Blockchain for Revolutionary Maritime Evolution

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The nautical sector is progressively transitioning towards a digital framework, aiming to harness collective benefits. This evolution involves integrating disparate existing systems into more unified, scalable platforms. Yet, this shift encounters several obstacles. In response, it is proposed to employ cutting-edge technologies like blockchain, which resonate well with the industry's requisites. The study adopts a comprehensive approach, intertwining an array of sources including scholarly literature, online data, practical applications, and industry projects, to illuminate blockchain's contributions and its potential applications. It further investigate its applicability, drawing parallels and projections from other industries. Moreover, the research delves into the challenges and proposes viable solutions. This inquiry serves as an initial exploration into blockchain's integration in the maritime realm, endorsing its transformative potential. The outcomes of this study are anticipated to be valuable for academics, policy strategists, and industry professionals in the maritime field.

Keywords: blockchain ; smart port ; shipping industry ; maritime sector

1. Blockchain: A maritime link

The attempts to establish new evolutionary approaches in the maritime sector retained findings and objectives set by the “industry 4.0” concepts. They aimed to achieve global interoperability by utilizing innovative technologies while maintaining a competitive edge for businesses. This was also evidenced in the new shipping business model which revolved around value.

2. A Profitable Argument

Value is created when the profit exceeds expenses and expands beyond tangible assets. It can consequently be generated through indirect revenues such as new technologies and scalable networks [1] embracing a more heterogeneous landscape of systems. An example of this can be portrayed through the shipping cost equation which accelerated the shift from bulk shipping to containerized cargo. Profit (P) can be calculated by subtracting expenses (C) from revenues over a period of time (t) as shown in the following equation:

$$R(t) - C(t) = P(t)$$

The cost of a cargo (C) is equal to the sum of all costs (operational cost, cargo maintenance, cargo voyage, cargo handling, and cargo capital costs). The operational cost also covers the vessel’s operational cost. The bigger the vessel, the bigger its operational cost. However, C is inversely proportional to the vessel’s size and also inversely proportional to the overall cargo size. This means that despite that the bigger the vessel the larger its operating costs, these costs are outweighed by the revenue increase for cargo, thus lowering its costs and maximizing profits in the above equation. An example of reasoning can be that the non-tangible asset, the ship’s idling time, where added control reduces error by a third, largely improves statistical analysis and consequently performance to minimize costs [2]. Moreover, a ship’s revenue (R) is directly linked to its productivity factors such as operational planning, backhauls, operating speed, off-hire time, dead-weight utilization, and port time. These factors can also be considered as operational parameters where added control also increases revenue, creating a larger profit. In an ecosystem that is largely driven by profit, having presented the importance of added control such as transparency and traceability for optimal operational parameters and profit increase, blockchain can be introduced as a revolutionary approach to the maritime 4.0 ecosystem for an increased value [3].

3. About Blockchain

Blockchain technology enables the distribution of infrastructure across both inter- and intra-organizational entities, without the need for a centralized authority that is trusted. The technological advancement in the shipping industry is currently embodied by the use of PCS and data-driven tools. However, operational efficacy and logistics management are still far

from optimum across the supply chain, with poor global transparency and data exchange. Moreover, the supply chain remains haunted by the aberrant use of physical documentation halting any real-time access to information and decreasing overall efficiency and accountability. Despite the introduction of advanced and increasingly digitized systems in fragments of the supply chain, as a whole, it is still fragmented. It consists of successively intertwined processes and actors having their distinct systems, where any detrimental variable can cascade over the whole chain as shown in **Figure 1**.

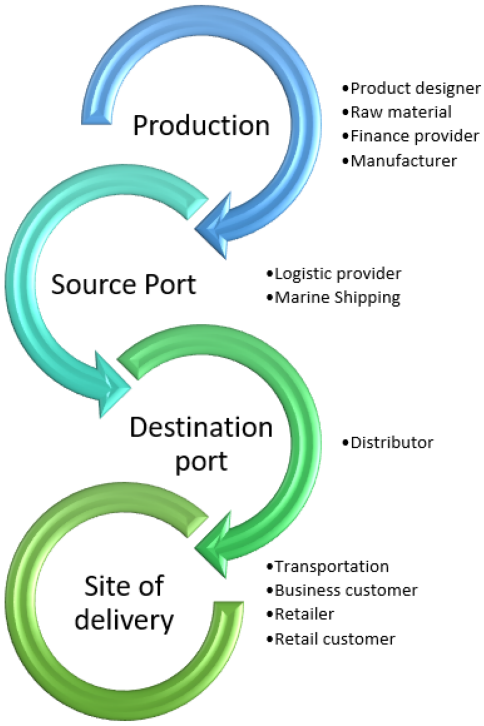

Figure 1. A simplified scheme of the supply chain elaborated by the author.

With blockchain, the information register can be replicated for all relevant actors beyond any predefined local networks such as PCS or cargo community systems. It allows real-time dissemination through all needed checkpoints over the supply chain. It creates a decentralized distributed communication system where data can be verified and certified through consensus protocols. This aligns with the distinctive results presented in [4] that highlight the importance of decentralized approaches and unconventional representation of the supply chain beyond port zones. The maintenance of such systems does not rely on any unique centralized trusted entity but instead on the infrastructure of the system itself. Decision making, processing, auditing, maintenance, transaction approvals, and data validation is carried out collectively. Moreover, actors are forced to maintain a minimum of reliability for not only the collective convenience but only their own individual gains. Any inconsistency can be quickly detected and unvalidated through the replicated ledger, data chaining, time stamps, encryption, and the collective consensus protocol. Such a system unlocks further transparency and traceability that consequently reduces fees including accounting and auditing, unnecessary trusted intermediaries and single point of failures [5].

Nevertheless, using blockchain is not analogous to data divulgence. As mentioned, blockchain technology was deployed as an infrastructure for digital currency. It established trust within a trustless environment based on a peer-to-peer system, and allowed users to exchange financial transactions without trusted centralized establishments (such as banks) while also freeing currency concepts from being entangled with countries' economical statuses and banks. This explains the need for such an application to be public, as it is deployed within a public pool of users, where various unrelated actors are responsible for ledger examination, maintenance, and data validation, declaring it as a valid trusted platform used as a global digital currency-exchange liaison. However, the financial sector is quite different from the maritime sector. In the latter, despite the need for distributed global approaches, the presence of centralized entities such as governments remains necessary, and is a mandatory consideration for any technological deployment, in addition to the presence of sensitive data that comes along with all the competitive entities that negate the concept of an open data-sharing platform for competitiveness and security reasons, among others. The technology can be introduced to the shipping industry by the creation of a hybrid network that includes clusters of public, private, and consortium networks communicating among each other [5][6][7]. It is also important to distinguish between each type's characteristics for it to answer to the maritime ecosystem's constraints. For example, an end user or a retail customer can be a part of the public globally spread blockchain network communicating with other types of networks that consist of shipping agencies, ports, freight

forwarders, and transportation agencies. It would grant the user transparent and clear visibility of its cargo's journey (such as arrival time) while maintaining accountability at its optimum without the need to divulge sensitive irrelevant data, such as the ship's manifest. A theoretical conceptual representation of the envisioned system without a pre-defined set of network types is represented in **Figure 2**.

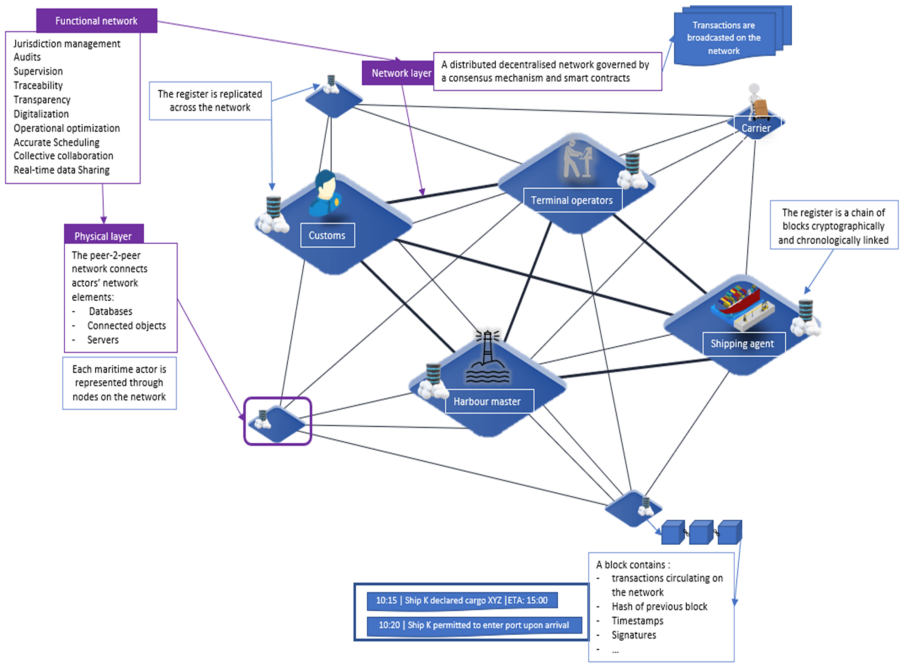

Figure 2. A conceptual blockchain-based maritime ecosystem elaborated by the author.

The network choice should not be only based on literary information and each type's characteristics, but also should include maritime actors' experiences through surveys, and studies to reach effective optimality between decentralization, trust, and immutability. In a public blockchain, trust is established through decentralization and immutability. The replicated ledger over a larger number of nodes makes it harder to alter information in the ledger since each block is linked to the previous one. The larger the network and bigger the ledger, the more time- and computationally-consuming it is, which renders public networks immutable. In private or permissioned networks, the number of nodes and ledger size is more limited, making them less immutable.

4. Partial Recognition and Early Adopters

Blockchain has successfully evolved in the financial sector with several successful projects such as Bitcoin, Ethereum, and others that have been adopted on a global scale. A user in a time zone A with a native currency X can transfer a Bitcoin to another time zone B with a native currency Y independently of any singular trusted entity or bank, relying only on the Bitcoin network. After a certain time, the transaction can be successfully observed and is certified and verifiable. This seamless exchange is not only restricted to financial assets but expands to include tangible and intangible assets. This confirms the hypothesis that blockchain can be used in the maritime sector for more seamless operational processing and digitization. It has been reflected as the technology has successfully sparked interest in other sectors, including the maritime industry, where multiple projects emerged (see **Table 1** [8]).

Table 1. Blockchain projects' use cases in the maritime sector.

Usecase	Project	Owner/Proposer	Blockchain Used	Documentation
Fuel quality and traceability	**BunkerTrace**	**Blockchain labs for open collaborative and Main Blockchain Labs**	**Ethereum**	**https://bunkertrace.co/**

Usecase	Project	Owner/Proposer	Blockchain Used	Documentation
Shipment Tracking	TradeLens	Maersk and IBM	Hyperledger Fabric	https://www.tradelens.com/
	GSBN	Oracle, Microsoft, AntChain and Alibaba Cloud	AntChain	https://www.gsbn.trade/
	Silsal	Abu Dhabi Port	Hyperledger Fabric	https://www.adports.ae/abu-dhabi-ports-collaborating-with-msc-mediterranean-shipping-company-on-international-blockchain-solution-silsal/
	Calista	PSA International, and Global eTrade Services (GeTS)	Not a blockchain but an intensive API delivering end-to-end data (based on blockchain concepts)	https://calistalogistics.com/
Track and Trace hazardous goods	(pilot project)	BLOC and Lloyd's register foundation and rainmaking consortium project	–	https://www.lr.org/en/latest-news/lr-foundation-bloc-establish-maritime-blockchain-lab/
Smart Bill of Lading	CargoX	CargoX	Ethereum	https://cargox.io/
	TradeLens	Maersk and IBM	Hyperledger Fabric	https://www.tradelens.com/
	Bolero's digital trade platform	Bolero	Volton Corda based	https://www.bolero.net/
	Easy Trading Connect	Blue Water Shipping Louis Dreyfus	Ethereum Quorum	https://www.ldc.com/press-releases/louis-dreyfus-company-ing-societe-generale-and-abn-amro-complete-the-first-agricultural-commodity-trade-through-blockchain/
	(proof of concept)	Pacific International Lines ,and PSA International and IBM Singapore	Hyperledger Fabric	https://www.globalpsa.com/psa-pil-and-ibm-conclude-a-successful-blockchain-trial-along-the-southern-trade-corridor-stc/
	WAVEBL	https://wavebl.com/about/	private blockchain	https://wavebl.com/
	Tokio Marine	Tokio Marine Holdings	Corda	https://www.gtreview.com/news/fintech/insurance-blockchain-alliance-leaves-ibm-hyperledger-for-r3s-corda/
Digitization	(storage on blockchain)	DNV GL	Vechain Thor	https://www.dnv.com/assurance/certificates-in-the-blockchain.html
Smart Contracts	Blockconnect	300Cubits	Ethereum	https://www.300cubits.tech/
	ShipChain	ShipChain	Ethereum	https://www.freightwaves.com/news/logistics-provider-shipchain-which-built-on-blockchain-shutting-down-after-big-payment-to-sec

Usecase	Project	Owner/Proposer	Blockchain Used	Documentation
Insurance and finances	(proof of concept: maritime insurance platform)	A.P.Møller-Maersk, Willis Towers Waston, MS Amilin, and XL Catlin	Corda	https://www.wtwco.com/en-GB/news/2018/06/willis-towers-watson-at-the-forefront-of-blockchain-technology
	(proof of concept: Blockchain Insurance Industry Initiative)	B3i Services AG	Corda	https://b3i.tech/
	(enterprise-level blockchain consortium)	RiskStream Collaborativ	Corda	https://web.theinstitutes.org/institutes-riskstream-collaborative-launches-canopy-risk-management-and-insurance-industrys-first
	Shipowners	Shipowner.io	Ethereum	https://shipowner.io/
	Skuchain	Founded by Srinivasan Sriram	Hyperledger Fabric	https://www.skuchain.com/
	Provenance	Owned by Morgan McKenney	Ethereum	https://www.provenance.io/
	Tallysticks	Co-founded by Kush Patel		https://www.f6s.com/tallysticks
VGM Portal	SOLASVGM	Kuehne + Nagel Group	Hyperledger Fabric	https://newsroom.kuehne-nagel.com/kuehne–nagel-deploys-blockchain-technology-for-vgm-portal/

These projects differ in concept and cover multiple areas of the logistical maritime operations, from storage to delivery and payments, as well as the improved transparency and security achieved. For example, the project “TradeLens” is a joint idea between two competent companies, IBM and Maersk, with an ultimate goal of cost-effective improved traceability. Another example is “CargoX” which focuses on document digitization, such as bills of lading. It aims to provide a secure, reliable, and time- and cost-effective method of processing shipping paperwork anywhere on the globe. Other projects went further and targeted payment methods in the maritime industry with an idea of a global decentralized currency such as ShipChain or 300Cubits. ShipChain created a SHIP token to facilitate transactions. However, this project failed to overcome the regulatory novelty of the technology. The initial coin offering that put the token into circulation was unregistered with the security and exchange commission. The project shut down after a huge payment to settle its charges and cut down its resources. The 300Cubits project idea was to create TEU tokens targeting the problem of no-shows and rolled cargo.

Similarly, the project faced certain challenges that obstructed its adoption. This could be due to the lack of inherent interest in the project’s concept by the maritime ecosystem. The project over-complicated the problem. Cargo overbooking and rolling may be solved with a simple edited freight contract. Additionally, there is no currently pressing change to induce a contractual change; nevertheless an investment in a new technological solution is required.This state-of-the-art work highlights the need for a study targeting the technology’s potential to identify the real and successful application for the technology in the maritime sector to achieve its full efficacy and avoid being substandard.

Moreover, Blockchain is still often described in the literature as a novel technology. The term novel represents the recency degree of the technology. The more recent the technology is, the more it is important to dissect it and explore not only its potential but also to understand the challenges it may face. Once challenges are known, the technology can be introduced to the ecosystem levitating the ambiguity it faces. However, the full potential of a decentralized technology such as the blockchain cannot be exploited without efforts being made in the ecosystem to ensure total coordination and widespread adoption. Therefore, the researchers re-addressed some of the challenges and brought forth additional challenges with a deeper analysis using the triangulation approach to confirm hypothetical challenges probe for solutions and analyze them. Hence, the deployment of blockchain technology will become less ambiguous as solutions are identified, listed, and analyzed for suitability.

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