Can the Blockchain Facilitate the Development of an Interport Community?

Patrizia Serra[1(✉)], Gianfranco Fancello[1], Roberto Tonelli[2], and Lodovica Marchesi[2]

[1] DICAAR – Department of Civil and Environmental Engineering and Architecture, University of Cagliari, 09123 Cagliari, Italy
pserra@unica.it

[2] DMI – Department of Mathematics and Computer Science, University of Cagliari, 09123 Cagliari, Italy

Abstract. Seaports are part of a complex and information-intensive maritime supply chain that includes a set of organizations and operators who need to exchange a large amount of information and data with each other. As supply chains become increasingly integrated and connected, the connectivity of stakeholders must be ensured not only within individual ports but also between ports. This paper explores the application prospects and practical implications of the application of Blockchain technology for the establishment of an interport community within which different ports organized as a network can exchange information and data in a secure and effective way. With the support of SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis, this paper addresses several research questions concerning the practical impacts, benefits, pros and cons, economic and technical barriers related to the implementation of Blockchain technology to support the creation of an interport community.

Keywords: Blockchain · Port 4.0 · Inter-port connectivity · Smart port

1 Introduction

In the framework of the 4.0 revolution, digital transformation is of utmost importance for port and maritime logistics. Particularly, as crucial nodes in supply chains, seaports are required to constantly innovate and evolve in order to keep up with technological changes and remain competitive. Since the 1980s, the modernization of seaports has been shaped by digital innovation through three main stages of transformation:

- first stage (1980s): transformation into paperless procedures (development of the first EDI-based port community system, development of maritime industry-specific UN/EDIFACT message standards, etc.)
- second stage (1990s–2000s): transformation into automated procedures (application of automatic identification systems AIS, introduction of radio-frequency identification for port operations, etc.)

© Springer Nature Switzerland AG 2021
O. Gervasi et al. (Eds.): ICCSA 2021, LNCS 12958, pp. 240–251, 2021.
https://doi.org/10.1007/978-3-030-87016-4_18

- third stage (2010s–onwards): transformation into digital procedures to improve responsiveness and decision making (sensors, mobile technologies, cloud computing, machine learning, etc.), and to support the ongoing interaction and connection between the actors involved.

Now, as supply chains become increasingly integrated and connected, it is essential to ensure the connectivity of stakeholders not only within the single port but also between the various nodes of the transport network [1, 2]. In particular, seaports are part of a complex and information-intensive maritime supply chain that includes a set of organizations and operators that are connected and distributed [3]. However, several challenges have so far characterized and slowed down the development of shared digital solutions in the port community: different levels of digital maturity between actors, missing standards, reluctance of operators to participate and share information, etc. [4]. The recently much debated Blockchain technology could offer interesting opportunities in this regard and is believed to have a huge impact on the future of the digitization of port and maritime logistics [5].

Blockchain is defined as a digital ledger, decentralized and distributed, shared and agreed on a peer-to-peer network, where transactions are recorded and added in chronological order with the aim of creating permanent and tamper-proof records [6]. Whatever the sector of application, Blockchain technology allows for more secure tracking of all types of transactions (money transactions, data transactions, information transactions, etc.), reducing delays, additional costs and human errors [7]. Blockchain is designed to achieve decentralization, real-time peer-to-peer operation, anonymity, transparency, irreversibility and integrity in a widely applicable manner [8]. In the context of shipping, Blockchain technology is potentially a solution to the problem of distrust among players, as it does not rely on commercial third parties, but on a network of peers [9]. It is also believed to have the potential to positively affect maritime processes [10] and accelerate the physical flow of goods [11].

The growing interest towards Blockchain technology in the shipping sector is also evidenced by the development of the related scientific literature. In order to have an overview of the quantitative impact (in terms of number of published works) the topic of Blockchain in the maritime sector is having on the scientific literature, in early December 2020 a preliminary keyword search was carried out using the Scopus database. The search identified 61 studies (including only journal articles and conference proceedings), all published starting from 2017, which contained the following terms in the title, abstract or keywords: Blockchain + shipping, Blockchain + maritime, Blockchain + port(s). Most of these studies seem to focus primarily on the main trends and challenges, technical aspects, general opportunities and impacts related to state-of-the-art technologies, while the practical implications of adopting Blockchain solutions for specific port processes, as well as the actual repercussions for the different actors, seem to need further investigation, also considering that the technology is still new and immature [12, 13]. In fact, some trials and Blockchain pilot projects are already available in the maritime industry. However, most of them are linked to autonomous initiatives of industrial operators or single ports. For example, Maersk and IBM have decided to jointly build their own Blockchain solution to reduce the cost of global shipping by eliminating inefficiencies resulting from

paper-based processes [14] while the ports of Rotterdam and Antwerp are developing their own Blockchains. In this regard, it should be emphasized that as long as Blockchain exists only in individual ports or in small groups of operators, its benefits will not be fully explored and exploited. In fact, in increasingly connected and integrated markets, the new era of digitization concerns not only the port's ability to become smart, but above all the ability to do so by connecting to larger networks.

In light of the above, this study intends to add to the existing literature by exploring the application prospects and practical implications of Blockchain technology for the construction of an interport community within which different ports organized as a network can exchange information and data in a secure and effective way.

2 Case Study

The idea for this exploratory study was born in the framework of a previous research project, the so-called EasyLog project, which designed and implemented an ICT system for the exchange and sharing of operational data between five ro-ro ports in the upper Tyrrhenian Sea [1]. The EasyLog system was designed according to a modular structure in which each port had its own customized local module for managing gate-in gate-out operations, and the five local modules communicated with each other using a shared set of rules for data exchange, formatting and availability. The EasyLog system allowed the exchange of data both within the port (between haulers, port authorities, and terminal operators) and between the five ports of the network. Despite the important innovation introduced by the EasyLog system, it did not include all the parties involved in the process (for example, shipping companies), it concerned only a limited number of operational information related to gate operations but no sensitive data, its process phases were not systematically linked between the stakeholders, thus leaving some room for improvements that Blockchain technology can potentially achieve. Figure 1 illustrates a simplified flow diagram relating to the diverse activities, and related information flows and operators involved, that could potentially benefit from the use of Blockchain for the purpose of creating an interport community between port "x" and port "y".

With the support of SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis, this paper analyzes the application prospects to exploit the advantages of Blockchain to facilitate the secure exchange of information between the ports and the parties involved in an interport logistics chain.

3 Research Questions

It should be emphasized that, to the best of the authors' knowledge, no available studies have been found that explore the practical implications and impacts of the application of Blockchain technology for the establishment of an interport community.

This exploratory study tries to provide insights on the topic by addressing the following research questions:

- Can Blockchain facilitate the development of an integrated port community?

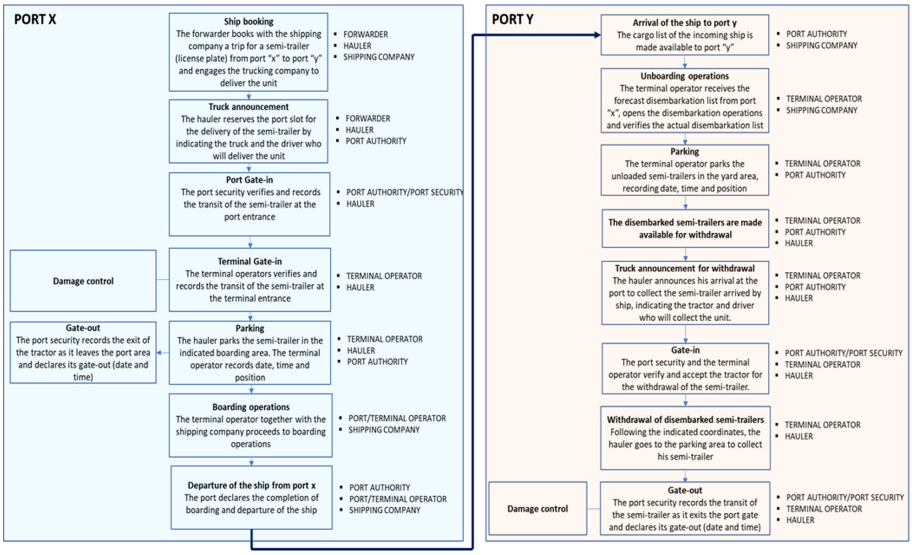


Fig. 1. Procedural and informative workflow in a ro-ro interport logistics chain. Source: elaboration of the authors

- Which logistic activities in an interport community would be most impacted by Blockchain and in which way?
- What parties involved in a port community would benefit the most from Blockchain?
- What are the pros and cons of introducing Blockchain in a port community?

4 Blockchain and Smart Contracts

In order to better understand why Blockchain technology and Smart Contracts can be helpful for port logistics and transportation we first recall a few basic notions and properties to grasp insights on how to use them for the establishment of an interport community avoiding to deeply dive into unessential details for this work.

The Blockchain is a distributed, shared database whose past history is unalterable. It is open to anyone who wants to contribute by installing the management software and a copy of it on their computer (thus becoming a node of the network). It is equipped with mechanisms to reach consensus among all nodes on the information to be stored, so that no one can take control of it, not even generating a mass of fictitious nodes. The security of the Blockchain technology is such that, even if only one copy of the Blockchain remained, from this copy it could be restarted by reconstructing all past operations. Furthermore, if one were to alter the past history of such a single copy, this would still require a prohibitive number of calculations. Basically, Blockchain can be thought of as an automatic, non-centralized, inexpensive, and secure way to gain trust.

Transaction and all the related information are cryptographically signed and packed into temporally ordered blocks which are all cryptographically linked to the previous one by means of hashing to create an inalterable chain of information. Transactions are

signed by the sender address so that they belong to the owner of the private key associated to the public address on the Blockchain. This allows to "identify" transaction's sender. Transactions and blocks are validated and added to the chain when a decentralized consensus is reached by the software, so that no one can be in control of the chain and there is not central authority providing permits or prohibiting anyone to freely submit transactions or to validate blocks. Among the main properties of the technology, we highlight:

- Distribution: information is stored on multiple nodes, giving resilience and security
- Disintermediation: transactions are managed without intermediaries and without a central management authority
- Transparency: all transactions are stored unalterably and in clear text. For each transaction the involved addresses are known. In this way, a complete tracking of transaction flows from one address to another is possible
- Immutability/Non-repudiation: once a transaction has been sent and accepted, it cannot be cancelled for any reason
- Security: the transaction can only be activated by knowing the private key related to the address. If this key is lost, the address cannot be used anymore
- "Notarial" storage: it is possible to use special transactions to store information on the Blockchain. This information (usually limited to a few tens of Bytes per transaction) is used to certify the existence and integrity of a document, or set of documents, at a certain date
- Programmability: complex actions can be programmed and executed by on chain software called Smart Contracts (SC), which are also fully verifiable and can be activated by multiple parties involved (with their respective private keys). Ethereum is the currency that offers the most features

Another fundamental property of the Blockchain is that it can be the infrastructure for running Smart Contracts. Smart Contracts are automated contracts, in which participants prove their identity and approval of the contract with their private key. According to [15] a Smart Contract is a computerized protocol for executing transactions, which executes the terms of a contract.

The general objectives of a Smart Contract are to satisfy the usual contractual conditions (such as payment terms, rights, confidentiality, and even enforcement), to minimize both deliberate and accidental exceptions, and to minimize the need for trusted intermediaries. A Smart Contract is basically a program, which runs on a secure medium (trusted) and is itself secure. It takes digital signatures of participants, and other information, from secure sources as input. In output, it transfers cryptocurrency amounts, can activate other contracts, record information or connect to external systems. Smart Contracts also often have a user interface that emulates the jargon and logic of contract clauses.

Since the execution of a software program is deterministic and immutable, with the same input and program status, the code can be considered a contract. Once the contractual clauses are correctly inserted in the code of a Smart Contract, and this is accepted by the contractors, the effects are no longer linked to their will or the action of intermediaries.

Obviously, the code must have no errors, must be executed correctly and must not be modified; the inputs to the code must come from safe and identified sources; the code outputs must achieve the desired effects. In other words, there must be a mechanism that guarantees the trust that the contractors place in the smart contract. This is granted by the Blockchain, which provides all the aforementioned guarantees without the need for a central authority. The introduction of Ethereum in 2015 led to a Blockchain and a low-level language, along with various high-level and effectively usable languages (e.g., Solidity and Yul), to extensively code and execute Turing-complete Smart Contracts [16].

With respect to the application of such technology to port logistic and shipping it is now clear that the Blockchain can contribute to the digital innovation in a number of ways, from granting transparency and unforgeability of records to data security and trust, to the automation of many operations and checks by means of Smart Contracts execution, to managing authorizations and permits for different actors by mean of Blockchain addresses and the related private keys.

Another immediate advantage provided by the technology is supply chain flows tracking with respect to physical, financial and logical information flows. In the next section we discuss all these and other aspects of the application of Blockchain technology for the establishment of an interport community by means of a detailed SWOT analysis.

5 SWOT Analysis

It should be emphasized that, to the best of the authors' knowledge, no available studies have been found that explore the practical implications of Blockchain technologies for what concerns strengths, weaknesses, opportunities and threats in managing port logistics and in particular for the case of an interport community. In the following, we present a SWOT analysis for this specific case examining how the Blockchain can be used to concretely contribute to enhance port logistics. Table 1 identifies the main features

Table 1. SWOT analysis of Blockchain technology

Strengths	**Weaknesses**
• Trust • Security • Transparency • Tamper proof • Identity management	• Governance • Scalability • Adoption • Redundancy • Compliancy to GDPR
Opportunities	**Threats**
• Traceability • Disintermediation • Cost reduction • Supply chain flow management • Coordination	• Privacy • Legal aspects and normative • Connection to out-of-chain data

contributing to the four dimensions of the SWOT analysis. The individual aspects are then discussed in the following paragraphs.

5.1 Strengths

Trust: In ports it is important that companies in the supply chain can trust each other to share information and increase efficiency in shared processes. A major obstacle to data sharing is that a leakage in sensitive information can affect companies' business. Managing the information flow of shared data with the Blockchain on the contrary can provide a trusted and unforgeable corpus of data records that can help in clearly identify responsibilities and sources of damages, delays, misconducts, errors and other aspects.

Security: Records stored into Blockchain blocks are secure since a double encryption mechanism is in place [17]. First, transactions are validated by means of private keys that make extensive use of cryptography. Thus, transactions cannot be altered and are secure. Second, each block is cryptographically chained to the previous one so that any attempt of records manipulation in a block is mirrored in changes in all the following blocks, so that after the addition of some block at the end of the chain data can be considered secured.

Transparency: Shipping companies typically keep their data reserved and secret in order to keep a competitive advantage over their competitors. On the other hand, port logistics can benefit from data sharing for planning in advance, for monitoring and coordinating operations and so on. Recording data on the Blockchain directly provides transparency and renders information directly and immediately available to authorized actors [17]. This is especially useful when the information needs to be updated and quickly broadcast to all the actors. With Blockchain solutions, data is shared in real-time, and payment can be made and confirmed almost instantly.

Tamper Proof: Transparency is also provided by the tamper proof of Blockchain data. In fact, once data are loaded into the blocks they cannot be manipulated or altered in any way. All the actors involved in port logistic will benefit from this certainty of information not only in real time but also for what concerns historical data for retrospective analysis for process improvement.

Identity Management: Given that all writing operations on Blockchain are managed through Blockchain addresses which can operate only using the associated private keyword all operations can directly be reconducted to the address' owners providing a transparent a built-in mechanism for managing identities. Furthermore, Smart Contracts can be written so that only specific addresses are allowed to perform specific operations providing a built-in secure mechanism for managing permits and authorizations.

5.2 Weaknesses

Governance: The missing of a central authority can be an advantage but also a problem. In some cases, in fact there is the need for organizing some governance at different levels.

In port logistic, once multiple participants are connected, questions will arise about the governance of the system, how and who is authorized to access the data (accessibility), and who owns the data (ownership) shared in the Blockchain. Furthermore, in the case of a private Blockchain solution, there is the question of who is the neutral party in charge of setting the network rules and granting access authorization.

Scalability: Blockchain technology suffers from scalability and performance problems: all nodes in the chain have to process all transactions and this may present a problem with large-scale and especially global implementations [8]. In a large interport community the number of actors and operation involved can be cumbersome and peaks of activities in short time (e.g. load or download of a ferry carrier) can become critical. The adoption of the correct Blockchain solution must take into account this problematic so that the proper transaction rates and throughputs must be assured to match logistic needs.

Adoption: The adoption of Blockchain technology can be difficult due to technical and functional aspects. Implementing Blockchain technology on a very large scale would require a great deal of computing power. Currently, only a few larger companies seem to be experimenting with Blockchain. Eventually, they will create a platform that SMEs could also connect to. SMEs, however, may be reluctant to participate in the platforms of these large players. Also, because different companies' databases may use different standards or languages to store data, interaction may prove difficult. Addressing this would require resources and time to align databases or invest in a shared language for the Blockchain.

Redundancy: Blockchain provides a redundant distributed ledger replicated on all the nodes. If this is an advantage for what concerns security, transparency and trust, it can be seen as a waste of resources which could be leveraged to other purposes. This may become particularly problematic when storage and computational power are critical resources for the actors involved.

Compliance to GDPR: In the framework of EU GDPR (General Data Protection Regulation) all sensitive data pertaining to private citizens or companies must be treated according to a strict regulation. In particular, citizens and companies have the right to be forgotten, so that upon a specific request all organization keeping citizens' or companies' data must remove them from their public databases. In the case of Blockchain all data recorded on the ledger cannot be removed or canceled anymore. This means that a specific strategy must be adopted from the very beginning to decide and plan what data must be recorded on-chain and what data must be kept off-chain.

5.3 Opportunities

Traceability: The Blockchain natively stores record in a temporally ordered sequence of valid transactions so that all operations related to port logistic can immediately be tracked, like load or unload of tracks and containers into shipments and other physical movements. But also, other events, like business agreements, buy and sell, signing of insurance contracts, can be easily included into the Blockchain tracking system, strongly reducing monitoring and auditing costs [17].

Disintermediation and Cost Reduction: Currently many of the port logistic transactions are carried out by e-mail or telephone calls, there are several intermediaries involved, with consequent increases in costs and possible human errors. As for the Blockchain and the smart contracts, these promise an increase in efficiency, a reduction in brokerage costs and greater neutrality in the regulation of contracts. In fact, since all the relevant events of a supply chain are recorded in a certain and immutable way, all the notified parties can immediately plan the consequent actions, including any payments [18].

Supply Chain Flow Management: The Blockchain is the ideal technology for supply chain management, where the supply can be physical or simply information flow [18]. Instead of exchanging documentation, the stakeholders involved in the process are given permission to access the blocks where the data is stored. This leads to the creation of unique and shared information that can be accessed in real-time and with lower transaction costs. The process can be further accelerated by involving stakeholders external to the process (banks and insurance companies). The database can be further enhanced by using Internet of Things (IoT) devices and connecting them as Blockchain nodes. Furthermore, by connecting smart devices, it is also possible to fully automate the process.

Coordination: Currently, each freight operator has its own management platform and data set, with limited interconnection capacities. Operators operate with a limited view of the situation and of the impact of each element on the overall performance of the supply chain. Container supply chain information is dispersed. With Blockchain, transport operators can securely share their information with their trading partners through a reliable, multi-layered data access architecture. This would foster interoperability, efficiency and productivity. Furthermore, different Blockchain networks could interact with each other around the world [18].

5.4 Threats

Privacy: User privacy could be reduced because all nodes contain a complete copy of the ledger and there is no central authority to contact in the event of an obvious security breach [8]. One of the solutions is a platform that will combine a Blockchain, repurposed as an access control moderator, with an off-chain storage solution [19]. Users will not have to trust third parties and are always aware of the data that is collected about them and how it is used. Furthermore, the Blockchain recognizes users as owners of their personal data.

Legal Aspects and Normative: Currently there is a lack in the normative and regulation for what concerns the role of Blockchain technology as distributed ledger and on the legal recognition of Smart Contracts. This lack creates insecurity, because some aspects of smart contract technology could be adopted by the logistics market, only to be upregulated, or even to be considered illegal [20].

Connection to Out-of-Chain Data: When dealing with massive documents, due to space constraints or costs, the typical pattern is to store them off-chain and to upload on-chain only their hashes and a pointer or reference to the external storage location. This does not grant that the external storage has the same properties the Blockchain has, and eventually the external storage can be dismissed over time. In this case only the metadata related to the documents can be retrieved but not the documents themselves. When planning to use off-chain storage this aspect must be considered [21].

6 Answer to Research Questions and Conclusions

Based on the considerations made, it can be said that Blockchain has considerable potential to facilitate the development of an integrated interport community as it can increase trust between the parties, it can provide a facilitated communication platform, and it allows to guarantee the identities of the involved parties and their will to send the transaction. The logistic activities that can be most affected by the Blockchain seem to be those relating to the notarization of contractual documents and passageways to the gates, including photographs and documents relating to the state of vehicles and goods for any insurance purposes. In addition, the management of access authorizations to the system in all ports with a single system and in a decentralized way, the guarantee of the origin of documents, and the sharing and secure transmission of information and notifications of events between the port actors, while preserving privacy and data ownership, can significantly benefit from the Blockchain. All the players may benefit from the use of the Blockchain in support of intermodal traffic, from the for-profit enterprises, such as freight forwarders, terminal operators, shipping companies, haulers, to the port authorities. The former can think of reducing direct costs and increasing efficiency, thanks to a greater automation, the reduction of intermediaries and delays, but also of reducing indirect costs, such as legal ones, thanks to the decrease in disputes guaranteed by Blockchain certification and smart contracts. The latter can also have advantages in terms of reducing costs and having greater guarantees that laws and regulations are respected. The pros of introducing Blockchain to a cross-border port community have been clearly listed in the previous sections. As for the cons, there are probably no negative consequences related to the introduction of a technology that increases the transparency of operations, the trust of the parties, the automation of many activities, the security and confidentiality of data transfers. The only reasons, not all justifiable, why one party could negatively view the introduction of the Blockchain in a cross-border port community may include the need to bear the costs of technological adoption and transition, low propensity to increase transparency, little trust against a new technology, possible privacy or scalability issues or system governance issues.

Acknowledgements. This research was supported by the EasyLog project (Interreg IT-FR Maritime Program 2014–2020).

References

1. Serra, P., Fancello, G.: Use of ICT for more efficient port operations: the experience of the EasyLog project. In: Gervasi, O., et al. (eds.) ICCSA 2020. LNCS, vol. 12255, pp. 3–14. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-58820-5_1
2. Jović, M., Kavran, N., Aksentijević, S., Tijan, E.: The transition of Croatian seaports into smart ports. In: 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics – MIPRO, pp. 1386–1390. IEEE (2019)
3. Stopford, M.: Maritime Economics, 3rd edn. Routledge, London (2017)
4. Heilig, L., Schwarze, S., Voß, S.: An analysis of digital transformation in the history and future of modern ports. In: Proceedings of the 50th Hawaii International Conference on System Sciences (2017)
5. Weernink, M.O., van den Engh, W., Francisconi, M., Thorborg, F.: The blockchain potential for port logistics (2017). https://smart-port.nl/wp-content/uploads/2017/10/White-Paper-Blockchain.pdf
6. Treiblmaier, H.: Toward more rigorous blockchain research: recommendations for writing blockchain case studies. In: Treiblmaier, H., Clohessy, T. (eds.) Blockchain and Distributed Ledger Technology Use Cases. PI, pp. 1–31. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-44337-5_1
7. Jović, M., Filipović, M., Tijan, E., Jardas, M.: A review of blockchain technology implementation in shipping industry. Pomorstvo **33**(2), 140–148 (2019)
8. Tijan, E., Aksentijević, S., Ivanić, K., Jardas, M.: Blockchain technology implementation in logistics. Sustainability **11**(4), 1185 (2019)
9. Jabbar, K., Bjørn, P.: Infrastructural grind: introducing blockchain technology in the shipping domain. In: Proceedings of the 2018 ACM Conference on Supporting Groupwork, pp. 297–308 (2018)
10. Gausdal, A.H., Czachorowski, K.V., Solesvik, M.Z.: Applying blockchain technology: evidence from Norwegian companies. Sustainability **10**(6), 1985 (2018)
11. Lindman, J., Tuunainen, V.K., Rossi, M.: Opportunities and risks of blockchain technologies–a research agenda. In: Proceedings of the 50th Hawaii International Conference on System Sciences (2017)
12. Dutta, P., Choi, T.M., Somani, S., Butala, R.: Blockchain technology in supply chain operations: applications, challenges and research opportunities. Transp. Res. Part E Logist. Transp. Rev. **142**, 102067 (2020)
13. Bavassano, G., Ferrari, C., Tei, A.: Blockchain: how shipping industry is dealing with the ultimate technological leap. Res. Transp. Bus. Manag. 100428 (2020)
14. IBM: TradeLens: how IBM and Maersk are sharing blockchain to build a global trade platform – THINK blog (2018). https://www.ibm.com/blogs/think/2018/11/tradelens-how-ibm-and-maersk-are-sharing-Blockchain-to-build-a-global-trade-platform/
15. Nakamoto, S.: Bitcoin: a peer-to-peer electronic cash system (2008). https://bitcoin.org/bitcoin.pdf. Accessed June 2021
16. Wood, G.: Ethereum: a secure decentralised generalised transactionledger (2014). (updated version). https://ethereum.github.io/yellowpaper/paper.pdf. Accessed June 2021
17. Ahmad, R., Hasan, H., Jayaraman, R., Salah, K., Omar, M.: Blockchain applications and architectures for port operations and logistics management. Res. Trasp. Bus. Manag. 100620 (2021)
18. Irannezhad, E.: The architectural design requirements of a blockchain-based port community system. Logistics **4**, 30 (2020)

19. Laurent, M., Kaaniche, N., Le, C., Vander Plaetse, M.: A blockchain-based access control scheme. In: SECRYPT 2018: 15th International Conference on Security and Cryptography, July 2018, Porto, Portugal, pp. 168–176 (2018). https://doi.org/10.5200/0006855601680176. hal-01864317
20. Gatteschi, V., Lamberti, F., Demartini, C., Pranteda, C., Santamaria, V.: Blockchain and smart contracts for insurance: is the technology mature enough? MDPI: Future Internet **10**(6), 8–13 (2019). https://doi.org/10.3390/fi10020020
21. Marchesi, L., Marchesi, M., Destefanis, G., Barabino, G., Tigano, D.: Design patterns for gas optimization in ethereum. In: Proceedings of the IEEE International Workshop on Blockchain Oriented Software Engineering (2020)