



## Navigating the Future: Unlocking the Potential of Blockchain Technology in the Maritime Sector

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**Abstract:** Starting from the paradigm that 80% of global cargo transport occurs through the shipping sector, this article explores not only the transformative potential of blockchain technology in this industry, but also the challenges that may arise from it. In this light, this study aims to explore the critical success factors of blockchain implementation by analyzing the theoretical context and practical applications of the maritime sector, developing a specific blockchain implementation framework for maritime logistics and operations. Through detailed analysis and examples, including initiatives like TradeLens and CargoX, this article demonstrates blockchain's ability to streamline processes, reduce bureaucracy, and improve integrity across the supply chain. Furthermore, the proposed conceptual methodology promises a more interconnected and reliable supply network by increasing transparency, simplifying documentation and improving security is a valuable contribution to the future decision-making literature, which currently has few structured methodologies. In conclusion, the implication analysis of blockchain adoption indicates that for industry organisations, a good understanding of blockchain and their own specific problems and requirements is key before adopting the technology. Recommendations are provided to various maritime stakeholders to seize the emerging opportunities provided by blockchain and mitigate relevant risks.

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## 1. Introduction

The maritime sector represents a main actor in the global economic landscape, maritime transport covers approximately 80% of the world's freight transport, thus it acquires an essential role in international trade (UNCTAD, 2019). Supply chains are particularly complex systems, with a multitude of actors, and as technological evolution takes hold, the processes become more and more complicated and vulnerable. These challenges may be due to operational inefficiency, cyber security, or lack of transparency in transactions (Ambrozie & Sorcaru, 2022).

Blockchain technology is a decentralized system that promises to revolutionize various industries through its characteristics: transparency, security and efficiency (Nakamoto, 2008). Originally designed for peer2peer transfers of digital currencies, today this technology is gaining new areas of application. The maritime sector is one of those areas where blockchain can be applied, as maritime transport is a very complex network, besides shipping companies, port authorities, maritime service providers, customs brokers, terminal operators, regulatory and safety organizations, technology providers, the maritime sector also encompasses a multitude of transactions and operations between component parties. Due to these facts blockchain is gaining interest and becoming more and more promising in the maritime sector (Pu & Lam, 2020). Its ability to provide a clear, transparent, secure record that cannot be altered and is not dependent on a central authority may provide a solution for this area.

More and more companies in the maritime industry are beginning to turn their attention to blockchain technology and are beginning to realize how much potential this technology has. Since this technology has the ability to record information transparently, decentralized and immutable, it comes as a solution to many of the challenges encountered in the maritime sector (Zhao et al., 2019). Even though this interest is growing, both blockchain technology and its applications are in their infancy. This article aims to provide a comprehensive perspective on the implementation of blockchain in the maritime sector, by developing a framework, this research aims to provide a clear perspective of the application of blockchain technology in this field.

## 2. Theoretical Background

### 2.1. Overview of the Maritime Sector

Since ancient times, the maritime sector has been and is a vital component of international trade, the historical relevance lies in examples of well-known ancient routes such as the Silk Road which allowed the transport of goods from China to the Mediterranean world, the Phoenicians were also renowned for their skill maritime and established trade routes on the Mediterranean Sea, the Viking routes were extensive and allowed trade from the entire European coast to North America.

The maritime industry also played a very important role for the development of people, not only for trade, besides the movement of goods, these routes allowed the mixing of cultures, teachings and ideas. Thus we, the people, have become dependent on maritime transport for economic prosperity, the proof lies in the volume of maritime transport, in well-organized routes, the number of maritime companies and participants in this sector.

In the modern era, the maritime sector has become a well-structured, complex, advanced and interconnected network. Mega-ships that can carry tens of thousands of containers are the backbone of important economic nodes and support world economies (Levinson, 2006, p.45).

Due to its complexity, the maritime sector can face many challenges. Operational inefficiencies are often encountered due to the large number of procedures, manual processes are also a vulnerable point along with document processing. Ineffective communication between the parties involved often leads to delays at ports. Regarding regulatory arrangements, the maritime sector must comply with a complicated network of laws due to the international nature of the activity.

Environmental impact is a concern for the maritime sector due to the high consumption of fossil fuels, due to ship emissions but also oil spills and waste management. (Psaraftis & Kontovas, 2019). Environmental standards, safety protocols and international legislation is a constant concern due to continuous changes (Branch, 2007, p. 36).

Digitization is increasingly present in the operations of the maritime sector, but with it the sector becomes more and more vulnerable and cyber security, data protection and the integrity of communication systems become essential priorities.

The ability of the maritime sector to innovate and adapt will dictate the future of the maritime sector. New technologies such as blockchain have the potential to solve many of the challenges facing this sector. With the help of emerging technologies, the maritime sector can continue its leading role in international trade.

## 2.2. Overview of Blockchain Technology

Blockchain technology appeared with digital currencies, one of the most innovative technologies of the 21st century, but the potential of this technology and the areas of application go far beyond the field of cryptocurrencies. The starting point of blockchain technology can be found in 2008, when the digital currency Bitcoin appeared. Blockchain is the underlying technology of Bitcoin, which has the role of recording transactions through a decentralized network of computers as a public ledger, guaranteeing security, immutability and transparency. From 2008 to today this technology has evolved, new types of blockchain, applications such as smart contracts and different consensus mechanisms have appeared (Ambrozie & Sorcaru, 2021).

The fundamental characteristics of blockchain are decentralization, transparency and immutability.

Blockchain operates on a peer-to-peer network and does not rely on a central authority as in traditional networks, thus the decentralized nature of this technology makes it more secure as there is no single point of failure and a single entity cannot control the entire system .

Transparency is ensured by the way data is recorded, any data changes are public, all transactions are visible to all participants in the network, thus transparency and traceability are ensured.

As for immutability, another fundamental feature of the blockchain, it is due to the way information is stored in the blockchain, from the moment the information is stored it cannot be changed without changing the following blocks, which requires the approval of the network. Thus the integrity and reliability of the data is guaranteed.

Blockchain uses consensus mechanisms such as Proof of Work (PoW) and Proof of Stake (PoS) to validate and verify transactions, through these mechanisms transactions are validated and verified, thus transactions are approved by network participants and prevent fraudulent operations (Zohar, 2015).

Although blockchain technology was first used in the field of cryptocurrencies, due to its characteristics it is increasingly found in other fields such as supply chain management, insurance, banking, medical and maritime. Blockchain is a viable solution for all sectors that want to achieve increased efficiency, improve transparency and ensure data integrity.

### **2.3. Blockchain Applications in the Maritime Sector**

Due to the complexity of the maritime sector, with multiple participants and transactions, it offers the opportunity for blockchain technology to solve the existing challenges. In recent years there have been various attempts to apply blockchain to the maritime sector.

Tracking documents and goods, a very important element in the vulnerable maritime sector when traditional methods are used, prone to errors, delays and fraud. Blockchain has come as a solution, providing transparent and immutable data records in terms of commodity traceability. Thus, most blockchain applications are registered in this section. Maersk in collaboration with IBM launched the TradeLens project in June 2016, designed using blockchain technology to provide increased transparency, security and traceability. The purpose of TradeLens is to digitize paper-based processes in supply chain management and the maritime sector. TradeLens has improved port operations, customs processes and cargo traceability globally (Ahmed, 2022).

Smart contracts are self-executing contracts whose terms are written directly in the code, when the conditions pre-written in the code are met, the contract is self-executing. In the maritime sector these smart contracts have improved automation processes and streamlined shipping contracts and agreements. These types of contracts reduce the need for intermediaries and ensure that the terms of the contract are respected.

CargoX is a company founded in 2017 based in Ljubljana, Slovenia, it offers a solution in the maritime industry and beyond, for the transfer of global commercial documents in a secure, efficient and transparent manner. The traditional process is slow, prone to fraud and expensive, through their Blockchain Document Transfer (BDT) platform they ensure that documents are encrypted and transferable only between authenticated and authorized parties. This platform significantly reduces document transfer time and increases the security and traceability of transactions.

WAVE BL is based in Israel and was established in 2016, its purpose is similar to that of CargoX and it focuses primarily on eliminating the costs and risks associated with physical Bills of Lading. The transfer of documents is streamlined and validation, accessibility and trust between the parties involved in the transaction are ensured. By implementing blockchain technology WAVE BL allows participants in a commercial transaction to exchange original documents electronically without the need for a central authority or intermediaries. In this way, the time for exchanging documents is reduced from a few days to a few seconds.

Port operations and customs clearance are essential links in the maritime supply chain, the Port of Rotterdam initiated a project to integrate blockchain into its operations in 2017 with the aim of automating and streamlining port logistics and

customs clearance (Verhoeven & Vanoutrive, 2020). The Maritime and Port Authority of Singapore is collaborating with IBM to implement blockchain in document trading securely and efficiently. The Port of Valencia announced its strategic decision in 2018 to create a “smart port” by integrating blockchain to improve logistics and container management, streamline port operations and reduce operational costs. In Australia, the Port of Brisbane has partnered with PwC Australia and the Australian Chamber of Commerce and Industry to launch a blockchain-based platform for supply chain logistics. The platform, named “Trade Community System”, aims to improve efficiency by digitizing trade processes and reducing paperwork.

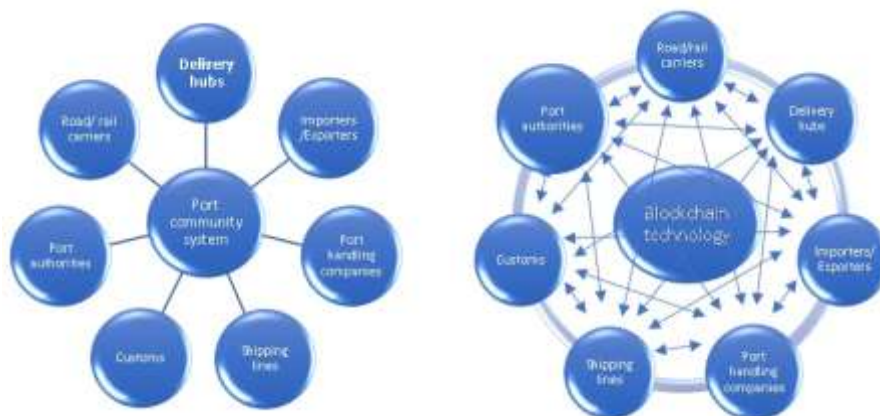
These are just a few examples that demonstrate the growing interest of the maritime sector in the ability of blockchain technology to solve existing challenges in this field. However, the adoption of this emerging technology is not without challenges, issues related to scalability, interoperability with existing systems are barriers to widespread adoption. Also, the decentralized nature of blockchain raises questions about governance and regulations that need to be addressed in a global context, especially in the maritime sector (Hackius & Petersen, 2017).

### **3. Conceptual Framework**

In the dynamic landscape of global trade, the maritime sector is forced to pioneer digitization and technological innovation. In an amalgam of digital technologies, blockchain has stood out for its features and ability to solve challenges encountered in maritime operations and supply chain management. This article proposes a conceptual framework to outline the multiple applications that blockchain can have in the maritime sector. Blockchain promises a more interconnected and reliable supply chain by increasing transparency, streamlining paperwork and improving security.

In the maritime sector blockchain technology can provide digital infrastructure improving certain operational aspects. For port authorities, it simplifies operations, has the ability to track goods in real time and can automate administrative processes, thus delays are reduced and management operations are streamlined. Shipping lines use blockchain for better ship and cargo traceability, efficient fleet management, automatic payments through smart contracts. Customs authorities have huge potential in blockchain technology due to its characteristics to record data securely and transparently, simplifying the customs process, preventing fraud and ensuring compliance with existing regulations. Exporters and importers have an advantage in improving traceability and ensuring the authenticity of goods, secure and immutable data records strengthen confidence and efficiency in international trade. Analyzing

the benefits of the parties involved we can say that blockchain technology can promote a coherent and efficient ecosystem in the maritime sector.



**Figure 1. Blockchain Application Framework in the Maritime Sector**

The Port of Veracruz in Mexico is an example of the successful implementation of blockchain technology to improve the safety and security of maritime transport. For shipping companies, the most significant project implemented is TradeLens, implemented by Maersk in collaboration with IBM, the ability of this platform to provide real-time access to shipping data and documents improves transparency and efficiency in global supply chains. The TradeLens project also offers solutions to customs agencies, thanks to the immutable character of the blockchain frauds are reduced and customs procedures are simplified and become faster. For port authorities, blockchain reduces paperwork and streamlines the management of port operations. Applications of blockchain in port operations include terminal scheduling, regulatory compliance and payment processing all of this can result in a more efficient port management.

Jugović et al. (2019) highlight that the maritime industry has effectively adopted new technologies regarding shipping lines, through the implementation of smart contracts and IoT, traceability and transparency are improved and through automated processes efficiency is increased. The use of blockchain in customs procedures is a broader topic that involves government decisions and budgets allocated for digitalization, the benefits are obvious but the investments can be expensive. Under an overview, when maritime companies incorporate information recording systems through IoT, when transactions are automated through smart contracts, when customs and port authorities simplify the documentation process, the level of compliance with ongoing regulations can also improve. These integrations can improve the transparency and integrity of supply chain management, allowing

stakeholders to track goods from origin to destination. Smart contracts can automate the terms in the contract and reduce disputes and increase efficiency.

The exchange of information can be improved, the transactions of the importer or exporter can benefit from the use of this technology, the impact on economic, environmental and social sustainability is stimulated in a positive way. Blockchain enhances regulatory compliance by providing auditable records of all transactions and movements within the supply chain. Additionally, its inherent security features mitigate the risk of data breaches, fraud, and tampering.

As presented in the conceptual framework figure, the implementation of blockchain in the maritime sector has a wide range of applications that can bring improvements, more efficient and transparent communication between all participants. Blockchain can revolutionize maritime operations because it enables real-time tracking and certifies the authenticity of goods, which is especially important for perishable food or medicine. Administrative burdens and operational delays in maritime logistics can be improved especially through document management and process automation. Immutability, a feature of this technology, brings an additional layer of protection against fraud and errors in document management, essential in customs and international trade transactions.

However, these changes are not without challenges, the complex maritime ecosystem with a multitude of participants and regulatory frameworks alongside the international nature of this sector require collaboration and consensus among all stakeholders globally. Investments to build a blockchain-based infrastructure are considerable, the costs of training staff to be able to work with this technology represent a barrier. Interoperability is another challenge that needs global agreement and regulations regarding these systems also need to be analyzed in a global framework.

Blockchain applications in the maritime sector are numerous, sustainability is yet another aspect supported by blockchain technology, fuel consumption and carbon emissions can be monitored, helping shipping companies meet environmental regulations and sustainability goals. The resilience of supply chains can be increased through blockchain implementation, especially when we are faced with global challenges such as the COVID-19 pandemic. Blockchain paves the way for a connected, efficient and secure global maritime industry.

#### **4. Conclusions**

The conceptual framework presented in this study illustrates the complex environment of the maritime sector and how blockchain applications can bring benefits. The relevance of this conceptual framework lies in the ability to understand



the impact of blockchain in the maritime sector, by disseminating this sector in distinct lines such as port authorities, customs, shipping lines, port handling companies, importers/exporters and delivery hubs, it allowed to observe how blockchain can influence the influence of these participants.

This framework is a basis for future research and provides perspective for future research in the field. The maritime sector is particularly dynamic, always changing, it faces opportunities but also challenges. Therefore, future research can consider longitudinal studies, which can analyze the evolution of blockchain applications over time. The interest from the regulatory frameworks for this technology is high, but it is interesting to observe what measures are being promoted in this regard. The issue of interoperability between the various parties involved in the maritime supply chain needs solutions.

In conclusion, we can say that this framework enriches our perspective on blockchain applications in the maritime sector, but is also a catalyst for future research to unlock the potential of blockchain technology in terms of increasing efficiency, security and sustainability.

Blockchain technology is an answer to the traditional challenges of the global trade, through its characteristics it can enhance transparency, efficiency and security. As the interest and the integration of the blockchain technology grows due ongoing collaborative efforts, the full potential of blockchain in the maritime sector is yet to be fully realized.

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