Blockchain technology in maritime industry

Peronja, Ivan; Lenac, Kristijan; Glavinović, Roko

Multidisciplinary
SCIENTIFIC JOURNAL
OF MARITIME RESEARCH

University of Rijeka
FACULTY OF MARITIME STUDIES

Multidisciplinarni
znanstveni časopis
POMORSTVO

https://doi.org/10.31217/p.34.1.19

Blockchain technology in maritime industry

Ivan Peronja[1], Kristijan Lenac[2], Roko Glavinović[1]

[1] University of Split, Faculty of Maritime Studies, Ruđera Boškovića 37, 21000 Split, Croatia, e-mail: iperonja@pfst.hr; rglavinov@pfst.hr
[2] University of Rijeka, Faculty of Engineering, Vukovarska 58, 51000 Rijeka, Croatia, e-mail: klenac@riteh.hr

ABSTRACT

Maritime industry is one of the most globally connected industries that include transportation of numerous types of goods and documents across the world. With that said, it is safe to say that abundance of financial and paper-trail transactions are made every day in order for goods to be transported from one place to another. The scope of this paper is to show that by implementing blockchain technology savings in time and money could be generated. This paper presents costs of container freights and rates in the last few years and assumes possible future costs of container freights and rates if blockchain based technology is implemented. Additionally, by using comparative method economical and time value of "traditional" bill of lading is compared with a blockchain bill of lading solution. It is also important to mention the potential impact of the blockchain technology on the world environment and ecology by reducing global paper consumption and emissions from vehicles that are used in the transportation process. This paper also gives a descriptive and comprehensive overview of current and future applications of blockchain technology in maritime industry.

ARTICLE INFO

Review article
Received 11 November 2019
Accepted 4 June 2020

Key words:
Blockchain
Maritime industry
Shipping
Smart contract

1 Introduction

Blockchain is an innovative technology that promises to disrupt applications and use-cases across most industry sectors, including the maritime industry. It is a platform that can transform many existing business processes and enable new ones. It has now been recognized as a pragmatic solution to different business problems [8].

This paper will argue that the use of blockchain technology in maritime industry will enable faster, safer and more efficient business. The paper will also show that the amount of capital and time saved by using this technology is significant compared to current expenses in maritime industry. Blockchain technology has the potential to transform the maritime industry by improving different aspects of processes and workflows currently in use by governments, maritime institutions, ship owners and other stakeholders in maritime industry. Blockchain technology, and new applications enabled by it, are steadily but surely being introduced in various industries. There are a number of possibilities for this type of technology [8] [11]. Several well-known companies have already carried out the necessary business changes in order to implement this technology. A relevant example being the joint venture formed by IBM and Maersk for the adoption of blockchain based solutions in maritime transport.

In the next chapter the blockchain technology is explained in detail sufficient to understand it's relevance to applications in maritime industry. The core properties and principles on which the technology is based are mentioned and discussed, giving fundamental meaning to the technology and a starting point to future users.

The third chapter further explains the possibilities of implementing the blockchain technology in maritime industries and in the process of transporting goods from one place to another. In particular, the chapter considers the advantages of using the blockchain technology for

processing the documents that have to be issued with the cargo during the whole transport process resulting in increased efficiency and time and cost savings.

2 Blockchain technology

The blockchain is a distributed database that does not need a central authority and eliminates the need for 3rd party verification [21]. It was first introduced for the Bitcoin cryptocurrency [26] [21] as a public ledger to keep count of all the transactions.

The idea of blockchain is a simple one: to avoid the need of mediation by using a distributed ledger that everybody agrees upon. Instead of placing trust in the authority or an intermediary, the trust is shifted to a computer code. However, the implementation of this simple and powerful concept and the technology behind it is actually very complex. In a blockchain implementation, this code runs in computers connected in a public or private network that communicate in a peer-to-peer-fashion. These computers, called nodes, are always ready to accept connections from other nodes and users of the same blockchain network. Each computer holds an identical copy of the database, a distributed ledger shared and synchronized across the entire network so there is no single point of failure.

The users can interact with the blockchain using simple software clients available for all common computer types, platforms and operating systems including smartphones and browser plugins. The data sent to be written to the blockchain is mathematically encrypted and digitally signed. It gets aggregated in blocks which are appended and cryptographically linked to a previous block, thus forming a chain of blocks, a growing ledger of historical records. Once the data is written and accepted by the nodes, no deletions or modifications are allowed, making the blockchain practically immutable.

The difficulty that was solved with the introduction of the Bitcoin cryptocurrency was to accomplish the above even in the presence of malicious nodes that do not follow the rules. A consensus protocol called Proof-of-Work was introduced to validate a new block of data with all other participants before it can be appended to the chain of blocks [18]. The description of the Proof-of-Work and other consensus protocols that have been proposed in the meantime is out of scope of this paper. What is important to know is that reaching a consensus between the majority of honest nodes on the contents of this distributed ledger means that everybody agrees upon the state of the database and thus prevents double spending and fraud without any need for a trusted party and central authority.

2.1 Blockchain properties and fundamental principles

By organizing the data in this way, the blockchain realizes some important properties:

- **Decentralization**: Data is replicated in a distributed network of nodes thus eliminating several risks that are present when data is stored centrally. There is no single point of failure;
- **Tamper resistance**: A consensus protocol used to validate the blocks of data appended to the ledger and the decentralized nature of the blockchain makes it extremely difficult for anyone to tamper with the data stored;
- **Security:** In addition to the security of the data in the form of immutability gained from the distributed consensus, blockchains use digital signatures and strong cryptographic primitives to sign and verify the data submitted to the network. Each user uses a private key to generate a signature for each blockchain transaction. This signature is used to confirm that the transaction came from that particular user and allows to verify its validity. The signature cannot be altered since it has been already issued [24]. All the data which makes up a blockchain is thus encoded. In order to perform some operations on data, you need to be in possession of the private key corresponding to that data, thus proving that you are entitled to make the operation, otherwise the blockchain node that received the request will simply discard it as invalid.

Blockchain also realizes the following additional fundamental principles:

- **Openness**: Blockchain is open and accessible to anyone. In public blockchains this means literally anyone can participate in the development and maintenance of the blockchain code or a decentralized application on top of it, in running a node and validating transaction (for a reward), or just simply using it to store information, verify documents and/or make any kind of a transactions allowed by the particular blockchain network. In blockchains run by an organization for internal use, blockchain is accessible to anyone who has been given permission to view it. This means that anyone on the network can monitor the shared ledger for changes. Blockchain code in particular is regularly released as open source to increase the trust in the system by providing transparent view on how the code works. The security is also increased allowing the code to be verified by many developers and making it less susceptible to bugs and malicious modifications. The open nature of blockchain reduces the barriers to enter, fosters growth of the ecosystem and is inclusive towards start-ups, business companies and individuals;
- **Transparency**: Blockchain makes the data open and transparent. All the network participants can view the data and the transactions stored in the shared ledger in real-time. They can access the information of interest using tools like block explorers that search the blocks of a blockchain and index their contents. A consensus on the blockchain contents guarantees that all the participants share the same view, even if they do not trust each other;

- **Network integrity**: The integrity is embedded in every step of the process and distributed in system, so it does not depend on one individual or institution. This principle implies that the network is decentralized, and all the users together maintain the integrity of the network. The trust comes from within, from the individuals who use the network. The members of the network can share data through the network considering that the other side will also follow this principle [7];
- **Distributed power**: There is no central point of control in a completely decentralized peer-to-peer network. It means that no individual or organization can shut down the network. If someone tries to overpower the blockchain, the costs of it would exceed the financial benefits [7];
- **Value**: The value of blockchain comes from its users and technology. In public blockchains the users are incentivized to participate in the network (running full nodes and validating transactions) by being rewarded for it in a form of the underlying cryptocurrency [9] [26].

  The value of the cryptocurrency comes from the fact that its supply, as encoded in source code of the blockchain, is limited. It is a scarce resource that can be used as a payment method and can be transferred electronically between two users that do not trust each other directly, without mediation of the financial institutions. Blockchain is often called Internet of Value because it enables attaching value to information that is exchanged between parties. In this regard, blockchain is as revolutionary as was the Internet for the global exchange of information;
- **Privacy**: Privacy is a principle which states that individual alone ought to be the owner of their information. Nowadays a lot of institutions and companies are collecting data about different individuals or other companies and institutions without their knowledge or consent. Since data written to blockchain is permanent and accessible to all, a special care to safeguarding privacy is necessary. Sensitive data is therefore never directly stored on blockchain. Instead a hash, i.e. a digital fingerprint of the data is encrypted, signed and stored on blockchain. This is sufficient to verify the document authenticity, provenance and the exact moment when it was stored (when the hash was included in the blockchain). The document can be safely and privately stored elsewhere. This gives rights to the individual to decide which information will be allowed for usage by institutions or other persons. For example, proving the possession of knowledge, the authenticity of a document and/or the moment of its creation are often all that is necessary, without having to reveal the contents.

2.2 Types of blockchain networks

In general, blockchain networks are classified as private or public depending on the degree of openness of the system to participants.

In a public blockchain anyone can participate both as a user and as a developer of applications that run on top of the blockchain. The code and the rules coded within are fully transparent. Anyone can publish and validate transactions and any node can join the network without permission. All the transactions can be observed by all the nodes in the network. In public blockchains the participants that run the nodes and validate transactions are typically incentivized to run the nodes and validate transactions in the form of the underlying cryptocurrency. Examples of public chains that run on open peer-to-peer networks are Ethereum and Bitcoin.

In private blockchains there is an administrator that regulates the access to the blockchain. Private chains run on a single node operated by the administrator or multiple nodes operated by the participants that were granted that right from the administrator. All the users of the blockchain have to trust the administrator. Due to the presence of a single blockchain regulator, the model that private blockchains provide is not that far from a distributed database in a cloud. Private blockchains do not have to incentivize the participants to run the nodes and validate transactions. Complex consensus protocols like those used in public blockchains are not necessary to agree on the transactions to include in the block, so these blockchains are highly performant and scalable, which is often required for industrial applications. This type of blockchains are common in industrial environments where the participants to the network are well-known. When a group of owners operate the blockchain these are also called consortium or federated blockchains. Examples of blockchain software projects that are often used by the companies and consortiums to deploy a private blockchain include Hyperledger Fabric [13] and Multichain [17].

Depending on permissions, the blockchains are also classified as permissionless or permissioned. In permissionless blockchains all the users are equal and can perform the same operations without any need for administration. Again, most popular blockchains of this type are Bitcoin and Ethereum, but also many others like Dash, Litecoin, Zcash, etc. Permissioned blockchains are those typically used in private blockchains where the administrator controls which operations are allowed for each user of the blockchain.

2.3 Smart contracts and automation

Smart contracts were introduced by [22] as computer protocols that facilitate, verify, or enforce the negotiation or performance of a contract. In blockchain they take the form of a computer program which can automatically execute transactions on the blockchain, i.e. the terms of a contract, when an event or condition has occurred. This can be done automatically, without human intervention and without the need for a third party [4]. The conditions to which smart contracts react can be internal to the blockchain network, like the occurrence of a transaction of cer-

tain properties, or may depend on external services, called oracles, that take data from the real world and store them into the blockchain. An oracle could, for example, monitor for the arrival of a package and record the information on blockchain thus enabling the smart contract to trigger the execution of the corresponding code.

Smart contracts provide the ability to directly track and execute complex agreements between parties without the need for contractual clauses or people to get involved in their execution. On the other hand, smart properties are agreements whose ownership is controlled via the blockchain, using contracts. Smart contracts can automate identity and asset verification, proving who an asset belongs to and eliminating many potential hurdles, inefficiencies and legal disputes [3].

Smart contracts add further strength to the development of decentralized applications on blockchain. Applications that are able to track and store transactions from multiple users and devices in near real-time, operating on a highly transparent, secure and robust platform like blockchain are extremely interesting to businesses and individuals. Business logic can be embedded in the application to automate workflows and increase efficiency. Furthermore, since the smart contract is simply encoded as a source code, the contract's performance and the business relationships encoded in it can be simulated and tested before the actual deployment and execution in a real-world business environment.

2.4 Blockchain challenges

Being a new and disruptive technology the blockchain technology also faces some important challenges. Some are more technical in nature, related to the energy efficiency of the consensus algorithms like Proof-of-Work, the inability to scale the number of nodes and to achieve the required performance in terms of transaction throughput under high load and to guarantee the time to finality required in some applications. Other challenges are related to the lack of standards and regulation by the authorities and law, and to the early phase of experimentation with new models of decentralized governance that are being introduced with public blockchains. These challenges are being addressed and it is likely that they will be overcome as the technology matures and the adoptions widens.

3 Blockchain in maritime industry

The enormous impact that blockchain technology could have on the maritime industry follows from the above mentioned blockchain properties and principles that govern its usage. In the maritime industry the blockchain technology provides a mechanism to verify the accountability of partners, suppliers, service providers and authorities and to add trust in the authenticity of the collected data in the transactions between the participants [14]. The maritime companies are increasingly realizing the potential of this technology for maintaining a certified history of information and the ability to automate the execution and reporting of transactions between participants. It can potentially reduce the cost of everyday business in the industry and also be time-efficient due to the technology that has relevant details encrypted on blockchain. Maritime companies and other organizations could share their information faster about their production process, maintenance and delivery programme, status of their deliveries, status and condition of vessels, crew changes, etc. [10]. The number of vital documents in terms of shipping could be reduced to being paperless, for instance bill of lading which must be issued for every cargo.

3.1 Blockchain in shipping

Shipping industry is still a traditionally oriented industry despite numerous technological revolutions. Current transportation includes large number of paper documents, including contracts, bills of lading, port authority documents and other documents related to shipping and cargo [20]. Many of the technological solutions from the information systems used by the shipping companies are outdated and most of the shipping companies are using expensive and time-consuming couriers for transportation of their valuable documents [15].

Blockchain technology can be used for tracking the cargo and providing an end-to-end supply, recording information on the vessel, and the usage of smart contracts and marine insurance policies. This leads to automatization and digitalization in the term of processing the documents which results in reducing the cost for clearance and movement of the cargo [25]. Blockchain technology is paving the path for new possibilities in all industries as well as maritime industry. Some maritime companies, such as Maersk, CMA-CGM, Hapag-Lloyd and MSC Mediterranean Shipping Company, have noticed the benefits of blockchain and are trying to implement the TradeLens, blockchain based digital shipping platform, in their operations [23].

Implementations on experimental and prototype levels have already been done and that includes smart contract bill of lading, known as CargoX. Another positive impact that could potentially be derived from using the blockchain technology is taking care of the environment. In the perspective of maritime industry, large amount of paper contracts and other paperwork could be replaced with blockchain technology and consequently reduce paper usage [6]. It is also important to mention that several couriers and their land, air or naval vehicles have to be used in order complete the transportation process of the documents alone. Since shipping and maritime industries are global industries, considerable amount of fossil fuel usage and emission could be reduced by implementing this kind of digitalization.

3.2 Smart contract – Bill of Lading

The bill of lading is one of the most significant and valuable document in the shipping industry. It acknowledges that the cargo has been shipped and can contain details such as quantity, descriptions, weight, loading and discharge port of the cargo and shipping marks. International trade and maritime industry involves numbers of actors which still continue to rely on paper documents. For example, in 2014 Maersk shipping company followed a refrigerated container sailing from Kenya to Netherlands to track the number of physical transactions needed in order to complete the trade. The researchers found out that there are around 100 individuals involved with more than 200 interactions required to complete the voyage and shipment. The documents needed 10 days to be processed [12].

Smart contracts can enforce a set of rules that every participant involved in the process is in agreement with. In the moment that predefined conditions encoded in the rules occur, the contract is automatically executed. In this way the execution time is shortened from a few days to just a few minutes. This is a significant amount of time saved when we take in consideration all the cargo being shipped and the amount of issued bill of ladings. Smart contract is the simplest type of decentralized automatisation.

Taking into consideration the distributed nature of the blockchain and its properties and principles described in the previous chapter, it is clear that a blockchain solution is preferred to simply modernizing the business process. The main drivers of using Blockchain in the maritime industry come from the fact that it is almost impossible to temper the information or data connected to bill of lading, freights or any other variable data that is used in maritime industry. On the other hand, centralized systems have a single point of failure, for example a server where all the data is stored. All it takes is one human error, security breach, technical malfunction or some other unexpected event to change or destroy that data.

It is hard to predict the price of container freight rates, but it is possible to expect that a company that starts using digital bill of lading will reduce their costs up to USD 300 and compared to other companies they will grab bigger market share and earn more profits [25]. The gap between amount of money saved is mostly dependent on the route the vessel is taking. The longer the route the bigger the save.

If we take the average for the last 4 years, we can assume that with the use of digital bill of lading companies using it will reduce prices by a minimum of USD 100 [5]. This makes a large difference if calculated in percentage which is particularly relevant for companies with a large number of ships.

It is easy to conclude that companies that will use digital bill of lading using the blockchain technology and smart contracts will be able to charge their costumers less and that way take a bigger part of the market and with more profits improve their fleet as well as services.

In the Table 1 in the column "Future without blockchain" formula used was average from years 2014, 2015, 2016 and 2017. Shaded column "Future with blockchain" is average from years 2014, 2015, 2016 and 2017 minus USD 100. Although this analysis and predictions are far from perfect, the difference of USD 100 between price with and without smart contracts can be considered minimum amount that could be saved. The amount saved can

Table 1 Container freight markets and rates with and without implementation of blockchain [25]

Freight market	2014	2015	2016	2017	Future with blockchain	Future without blockchain
Trans-Pacific	**(Dollars per 40-foot equivalent unit)**					
Shanghai–United States West Coast	1 970	1 506	1 272	1 485	1458.25	**1558.25**
Far East–Europe	**(Dollars per 20-foot equivalent unit)**					
Shanghai–Northern Europe	1 161	629	690	876	739	839
Shanghai–Mediterranean	1 253	739	684	817	773.25	873.25
North–South	**(Dollars per 20-foot equivalent unit)**					
Shanghai–South America (Santos)	1 103	455	1 647	2 679	1371	1471
Shanghai–Australia/ New Zealand (Melbourne)	678	492	526	677	493.25	593.25
Shanghai–West Africa (Lagos)	1 838	1 449	1 181	1 770	1459.5	1559.5
Shanghai–South Africa (Durban)	760	693	584	1 155	698	798
Intra-Asian	**(Dollars per 20-foot equivalent unit)**					
Shanghai–South-East Asia (Singapore)	233	187	70	148	59.5	159.5
Shanghai–East Japan	273	146	185	215	104.75	204.75
Shanghai–Republic of Korea	187	160	104	141	48	148
Shanghai–Hong Kong SAR	65	56	55	—	*	*
Shanghai–Persian Gulf/ Red Sea	820	525	399	618	490.5	590.5

Table 2 Traditional Bill of lading and CargoX Bill of lading – comparison of costs

	Traditional Bill of Lading	**CargoX Bill of Lading**
Time to prepare the documents	120 – 170 minutes	N/A
Transit time	Up to 10 days, dependable on conditions	Instant, as soon as uploaded on the Blockchain
Courier costs	USD 35 – 100	USD 0
Cargo costs		
General cargo	USD 350	USD 15 for all types of Cargo
Refrigerated Cargo	USD 500	USD 15
Hazardous Cargo	USD 500	USD 15
All Other Cargo	USD 350	USD 15

Source: Authors

make a significant advantage and companies that implement it possibly can take over most of the market.

The Table 2 compares traditional, paper Bill of lading with CargoX Bill of lading which represents the smart contract. Time to prepare all the necessary documentation for traditional bill of lading is somewhere between 120 and 170 minutes [1]. The time is related to effectiveness of the staff of the maritime company as well as their stakeholders from which they have to gather vital data to prepare the bill of lading. Also, the delivery time for conventional bill of lading can be up to seven days or even more in some extreme cases. The delivery time depends on several factors, some of which are: handling of the courier company, weather, transportation system, holidays or some contingencies. It is notable to say that in many cases delivery of bills of lading is done by courier companies. The price to deliver several pieces of documents, including valuable bill of lading, is arguably around USD 100. The courier costs and transit time for CargoX bill of lading does not exists, because it can be issued instantly and transferred to the legal owner of the goods by excluding couriers [5]. According to online transportation service, charges for cargo for bill of lading can vary depending on type of cargo. As seen below, the price can reach up to USD 500 [19]. The cost of issuing a CargoX bill of lading is significantly lower than traditional paper bill of lading and that concerns all types of cargo. According to CargoX company, the price for issuing one bill of lading would be USD 15. That price is only 15% of the usual price for a paper bill of lading document [2].

3.3 Technological solutions

Some companies saw the opportunity in this new technology and started investing their profits in research for possible applications. Supply chain is almost a perfect example for the use of blockchain especially with a lot of companies involved in shipping. Global shipping market has a lot of inefficient procedures and a lot of paper has to be used to fulfill all the procedures. Human error is common thing and it is hard to exclude possible manipulations. Many companies are aware of this and are trying to be the first that will implement some new process that will change the shipping industry. The amount of new patents and inventions registered in supply chain today is at levels when shipping container was introduced [16].

Some of the blockchain based technological solutions are [16]:

- TradeLens –blockchain platform for ports and shipping companies made by Maersk and IBM,
- CargoX Smart bill of lading tested between Shanghai and Koper, Slovenia,
- 300cubits made first transaction of money using Ethereum Blockchain,
- Silsal platform made as cooperation of Abu Dhabi port and Maqta Gateways to track the shipment and reduce the amount of administration connected to import and export of goods,
- Port of Antwerp developed documentation for working with logistics connected with fitosanitary certificates and certificates of origin.

4 Conclusion

Maritime and shipping industry are cautiously and steadily embracing innovative and modern technologies. New trend of digitalization is affecting the whole world and industries with it. Maritime industry and its stakeholders are trying to implement those technologies in their business operations in order to beat the competition. Modern technologies can be quite expensive to implement but if the possibilities of it have been researched thoroughly, steady financial benefits can be grasped. Necessary caution is required to prevent financial losses or even bankruptcies.

Blockchain technology offers a new and reliable system for maritime industry. It can be concluded that future of maritime and transportation industry will be intertwined with blockchain based technology because it incorporates several criteria for facilitating fast, secure, transparent, cost-effective and reliable transport. When the number of users of this technology increases and governments, insti-

tutions and business sector adapt to blockchain technology, we can expect new innovations in terms of logistics, transport and financial technology. Regulations ought to be created on global scale for using blockchain technology to prevent misuse and increase interoperability.

United Nations Conference on Trade and Development indicated that blockchain technology could save USD 300 just from custom clearances for each consignment. It could also potentially generate USD 5.4 million in savings. Savings are related to a vessel that has a capacity of 18,000 TEUs [25]. Joined venture of companies Maersk and IBM showed that administrative burden has dropped down several percent respective to the value of shipped goods. A lot of time also could be saved due to digitalization that blockchain technology offers. Documents and information could be transferred through blockchain in a matter of seconds instead of using couriers for documents transport which can take several days.

To conclude with, this paper showed that by implementing blockchain technology great progress and achievements can be made. Also, savings can be made related to costs and time with transparent manner. Transportation documents such as bill of lading and information related to transportation process could be facilitated faster with less errors and delays.

References

[1] Aulibrary.au.edu. (2019). [online] Available at: http://www.aulibrary.au.edu/multim1/ABAC_Pub/The-Journal-of-Risk-Management-And-Insurance/v16-5.pdf [Accessed: 13 Oct. 2019].

[2] A day to remember: The first ever blockchain-based CargoX Smart B/L™ has successfully completed its historic mission during a trial shipment from China to Europe", *Cargox.io*, 2019. [Online]. Available at: https://cargox.io/press-releases/full/first-ever-blockchain-based-cargox-smart-bl-has-successfully-completed-its-historic-mission/. [Accessed: 14 Oct. 2019].

[3] BlockchainHub. (2019). *Smart Contracts*. [online] Available at: https://blockchainhub.net/smart-contracts/ [Accessed 9 Nov. 2019].

[4] Buterin, V., A Next Generation Smart Contract & Decentralized Application Platform, Ethereum White Paper. (2015). [online] Available at: https://github.com/ethereum/wiki/wiki/White-Paper

[5] Cargox.io. (2019). [online] Available at: https://cargox.io/CargoX-Business-Overview-Technology-Bluepaper.pdf [Accessed 13 Oct. 2019].

[6] Czachorowski K., Solesvik M., Kondratenko Y. (2019) The Application of Blockchain Technology in the Maritime Industry. In: Kharchenko V., Kondratenko Y., Kacprzyk J. (eds) Green IT Engineering: Social, Business and Industrial Applications. Studies in Systems, Decision and Control, vol 171. Springer, Cham. Pages 561-577.

[7] D. Tapscott and A. Tapscott, Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business and the World, London: Penguin Publishing Group, 2016. Pages 29-51.

[8] Deloitte's 2019 Global Blockchain Survey, (2019) Available at: https://www2.deloitte.com/content/dam/Deloitte/se/Documents/risk/DI_2019-global-blockchain-survey.pdf [Accessed 9 Apr. 2020].

[9] DeVries, Peter. (2016). An Analysis of Cryptocurrency, Bitcoin, and the Future. International Journal of Business Management and Commerce. Vol. 1. Pages 1-9.

[10] E. Tijan, S. Aksentijević, K. Ivanić, and M. Jardas, "Blockchain Technology Implementation in Logistics," *Sustainability*, vol. 11, no. 4, p. 1185, Feb. 2019.

[11] T. M. Fernández-Caramés and P. Fraga-Lamas, "A Review on the Application of Blockchain to the Next Generation of Cybersecure Industry 4.0 Smart Factories," in IEEE Access, vol. 7, pp. 45201-45218, 2019.

[12] Ibm.com. (2019). [online] Available at: https://www.ibm.com/downloads/cas/KJDPQKBE [Accessed 14 Oct. 2019].

[13] IBM. 2020. Hyperledger Fabric. [online] Available at: https://www.hyperledger.org/projects/fabric. [Accessed 20 Apr. 2020].

[14] Locher, T., Obermeier, S., Pignolet, Y. A. "When Can a Distributed Ledger Replace a Trusted Third Party?", in Proceedings of the IEEE International Conference on Blockchain, Halifax, Canada, July 2018.

[15] Mearian, L. (2019). *Maersk adds two big shipping firms to its blockchain ledger*. [online] Computerworld. Available at: https://www.computerworld.com/article/3398923/maersk-adds-two-big-shipping-firms-to-its-blockchain-ledger.html [Accessed 7 Nov. 2019].

[16] Marineinsight.com. (2019). [online] Available at: https://www.marineinsight.com/know-more/7-major-blockchain-technology-developments-in-maritime-industry-in-2018/ [Accessed 7 Nov. 2019].

[17] Multichain enterprise blockchain. [online] Available at: https://www.multichain.com/ [Accessed 20 Apr. 2020].

[18] Narayanan, A., Bonneau, J., Felten, E., Miller, A., & Goldfeder, S. Bitcoin and cryptocurrency technologies: a comprehensive introduction. Princeton University Press, 2016. Pages: 27-38.

[19] Oocl.com. (2019). [online] Available at: https://www.oocl.com/eng/ourservices/eservices/tariffandrates/globalrule/Pages/rule05.aspx [Accessed 14 Oct. 2019].

[20] Opensea.pro. (2019). *Major advantages and challenges of blockchain technology for shipping market*. [online] Available at: https://opensea.pro/blog/blockchain-for-shipping-industry [Accessed 9 Nov. 2019].

[21] S. Nakamoto, (2008), "Bitcoin: A peer-to-peer electronic cash system", Available at: http://bitcoin.org/bitcoin.pdf

[22] Szabo, N., "Formalizing and securing relationships on public networks," First Monday, vol. 2, no. 9, 1997.

[23] "TradeLens blockchain-enabled digital shipping platform continues expansion with addition of major ocean carriers Hapag-Lloyd and Ocean Network Express," *Maersk*. [Online]. Available: https://www.maersk.com/news/articles/2019/07/02/hapag-lloyd-and-ocean-network-express-join-tradelens. [Accessed: 10 Nov. 2019].

[24] Tasca, P. and Tessone, C. (2019). A Taxonomy of Blockchain Technologies: Principles of Identification and Classification. *Ledger*, 4. DOI: 10.5195/ledger.2019.140

[25] UNCTAD, Review of Maritime transport 2018, Pages: 15; Executive summary x-xiii; 43-51, Sales No. E.18.II.D.5

[26] Wikipedia.org. (2020). *Cryptocurrency*. [online] Available at: https://en.wikipedia.org/wiki/Cryptocurrency [Accessed 24 Feb. 2020].