 5 summarizes the reviewed case studies along with the type of the blockchain (private, public, hybrid, or consortium) networks used to implement or simulate their work.

Discussion, challenges, and future directions

Due to the increasing development of maritime logistics and the growing need for advanced technologies, a lot of progress has been accomplished concerning the implementation of blockchain. However, many current issues and challenges still need both more analysis and discussion. Based on the existing literature, challenges and future research direction can be identified as follows.

Discussion

Given the geographical extent and distribution of manufacturing firms, sea logistics has become more attractive. Meanwhile, the lack of clear transparency, corruption in organizations, and scandal in audits has led to a reduction in global communications, resulting in a lack of willingness to invest in the maritime sector. Therefore, the fourth industrial revolution technologies are used to change business models, change the old structure of supply chain and logistics, and add value to the organization's cycle. The subject of our discussion in this study is the use of blockchain in the maritime logistics industry, so all studies conducted in the maritime sector can be viewed as a significant relationship between sea logistics and maritime logistics. On the other hand, a lack of attention to the potential of blockchain in maritime logistics is observable because there are few studies in this regard and that has created a motivation for research in this context.

Enhancing maritime performance based on blockchain is a global issue whose settlement needs noticing blockchain features and what this novel technology can bring to this industry. As you know, traditional supply chain and logistics slow down processes and operations because many parts of the logistics value chain are dependent on manual tasks since the regulatory authorities have made them compulsory. Literally, blockchain technology has a wide range of uses in maritime logistics. Blockchain has an effective role in this context and can foster trust between stakeholders by providing transparent data and ensuring secure exchange. In addition, it ensures the visibility of time-stamped proofed data, which are all visible to all parties involved; this is called digitalization. Digitalization can support port authorities to transform old businesses into novel business models to build diverse development and increase productivity.

Also, blockchain offers a substantial potential for developing logistics activities and allows an efficient connection for the supply chain by automated information and financial flow via smart contracts. It can create efficiency and reduce transaction costs as well. Additionally, smart contracts could transform commercial services into a digital form and enhance underlying business processes by eliminating paperwork and cutting down bureaucracy. Blockchain can track goods from the origin until delivery to the final destination. As such, not only does it make cargo check faster but it also reduces the risk of penalties for customs authorities.

As was mentioned, maritime performance can be upgraded by blockchain characteristics. Blockchain can influence all sorts of sustainability such as economic, environmental, and social sustainability. The maritime industry is still struggling with high air pollution, but blockchain can offer some environmentally-friendly solutions. Although it is related to the environmental aspect of sustainability, when it comes to the social aspect, it usually refers to trust between stakeholders and data security. It also minimizes human errors, decreases the possibility of providing inaccurate information, and reduces rework, which are key characteristics of blockchain technology. In addition, maritime can take advantage of predictive analytics. As it is known, big data has an enormous impact on the industry. It has the power to optimize processes and establish a cyber-security system against cybercrime and piracy, ensuring a fair deal for all parties involved.

Since it has been revealed that the application of blockchain technology has many benefits for marine logistics, it has attracted a lot of professionals to its use. Thus, according to Fig. 3, there are nine ways by which blockchain can add benefits to maritime logistics. Currently, blockchain is a competitive advantage for ports from the academic perspective. Since sustainability is one of the main issues in the evolutionary and digital development of structures, it can contribute significantly to this issue. In addition, advantages such as improving delivery quality by allowing customers to monitor the documentation from the distributor to see all events in logistics processes as well as simplifying data exchange via allowing all information to be transmitted in an arranged and secure manner can also be provided. On the contrary, since blockchain has just entered maritime logistics, it has challenges that are mentioned in the next section.

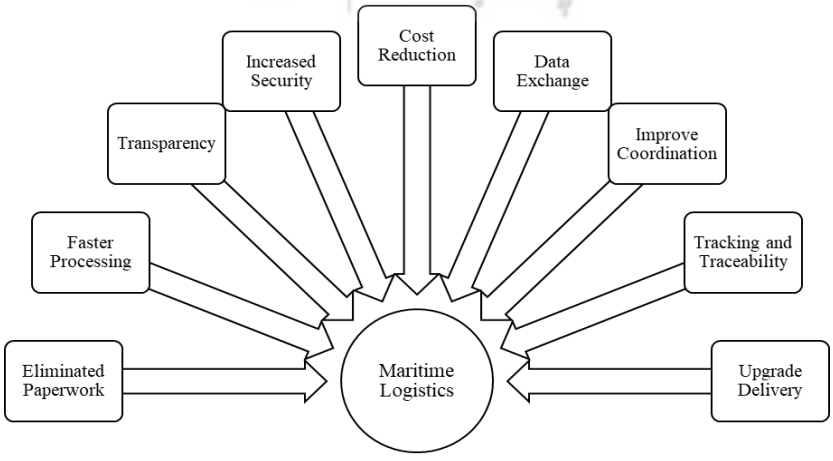


Figure 3. Nine ways by which blockchain will affect the shipping industry

With the special capabilities that blockchain possesses, many companies are attracted to this new technology, but before this paper points out the progress of this technology in logistics, it must be said that this technology is still in its early stages and there is a lot of uncertainties. However, the application of this technology at the industry level is broad and it has to be noted that most of the uses of technology are in the financial and business sectors although effective uses of blockchain can be mentioned in the maritime logistics industry. Multiple companies such as Walmart, Nestle, Unilever are cooperating with IBM to develop a system for inventory tracking. The technology will allow the company to backtrack individual food items from the origin point. Maersk, the world's biggest operator of shipping containers, has already been involved with blockchain to improve freight and shipping. They alongside the US Department of Homeland Security use the technology to keep tabs on the movement of their cargo across international borders (Balci & Surucu-Balci, 2021).

As this paper aims to explain the importance of blockchain technology and how it is used in the maritime industry, our audience is composed of two groups of academic people and industry people. This research argues about the use of blockchain for both scholars and practitioners to benefit from both in their research and in future practical works. The contribution of this study for researchers is to give them a new standpoint about blockchain and how it can be implemented in maritime logistics. It also highlights some future research to find some solutions for blockchain limitations. Moreover, the article addresses the existing gap in the literature, so academicians can use it for their future research in the field of blockchain, It is also suitable for those who are seeking information about the blockchain and its applications in logistics. Additionally, this survey is beneficial for practitioners because it gives them a managerial perspective so they can use it in their industry and recognize why blockchain is appropriate for corporations. So, it can contribute to improving productivity among organizations and increasing the understanding of this novel concept. Perhaps industry people are the perfect group for implementing blockchain in the near future.

Table 5. Categorization of the case study papers

Paper	Continent (country)	Focus of the study	Name of organization/port	Method	Network Type
(Boison & Antwi-Boampong, 2019)	Africa (Ghana)	Ships tracking	West Africa sub-region	Qualitative approach	Consortium
("Blockchain Technology and Maritime Shipping: An Exploration of Use Cases in the U.S. Maritime Transportation Sector," 2020)	America (U.S.A)	Fuel quality traceability Shipment tracking, Smart bills of lading	U.S department of transportation maritime administration	Conducting initial pilot trials	Private
(Henesey et al., 2019)	America (U.S.A)	Evaluation on the concept of crypto-currency	Small terminal in west coast U.S	Simulation method/NetLogo in python	Public

		in coordination and control of container stacking operations		language	
(Yoon et al., 2020)	Asia (Korea)	Priorities of blockchain adoption	1. Busan 2. Incheon	AHP analyze	Not Mentioned
(Tan, Zhao, & Halliday, 2018)	Asia (china)	Less Container Load Operations	China	LEP platform	Public
(Gausdal et al., 2018)	Europe (Norway)	Cost reduction	Norwegian offshore industry	NVivo software and a coding scheme	Private
(Philipp, 2020a)	Europe (Sweden, Poland)	Liquefied Biogas (LBG) Sulphur emission control, Reduce emissions	1. Karlskrona 2. Gdynia	GoLNG project INTERREG V B Baltic Sea Region programme	Private
(Ewald et al., 2021)	Europe (Germany)	Transportation management	Rhenus Logistics	Business research methods	Hybrid
(Philipp et al., 2019)	Europe (Germany)	Improving, Cross-border connectivity Sustainable transport	Wismar port	INTERREG projects	Public
(Hiranandani, 2014)	America (U.S.A) Europe (Netherland) Oceania (Australia) Africa (South Africa)	Sustainability Globalization	1. Port of Long Beach 2. Port of Rotterdam 3. Sydney Ports	Sustainable development framework	Public Private
(Tsiulin & Reinau, 2021)	Europe (Denmark)	Document workflow management Long-term development strategy Device Connectivity	Aarhus, Copenhagen, Malmo, Esbjerg, Aalborg, Fredericia and Hirshals	GDPR rules	Not Mentioned
(M Jović et al., 2019)	Europe (Croatia)	Optimized traffic across, Transport modes	Croatian seaports	PCS ICT solutions	Not Mentioned
(Berman et al., 2020)	Europe (Italy, Russia)	Trustable environmental monitoring	Heron Robots, Genova, Italy Airalab, Tolyatti, Russia	The robonomics platform based on a software called AIRA	Public
("Smart port with blockchain,")	Europe (Belgium)	Secure system for collecting container in the port	Port of Antwerp	T-Mining	Public

Challenges

Undoubtedly, managers, producers, and many businesses are eager to use blockchain. Indeed, since 2008, when blockchain became famous, it became one of the most influential modern world technologies. But it is not easy to implement and adopt it because until it become more broadly adopted in the marine logistics, like all new technologies, this technology has its problems, and this has slowed its development. Although, digitalization for blockchain is provide new revenue and valuable opportunities and also smart contracts automate business processes and increase productivity, but if they are not execute and developed correctly, hackers may cause an issues for both security and transparency of the blockchain which they are blockchain capabilities too and all of these malfunction will affect on chain and erodes trust between members. So, weak programming and management are additional challenges for a modern technology. Here, we discuss some of the problems of this novel technology. Blockchain is faced with several challenges for its implementation such as organizational, technical, and operational challenges.

- Organizational challenges: Primary challenges for corporate and organizations, especially the small and medium ones, are a lack of understanding about what blockchain is and how it can be implemented in the industry. Therefore, this may hamper investment and waste ideas. Another issue is the lack of cooperation, which brings lots of value to each organization if they work in a "shared pain or shared opportunity" environment. Yet, the unwillingness of enterprises to share their information is a major problem. Moreover, although blockchain could ensure data security and allow their management through the chain, it has some serious problems with the privacy and personal information of customers. Also, when it comes to a novel technology, local and global regulations always try to stop its progress and development. Therefore, as a destructive technology, blockchain operations across the globe are facing a lack of regulatory standards, inadequate monitoring technology, and a lack of regulatory experience.
- Technical challenges: The technical barriers that emerge are mainly represented in several ways. One of the main challenges that occur in the technical context is scalability. Since the nodes in the chain must process all the transactions carried out in the system, when a deal is developed in the global context, the technology will take a lot of energy and the calculations within the block will have significant energy consumption, so it is limited in scalability. Besides, transition and integration of people is a huge change in all aspects of an existing business, it is a big issue for all stakeholders to change their culture and work methodologies. Also, uncertainties and lack of awareness about its future hamper acceptance. Despite the improvement of blockchain, a critical shortage of professionals and experts is a significant concern for all companies.
- Operational challenges: Using new technologies instead of the old structure is costly for any organization. Also, the cost of learning this technology for employees brings costs to

that organization. In addition, ledger size is an important issue because, in the present world, the volume of data is very high and it is essential to record all the data in the ledger. In this situation, transaction processing speed is an important matter, but the delay in processing in some platforms is a major problem. Additionally, protecting the privacy and information of users involved in the network is a very important issue that brings concerns to stakeholders and makes them refrain from participating in their applications.

Future directions

Initially, before proposing a direction for the future, it is first needed to understand what problems are in the way of implementing this technology. Some of them are mentioned in the previous section.

- Firstly, to achieve an arbitrary result in the application of blockchain, models and quantitative variables can be used to analyze the impact of this technology on maritime logistics, especially in demand forecasting, which is one of the critical factors for planning in maritime logistics. Blockchain will eliminate third parties and facilitate investment decisions by automating contracts between producer and consumer.
- Secondly, it is also possible to eliminate some of the obstacles in marine logistics by removing the technical problems available in smart contracts. Moreover, by integrating ML and blockchain, predictions can be made more precisely in inventory management. This integration can impose a positive impact on coordinating their inventory management systems and also cargo handling.
- Thirdly, according to the structural equation model (SEM) and deep learning algorithms, a pattern can be predicted for blockchain structure. In addition, SEM can be integrated with conceptual models to measure the feasibility of blockchain in maritime logistics. Distributed computing systems, such as fog/cloud computing, can also be used to deal with cyberattacks.

Since blockchain requires proper rules and governance, more studies are needed to use blockchain as a standard and according to rules. In the end, attention to existing risks such as high energy consumption and hard disk capacity is essential and must be addressed in subsequent studies

Conclusion

Ultimately, disruptions and uncertainties in maritime logistics processes have inspired managers to use blockchain in maritime operations and have led to smart ports. Blockchain has the potential to make processes more efficient through the use of smart contracts and regulations. Besides, applying novel technologies in various industries is increasing over the years, among which blockchain is one of the most promising technologies. As it brings a myriad of benefits to organizations including digitalization of documents, transparency to

realize real-time data, traceability to allow tracking shipments and goods, security and safety in operations and conducting smart contracts to make operations more efficient by automating them. Despite all advantages, using blockchain needs cooperation and legal efforts in different stages.

Although this emerging technology could have many applications in inter-organizational activities and research on its applications is increasing, it has not reached maturity yet and there are a lot of uncertainties about its applications. Furthermore, the majority of organizations assume that blockchain is complex so the lack of a technical team is one of the main issues versed in this field. During the review of the literature, it was found that a few studies have exclusively addressed the use of blockchain in the maritime logistics industry. Thus, academic studies are needed on organizational change, social interaction, individual acceptance, and global trade. Finally, this study can be used to enrich the use of new technologies. It can also promote the application of blockchain technology in maritime logistics.

Conflict of Interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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