

## Challenges to Blockchain Adoption in Global Shipping: Insights from a Systematic Literature Review

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**Abstract** – Blockchain technology could transform global shipping. Replacing antiquated paper-based processes with a secure, immutable digital record of shipments would unlock efficiency gains, save costs, and reduce fraud. Yet blockchain has not been widely adopted. This study employs the PRISMA framework to systematically review the literature on the challenges to blockchain adoption in the global shipping industry. A total of 184 published documents from the Scopus database were identified, of which 54 journal articles met the study's eligibility criteria. By identifying and synthesising key barriers, the review provides valuable and comprehensive insights into the complexity of integrating blockchain technology into global shipping. The findings highlight practical challenges, such as substantial initial investment costs, and regulatory challenges, including uncertainty around dispute resolution, antitrust concerns, and data privacy and security, as pivotal to sustainable innovation and business model transformation through the adoption of blockchain technology in the sector.

**Keywords:** Blockchain, Shipping, Sustainable Innovation

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### 1.0 INTRODUCTION

Remarkably, the business of global shipping in the twenty-first century continues to rely heavily on the antiquated practice of presenting original (paper) shipping documents for cargo release, payment, and transfer of ownership of goods (Wilson, 2010). Shipping lines issue a physical (paper) bill of lading in a set of three originals to the consignor. One original bill of lading must be sent to the consignee and presented at the discharge port to claim delivery of the cargo. A second original of the bill of lading, together with the international contract of sale documents, will be sent to the consignee or their bank (where payment is secured by letter of credit). Blockchain technology is widely acknowledged as having the potential to transform this business model and eliminate the delays, costs and fraud associated with these paper systems.

The integration of blockchain technology in global shipping business models would provide a secure, immutable digital record of transactions between consignors and consignees in a shipping contract by storing the smart contract and delivering the bill of lading via a digital ledger (Takahashi, 2016). The blockchain is a permanent digital record (or ledger) that creates and stores transactions that are time-stamped and grouped in blocks linked to each other, as you would find in a chain. Each transaction entered into the blockchain database is authenticated by the consensus of every computer across the network, collaborating in this verification process (Manners-Bell & Lyon, 2019). A blockchain can store a comprehensive shipping contract in the form of a block of smart contracts that includes the terms of the contract of carriage, receipt of shipment, transfer of title and a bill of lading issued under charter-party (Bashir, 2018).

The potential advantages of integrating blockchain technology in the shipping industry are numerous, particularly regarding consignment tracking, accountability, transactional integrity and the form and period in which bills of lading are delivered to the appropriate consignees (Iansiti & Lakhani, 2017; Tricoli, 2018). While blockchain technology is not a cure-all for the logistical and regulatory problems

in the shipping industry, it can serve as a practical solution to some problems, such as immutability and transactional integrity, cost reduction, consignment visibility, and the registration and real-time finalisation of bills of lading on decentralised ledger systems (Manners-Bell & Lyon, 2019).

Despite these advantages, blockchain technology has failed to secure widespread adoption in the global shipping industry. In 2022, the blockchain-enabled global trade digitisation platform, TradeLens, was discontinued, only four years after it was launched by a joint venture of container shipping giant AP Moller Maersk and IBM (Maersk, 2022). The platform was created in 2018 to establish a digitised trade system built on open standards and designed for use by shipping industries across the globe (TradeLens, 2022). TradeLens facilitated a paperless supply chain, enabling the secure and seamless exchange of information about shipment events in real time. The blockchain-based platform enabled end-users to securely submit, validate and approve digital documents across organisational boundaries, ultimately helping to reduce the time and cost for customs clearance and cargo movement (Manners-Bell & Lyon, 2019). The rationale for the termination of TradeLens was the lack of achievement of “full global collaboration”, which is a necessity for the goal of the project (Maersk, 2022). This is the most recent failure of a large-scale blockchain initiative in the sector and underscores the importance of investigating the barriers to adoption.

This study employs the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) framework to systematically review the literature on the challenges to blockchain adoption in the global shipping industry (Page et al., 2021). By identifying and synthesising key barriers, and grouping them thematically as practical and regulatory challenges, the study provides a valuable and comprehensive contribution to the discourse on sustainable innovation and business model transformation through the adoption of blockchain technology in the sector.

## 2.0 LITERATURE REVIEW

The study performed a systematic literature review, adopting the PRISMA framework (Page et al., 2021). A systematic PRISMA review is a robust method to (a) retrieve relevant evidence on the study’s research problem, and (b), through appraisal and synthesis of the results, to inform practice and policy and identify areas for future research (Munn et al., 2018; Zhang & Gu, 2022). The systematic review process followed a standard procedure of literature search, quality assessment, data extraction, and synthesis (Mengist et al., 2020; Saif et al., 2022). The research team was composed of three academics with law backgrounds and based in South Africa.

### 2.1 Literature Review

The search was conducted on Scopus on 19 February 2024 by the first researcher. Scopus (Burnham, 2006; Zhu & Liu, 2020) was selected for its combination of comprehensive, rigorous coverage of scholarly literature and advanced search and filtering functionality (Bakkalbasi et al., 2006; Joshi, 2016; Martín-Martín et al., 2018). The search for keywords was applied to the title and abstract field using the following search query: TITLE-ABS-KEY (blockchain AND shipping OR maritime AND challenges OR solutions OR implementation). The search was unrestricted in date range because, although blockchain is a relatively new innovation, the study sought comparative insights to traditional business models. The search yielded 184 results.

### 2.2 Quality Assessment

A systematic screening process was applied as outlined in the PRISMA flow diagram (Figure 1). Using the filters on Scopus excluded 4 records not in English and 30 records not in peer-reviewed journal articles. The title, abstract, keywords, authors' names and affiliations, journal name, and year of publication of the remaining identified records were exported to an MS Excel spreadsheet (Annexure A). The first researcher then carried out a manual screening of the titles, abstracts, keywords, and full

texts, applying the eligibility criteria for inclusion. No automation tools, machine learning classifiers, or generative AI devices were used to eliminate records. The third researcher audited the results.

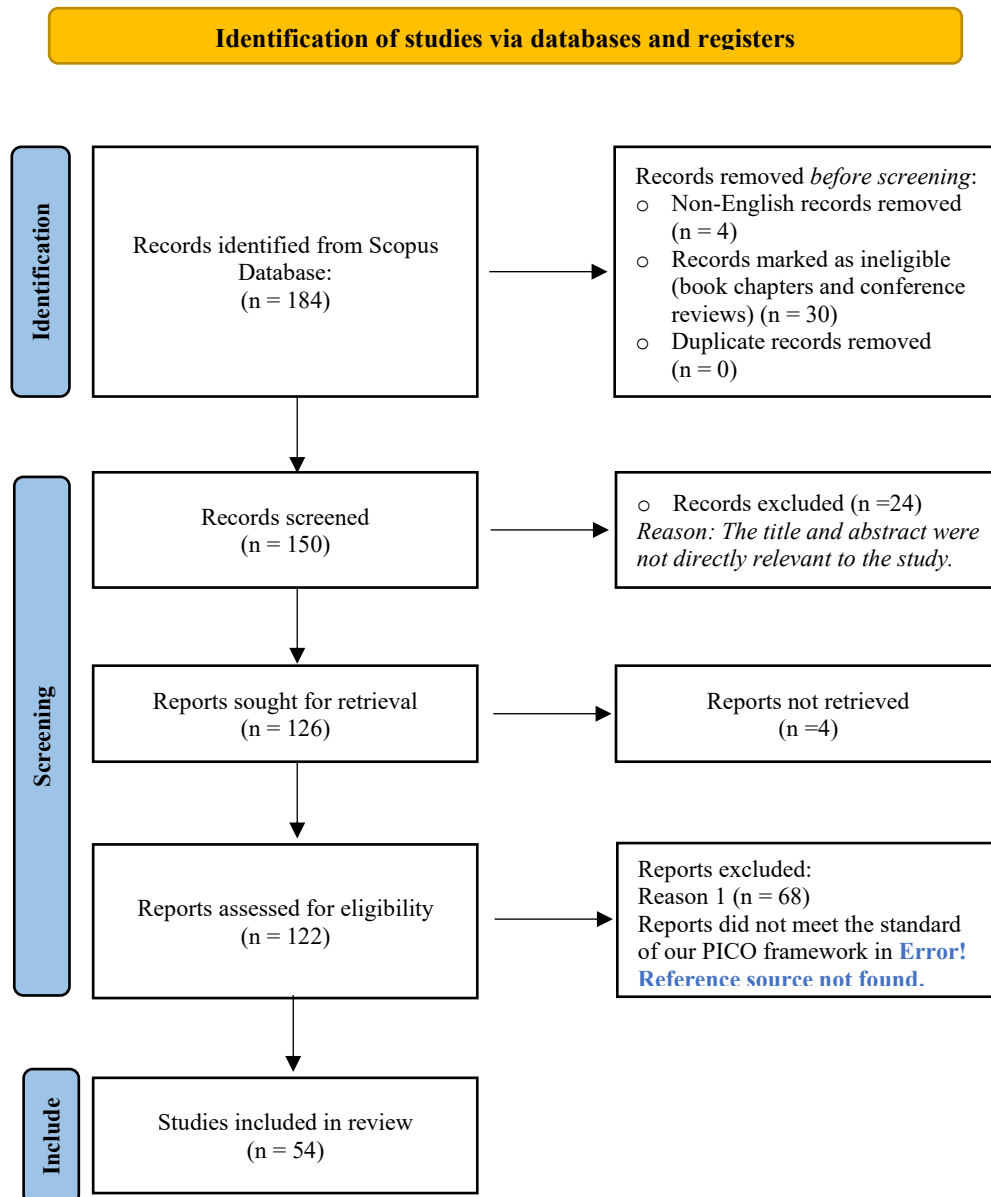


Figure 1: Flow Chart of Studies

### 2.3 Eligibility Criteria

The first and second research defined the eligibility criteria used to screen results according to the modified PICO (Problem-Intervention-Comparison-Outcome) model shown in **Error! Reference source not found.**. The PICO model is useful to develop research questions and define eligibility criteria for systematic searches (Frandsen et al., 2020). It was adopted in the present study in view of the highly diverse nature of the literature from various regions, industry sub-sectors and legal jurisdictions. As the study aimed to present a holistic, global or industry-wide review of challenges in blockchain implementation, publications were screened for high relevance according to whether they met all four criteria in the PICO model:

- (P) Population & Problem: The study population was the global shipping industry. Publications were included if they contained a global or industry-wide discussion of practical or regulatory challenges in blockchain implementation. Studies that only focused on a specific region, enterprise or individual case study were excluded.
- (I) Interventions: Publications presenting a qualitative analysis of an extant or terminated blockchain application in global shipping were included. Qualitative studies examine and interpret events and experiences within their broader legal and socio-economic context (MacEachen et al., 2016; Seale et al., 2004) and were selected as most appropriate to address the research objective of assessing the underlying reality of attempts to implement blockchain. Quantitative studies were excluded from the review.
- (C) Comparison: the publication compared blockchain solutions to traditional models against one or more of the following indicators: cost, documentation, transactions or port operations, and
- (O) Outcome: the publication findings discussed and analysed challenges.

Table 1: Modification of the PICO Framework

Modified PICO Framework		
	Guidelines	Application
P	Patient/Population/ Problem	(Problem) Challenges to the implementation of Blockchain technology in the Shipping Industry. E.g. Cost, Regulations and Security
I	Intervention/Indicator	(Intervention) Highlighting both extant and terminated Blockchain frameworks that have replaced traditional models. E.g. Insurwave switching from Blockchain to SaaS and Maersk & IBM terminating Tradelens.
C	Comparison/Control	(Comparison) Comparing the efficiency in cost, documentation, transactions and port operations between Maritime stakeholders using Blockchain technology and maintaining traditional methods.
O	Outcome	(Outcome) Conclusions and findings that identify practical and regulatory challenges to the implementation of Blockchain technology in the Shipping Industry.

### 3.0 SUMMARY OF RESULTS AND ANALYSIS OF KEY FINDINGS

The analysis and synthesis of results first reviewed the implementation of blockchain technology in the maritime industry and then considered practical and regulatory challenges identified in the literature as barriers to adoption and technological innovation.

### 3.1 Implementation of Blockchain Technology in the Maritime Industry

Before its dissolution in 2022, TradeLens was the leading blockchain platform in the container shipping industry. The TradeLens blockchain platform provided three distinct features which were the platform, marketplace, and ecosystem (Lorenz-Meyer & Santos, 2023). The platform was the underlying blockchain feature that allowed stakeholders and third parties alike to share information. The platform also provided user interface programming to allow its users to build their own applications on the platform (Philipp et al., 2019). The marketplace function provided real-time connectivity across the supply chain, linking cargo owners, freight forwarders and regulators such as customs and border management agencies (TradeLens, 2020). The TradeLens 'ecosystem' allowed for easy and reliable data sharing, encryption, and validation (Jovanovic et al., 2022). Cargo details and shipping milestones, as well as other key trade documents, were protected from both internal and external mutation and alterations (Jensen et al., 2019). The platform was the most successful blockchain project in global shipping to date. As of 2022, TradeLens had processed over 20 million documents, over 2 billion events and more than 42 million shipments (Lorenz-Meyer & Santos, 2023). The platform had attracted some of the biggest ocean carriers and major terminal operators such as Hapag-Lloyd, the biggest German shipping company, ONE, Japan's biggest shipping company and HSBC, one of the world's largest banks and financial service providers (Lorenz-Meyer & Santos, 2023). However, the platform failed to achieve "full global collaboration", which was cited as the main reason for its discontinuation (Maersk, 2022).

While TradeLens remains the most prominent blockchain-based solution in the global shipping industry, there have been other initiatives. Shin and colleagues (2023) identified 20 blockchain-based products introduced in the maritime industry between 2017 and 2021. These initiatives are itemised in Figure 3 below (Shin et al., 2023). Each represents an innovative solution to pervasive problems in the shipping industry.

For example, T-Mining, a Belgian company, built a blockchain platform to efficiently catalogue the process of shipping containers by assigning digital tokens to each container as an alternative to the traditional method of pin codes (Loohuis, 2020). In addition, the company created ID wallets, which serve as a Self-Sovereign-Identity (SSI) tool to provide a secure medium for its members to connect and transact on the platform (Loohuis, 2020). In the United States, ShipChain, a US start-up, developed an Ethereum-based maritime logistics system (DHL Trend Research, 2018). ShipChain's platform monitored the movements of all types of shipping products, allowing for the execution of smart contracts and trading, through the company's cryptocurrency called Ship Token (Cuccuru, 2017; DHL Trend Research, 2018). However, the company was shut down in 2020 due to licensing issues with their cryptocurrency (Kingston, 2020).

The publications reviewed identified a broad range of application potential in the maritime industry, including ship registration systems, smart contracts to manage financial flows within the industry, crew certification systems for training and qualifications, bunker tracking systems to monitor fuel consumption, marine insurance, international contracts of sale, documentation flow (principally, transfer of the bill of lading) and container and cargo tracking in real-time (Munim et al., 2021). The studies also identify key reasons for the hesitation to adopt blockchain technology, as well as practical, legal, and regulatory challenges of blockchain technology in the industry.

Table 2: Blockchain Application Cases (Shin et al.)

Company types	Lead company	Name of project	Main partners	Participating members	Year	Role and aim
Shipping liner	MOL	TradeLens	NYK Kawasaki, and NTT Data	14 members	2017	Trade data sharing platform to streamline procedure and reduce costs
	Hyundai Merchant Marine		Oracle, Samsung SDS, IBM Korea, Busan Port authority	38 members	2017	Blockchain consortium for shipment booking and cargo delivery
	APL		Kuehne+Nagel, InBev, Accenture,		2018	Solution to eliminate shipping documents and save logistics costs
	Pacific International Lines		PSA International and IBM Singapore		2018	Blockchain-based electronic bill of lading to cut the traditional paper trail and streamline the process
	Maersk		IBM	300 members	2018	Open and standardised platform for interaction through real-time access to shipping data and shipping document, including IoT and sensor data
Port	Ocean Alliance carriers	GSRN (Cargo Release)	Bank of China, DBS Bank, HSBC		2019	Blockchain-based open platform to connect stakeholders and allow them to digitise and organise dangerous goods documentation
	China Merchants Energy Shipping	Britc	China Merchants group		2021	Reliable platform for a shipping service platform, a documentation and contract system, as well as an information-sharing centre in dry bulk and tanker industry
	Authorities at the Port of Antwerp	Sisal	T-mining, PortXL programme		2017	Platform to optimise efficiency in the container handling logistics chain by eliminating physical paperwork
	ABU Dhabi Ports unit Maqta Gateway		Maritime SC		2018	Blockchain system providing seamless and secure link between stakeholders across the trade community with encrypted documentation
	Port of Rotterdam Authority		Samsung logistics and ABN Amro		2018	Open, independent and global platform for paperless integration of physical, administrative and financial streams within international chain
Software companies	Marine Transport International	INSURWAVE	Solas VGM		2017	Programme leveraging the legal requirements
	ShipNext		300 cubits		2018	Selling digital token for secured and reliable transactions in cryptocurrencies
	300 Cubits		Westports, LPR		2018	Deposit system using BCT and TEU token to address the problem of cargo 'no-shows' and 'rollovers'
	EY and Guardtime		Oracle	4 members	2018	Digital platform for marine hull insurance
	CARGOSMART				2018	Solution for supply chain parties to auto-fill repeated and verified information
Insurance	CargoX	TrustTrade	Hapag-Lloyd, Zim, MSC		2018	Blockchain-based electronic bill of lading
	Wave BL		Singapore's Infocomm Media Development Authority		2020	Blockchain-based electronic bill of lading
	BunkerChain		Blockchain Labs for Open Collaboration (BLOC)	8 members	2021	Real time visibility and control of the physical bunkering process with full audit trail
	LLOYD'S Register Foundation				2018	Tracking the risks and challenges associated with the declaration and handling of dangerous goods
	BNP Paribas and HSBC Singapore				2018	Digitised letter of credit transaction and digitalisation of trade finance

### 3.2 Practical Challenges

The hesitancy to adopt blockchain-based solutions contrasts with the maritime industry's generally positive approach to adopting technological innovation (Zhang & Gu, 2022). Some authors note greater caution in relation to risk-taking and organisational change among senior decision-makers (Gausdal et al., 2018). Yet, it is puzzling that blockchain is not being adopted more widely, particularly in relation to digital document transfer. Global shipping is information-intensive, involving the exchange of large amounts of data between multi-sector stakeholders from shipping organisations, traders, logistics service providers, and regulators (Gausdal et al., 2018). Disruptions to data exchange can result in liabilities of up to \$5 million per day, while poor information management can account for as much as a 20% deficit in operating budgets (Den Norske Veritas DNV, 2016). This warrants closer examination of the reasons behind the shipping industry's reluctance to adopt technological solutions to address these problems.

Gausdal and colleagues (2018) identified barriers to digital innovation. First, the authors highlight the high cost of adoption and the uncertain return on investment (Cygler & Sroka, 2016). Initial investment costs, including energy, equipment and training, are very high. This can be discouraging, especially when there is no guarantee of its effectiveness (Li et al., 2024).

Secondly, as shipping is a global business, the adoption of digital solutions is problematic due to limited and slow internet services in some parts of the world (Gausdal et al., 2018). Blockchain solutions and real-time freight analysis and tracking rely heavily on the Internet (Zhou et al., 2020).

Thirdly, diffusion and adoption rates within the sector are highly variable and are particularly low among small and medium-sized enterprises (SMEs). This may be explained by the constrained capacity of SMEs to invest in IT systems and software. Thus, a few large companies and tech start-ups have been early adopters of the technology. Without sector-wide adoption, blockchain solutions cannot reach their full potential.

### 3.3 Legal and Regulatory Challenges

The maritime industry is heavily regulated across all sectors by both international and national agencies. This complex regulatory framework complicates efforts to achieve standardisation. Furthermore, legal frameworks are currently inadequate to regulate new technologies (Deffeyes, 2001; Schellekens, 2022) with significant amendments required (European Commission, 2020). The resultant regulatory uncertainty impacts confidence in dispute resolution measures, anti-trust laws, and data privacy and security (Thanaraj, 2021), which emerged from the review as key legal concerns (Peronja et al., 2020). Moreover, the challenge of complying with multiple (and sometimes incompatible) regulations and standards has the potential to stifle blockchain innovation and implementation (Lacey et al., 2015). Clear regulations and standards for blockchain technology must be developed to address adoption hesitancy (Gausdal et al., 2018).

#### 3.3.1 Dispute Resolution

Dispute resolution in the maritime industry is already complicated. The global nature of the industry presents jurisdictional challenges, differences in substantive rights, and procedural rules. These difficulties are exacerbated in relation to the adoption of novel technologies (Greenstein, 2022; Todd, 2019).

Technological advancements in the exchange and execution of electronically generated documents have revealed several gaps and inadequacies in legal regulation (Mahmoud, 2023). Many jurisdictions have begun amending or developing procedural rules to accommodate the use of electronic documents and smart contracts (Swales & Mahmoud, 2023). However, despite progress, rules relating to electronic evidence still require harmonisation (Mahmoud & Bellengere, 2020).

#### 3.3.2 Antitrust Regulations and Blockchain Transparency

Antitrust regulations are designed to prevent monopoly, price manipulation and other anti-competitive practices. In the maritime industry, sharing of sensitive information such as pricing, production levels, and market allocation is highly restricted (e.g. the United States of America Sherman Antitrust Act, 1980). Consequently, the transparency feature of blockchain poses a significant challenge to its adoption. Blockchain is designed in a way that all information shared on the platform is visible to all permitted users in the case of a private blockchain and to anyone in the case of a public blockchain. To this end, the exchange of information on a blockchain platform potentially violates extant legal requirements (Jović et al., 2019).

#### 3.3.3 Regulation of Data Privacy and Security

While security is one of the primary benefits of blockchain platforms, they are not foolproof. Blockchains, particularly public platforms, are susceptible to security breaches such as denial of service (DoS), eclipse attacks, man in the middle (MitM), and signatures can be deciphered with technological advancements such as quantum computing, compromising blockchain data, since it is immutable (Abdallah et al., 2023). Most of the attacks on blockchain platforms targeted cryptocurrencies due to vulnerabilities in application software, smart contracts, and protocols (Orcutt, 2019). Although improved security measures have been implemented in response to these incidents, the claims that blockchain is secure have been tarnished, leading to fears about the privacy and security of data in the event of a data breach (Abdallah et al., 2023). Most of the blockchain platforms used in the maritime industry are private, and this significantly reduces the chances of security breaches (Li et al., 2024). This is because the validation process is assigned to certain users, reducing, but not eliminating, the risk of a data breach (Munim et al., 2021). The laws and policies regulating the maritime industry at both the national and international levels need to be updated to include data security concerns on blockchain platforms and clarify data privacy rights and responsibilities in order to rebuild stakeholder confidence (Perkušić et al., 2020).

#### 4.0 CONCLUSION

The review identified a large corpus of published literature addressing the benefits and potential of blockchain platforms in the global shipping industry, but much of the research was region-specific or narrowly focused on specific sub-sectors of the industry or individual case studies. This systematic literature review offers a holistic global review that identified 54 highly relevant academic studies that discuss blockchain's application and the practical and regulatory challenges to its implementation in global shipping practice.

Despite its potential to transform global shipping, the study found that unless there is sector-wide acceptance of blockchain, the technology does not present a viable alternative to traditional business models. This is especially relevant to secure document exchange solutions like TradeLens, where sector-wide adoption by all stakeholders is necessary for blockchain to reach its full potential (Papadakis & Kopanaki, 2022).

Secondly, the study found that the shipping industry remains hesitant to adopt blockchain for two primary reasons: switching costs and regulatory concerns. Switching to a blockchain solution involves substantial investment in technology infrastructure and training of staff (Lorenz-Meyer & Santos, 2023). The switching cost is amplified by first-mover disadvantages, as cost savings and efficiency gains are only fully realised when most stakeholders adopt the technology (Jensen et al., 2019). Thus, paradoxically, companies prefer to avoid the risks and costs associated with being early adopters of the technology. Regulatory uncertainty presents a further challenge, with a lack of clarity around the application of rules pertaining to electronic evidence in the resolution of disputes and concerns about how anti-trust laws apply to information shared on the blockchain. Moreover, shipping companies are cautious about divulging confidential information, proprietary knowledge, and intellectual property on blockchain platforms, as they are sceptical about the adequacy of security and privacy safeguards (Lorenz-Meyer & Santos, 2023).

In conclusion, this paper recommends that regulators at both the international and national levels work to address the regulatory lacuna and enhance capacity building across the sector to provide the basis for technological innovation and the adoption of new business models in the shipping sector.

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