How Does Consortium Blockchain Revolutionize the Maritime Supply Chain? A Systematic Literature Review from a Holistic Perspective

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Abstract

Maritime supply chains (MSCs) are pivotal to the global economy yet face persistent challenges from external volatility, fragmented collaboration, and sustainability mandates. While consortium blockchain technology is heralded as a transformative solution, its adoption remains underexplored and lacks a holistic analytical framework. This study addresses this gap by conducting a systematic literature review of 81 studies to develop a comprehensive framework. The findings reveal that consortium blockchain adoption is not a binary event but a dynamic process shaped by the interplay of technological, organizational, and environmental factors. The analysis demonstrates that heterogeneous actors—governments, shipping lines, ports, and freight forwarders—assume distinct roles as drivers, pioneers, followers, or skeptics based on absorb capacity costs versus capture value within the emerging ecosystem. The successful transition from a technical platform to an operational system depends on a structured, multi-stage workflow encompassing identity authentication, smart contract collaboration, execution monitoring, and disintermediated payment settlement. Furthermore, this study identifies dual effects. While blockchain enhances efficiency, transparency, and sustainability, it simultaneously introduces power imbalances, systemic rigidity, and market concentration risks. By elucidating the strategic dynamics of adoption, operational implementation mechanisms, and paradoxical outcomes, this study provides a nuanced understanding of how consortium blockchain revolutionizes MSCs.

Keywords: blockchain; maritime supply chain; systematic literature review, holistic perspective

1. Introduction

The maritime supply chain (MSC) is crucial to the global economy, handling 90% of cargo flows. Maritime transportation and port activities are vital for many countries, as shown by Singapore's status as a global transshipment hub and the Rotterdam port serving as Europe's primary gateway. However, external uncertainties, such as seasonal fluctuations and geopolitical tensions, cause trade volatility, affecting freight rates and disrupting MSCs (Alamoush et al., 2022). For instance, the COVID-19 pandemic triggered widespread port congestion and high shipping costs, while the 2023 Panama Canal drought forced rerouting and delays in Asia-U.S. East Coast trade. As globalization grows, MSC require improved data collaboration and agility to address these issues. Moreover, the maritime industry contributes 2.2% of greenhouse gas emissions (UNCTAD, 2024). The International Maritime Organization (IMO) has set regulations to reduce carbon intensity (EEXI/CII), targeting a 40% reduction by 2030. In April 2025, the IMO adopted a net-zero emissions framework for vessels over 5000 gross tonnage, targeting net-zero by 2050 (IMO, 2025). These sustainability regulations present challenges to MSC operations.

Blockchain technology, with its distributed ledger and immutability, is key to restructuring the MSC (Papathanasiou et al., 2020). Currently, blockchain spans the business, platform, and alliance dimensions in the MSC, enabling carbon tracking and intelligent shipping, where smart contracts serve as digital agreements, triggering automated transactions. In particular, for consortium blockchain, a permissioned network is jointly established and maintained by pre-selected organizations based on a shared protocol. In MSCs, consortium blockchain showed distinct applications through paperless certificates, ship classification (Lloyd's Register), cargo management (China Merchants Group), and the Global Shipping Business Network (GSBN) by COSCO.

However, consortium blockchain implementation in MSC faces challenges, as shown by the discontinuation of TradeLens in 2023 (developed by Maersk and IBM in 2018). This failure reveals hurdles in consortium blockchains, including critical mass achievement, incentive alignment and governance. While prior literature has identified key factors, understanding the process-oriented nature of consortium blockchain adoption remains a research gap. Existing studies typically list barriers and enablers (e.g., cost, security, and regulations) without explaining how stakeholder attitudes and decision-making roles (e.g., competing carriers, ports, and shippers) influence formation, governance, and value assessment. This study argues that adoption is a complex process shaped by stakeholder strategies and power dynamics, which requires exploration. Therefore, to address these challenges, this study focuses on consortium blockchain and aims to address the following research questions:

RQ1: How do heterogeneous stakeholders (e.g., competing carriers, ports, shippers, and freight forwarders) with differing strategic attitudes and influencers affect consortium blockchain adoption decision-making in MSCs?

RQ2: What are the key operational mechanisms among key stakeholders that enable the transition from a technical feasible consortium blockchain to a fully operational and sustainable platform?

RQ3: What are the consequent positive and negative (dual-effect) outcomes of consortium blockchain implementation?

This study systematically reviewed 81 research articles. The findings show that consortium blockchain adoption in MSCs is a multi-stage process characterized by the interplay of strategic stakeholders, structured collaboration, and inherent dual effects. First, adoption is not binary but a strategic positioning game in which stakeholders assume roles based on their capacity to absorb costs versus their ability to capture value, driven by a resource-value-institution nexus. Second, successful implementation requires orchestrating a sequential workflow in which heterogeneous stakeholders, despite divergent attitudes, contribute critical steps within a shared digital ecosystem. This transforms potential conflicts into structured collaborations, making implementation a governance and technical challenge. Third, the dual effects show that the impact emerges from interaction with the socio-economic context, necessitating nuanced governance models to leverage benefits and mitigate risks. This study provides a holistic framework for understanding the blockchain revolution in MSCs.

This study makes three key contributions to the maritime blockchain research. First, it reveals adoption decision dynamics, showing how stakeholders become "pioneers" or "skeptics" based on value capture in the emerging ecosystem. Second, it identifies critical mechanisms—from digital identity to smart contracts—that transform technical feasibility into functional collaborations. Third, it demonstrates the dual effects of blockchain: while enhancing efficiency and sustainability, it creates new power imbalances and implementation challenges. These insights provide a framework for understanding how blockchain technology reshapes MSCs, offering guidance for research and practice.

2. Theoretical background

2.1 Blockchain and MSC

Blockchain technology is a decentralized, shared data repository that maintains copies to resist alterations (Önder & Treiblmaier, 2018) and provides access to trusted data (Lieber & Press, 2017). MSC comprises a network of shipping service demanders, providers, and nodes (Jensen et al., 2019). Blockchain enables collaborative commerce and improves decisions through partner auditing and supply chain trust and integration in MSC (Queiroz & Fosso Wamba, 2019).

Blockchain technology can be categorized into public, private, and consortium blockchain, with the latter emerging as the predominant future form (Brousmiche et al. 2018). MSCs typically adopt consortium blockchain (Zheng et al., 2024), which combine the features of both public and private blockchains (Tyma et al., 2022). Similar to a private blockchain, a consortium blockchain maintains data control while offering higher security through decentralization, similar to a public blockchain (Tyma et al., 2022). Furthermore, blockchains can be classified as permissioned or permissionless, based on network openness. In a permissioned blockchain, access is restricted by limitations on validation permissions or both access and validation (Marianna, 2019). In contrast, permissionless blockchains allow open public access and participation. MSCs primarily use permissioned consortium blockchain, which utilize the real-world identities of participants, and better align with MSC regulations. Additionally, a permissioned consortium blockchain allows owners to modify rules and reverse transactions.

Consequently, the current study focuses on permissioned consortium blockchains, enhancing shipping efficiency and sustainability by improving product traceability (Kamble et al., 2020) and supply chain transparency (Kshetri, 2018). They mitigate risks from delayed payments and data threats while shortening the settlement cycles (Kamble et al., 2020). Studies have shown that blockchain optimizes carbon emission tracking (G. Xiao et al., 2025) and achieves low-carbon transformation by balancing economic and environmental goals (T. Wang et al., 2023).

2.2 Existing literature review

As blockchain technology in MSC expands, scholarly interest has correspondingly increased. Several researchers have conducted systematic reviews of the advancements in this field (Table 1). However, the current study differs from existing research in several ways.

First, this study differs from existing reviews in terms of its research objectives. Although previous research distinguished between permissioned and permissionless (Nguyen et al., 2021), consortium, private, and public blockchain (K. Li et al., 2024), the research objects were general. The development of permissioned consortium blockchain is mainstream in practice and faces challenges; however, research on these issues in MSC needs further deepening.

Second, the research topic highlights the multi-stakeholder roles that differ from previous research. Early literature reviews focused on applications such as document flow management, financial transaction management, and IoT device management in cargo, vessel, and terminal operations (L. Li & Zhou, 2021; Pu & Lam, 2021; Tsiulin et al., 2020). Liu et al (2023) identified pain points of blockchain technology adoption in MSC and developed a blockchain-based MSC system. This system includes various stakeholders but does not focus on stakeholder attitudes and practices in adopting blockchain technology. Therefore, existing research offers limited discussion on implementation decision-making in multi-stakeholder contexts and lacks an analysis of stakeholder role positioning and collaboration pathways.

Subsequently, the review paper focused on the benefits, challenges, and outcomes of blockchain technology adoption in MSC (Shin et al., 2024; K. Li et al., 2024; Surucu-Balci et al., 2024). For instance, Surucu-Balci et al. (2024) examined the impact of blockchain technology on digital information sharing in MSC, while Shin et al. (2024) explained how blockchain applications influence MSC integration. However, the primary issue in applying blockchain to MSC, especially for consortium blockchain, is attitudes toward blockchain that affect decisions to adopt and join the consortium chain. Additionally, as blockchain applications deepen in MSC, research should focus on the holistic process from pre-adoption to adoption and effect evaluation.

Finally, this study focuses on the latest research progress in this field. Most review articles covered up to 2022-2023, as shown in Table 1, while 2023-2026 is a period of rapid application and blockchain technology development. The latest research progress and practical cases must be systematically analyzed to identify future directions. As above, this study reviews the latest studies from 2017-2026, focuses on the various stakeholders’ attitudes and behaviors in adopting consortium blockchain technology, and employs a holistic perspective to develop a conceptual framework termed "pre-adoption– adoption – post-adoption" to examine blockchain technology implementation in MSCs.

Table 1. Summary of Literature Reviews

Publication	Journal	Methodology	Research theme	Main findings
Blockchain application in maritime supply chain: a systematic literature review and conceptual framework (Shin et al., 2024)	Maritime Policy and Management	SLR (2017-2022)	Maritime supply chain integration	This study examines the opportunities and challenges associated with the application of blockchain technology in the maritime supply chain that impact supply chain integration. The study spanned three primary domains: document management, transaction management, and cargo, vessel, and terminal operations.
Blockchain implementation in the maritime industry: a literature review and synthesis analysis of benefits and challenges (K. Li et al., 2024)	Maritime Economics and Logistics	SLR (2019-2023)	Benefits and challenges	Blockchain benefits in MSC include improving transaction efficiency, enhancing transparency, traceability, and security, cost reduction, enhancing trust, and promoting sustainability. Moreover, blockchain adoption in MSC faces challenges in terms of technology, governance, regulation, cost, awareness, and culture.
Digital information in maritime supply chains with blockchain and cloud platforms: supply chain capabilities, barriers, and research opportunities (Surucu-Balci et al., 2024)	Technological Forecasting and Social Change	SLR (2006-2022)	Digital information sharing	This study examines the barriers and enablers of blockchain and cloud platforms to enhance digital information sharing in the MSC. In addition, the necessary dynamic capabilities and assessable performance metrics were identified as the consequences of adopting blockchain and cloud platforms, which lead to digital information sharing.
Blockchain technology in maritime supply chains: applications, architecture and challenges (Liu et al., 2023)	International Journal of Production Research	Conceptual Framework Development	Pains, structure, and challenges	The blockchain-based maritime system addresses core operational issues, such as trust, cargo tracking, and paperless and network collaboration. In addition, this study examines the blockchain system structure and implementation challenges.
A survey of blockchain with applications in maritime and shipping industry (L. Li & Zhou, 2021)	Information Systems and e-Business Management	SLR (2015-2018)	Application	The study found that blockchain technology can be applied in areas including supply chain visibility, food safety traceability, multimodal transport tracking, port collaboration networks, document digitalization, green shipping, and insurance and finance.
Blockchain adoptions in the maritime industry: a conceptual framework (Pu & Lam, 2021)	Maritime Policy & Management	Conceptual Framework Development	Application	Four key application areas have been identified for MSC: electronic bills of lading, vessel operations, ship financing, and marine insurance.
Blockchain-based applications in shipping and port management: a literature review towards defining key conceptual frameworks (Tsiulin et al.,2020)	Review of International Business and Strategy	SLR (2015-2019)	Application projects and scenarios	This study categorizes blockchain applications into three core domains: document processes, financial processes, and equipment connectivity.

3. Systematic literature review protocol

This study uses SLR, that can support exploratory research when the research object is dynamic (Petticrew and Roberts, 2006), to examine blockchain in MSCs. SLR ensures reproducibility and transparency, minimizing bias through literature retrieval. Following Tranfield’s (2003) three-stage framework, literature retrieval includes the identification, screening, and inclusion phases, as shown in Figure 1.

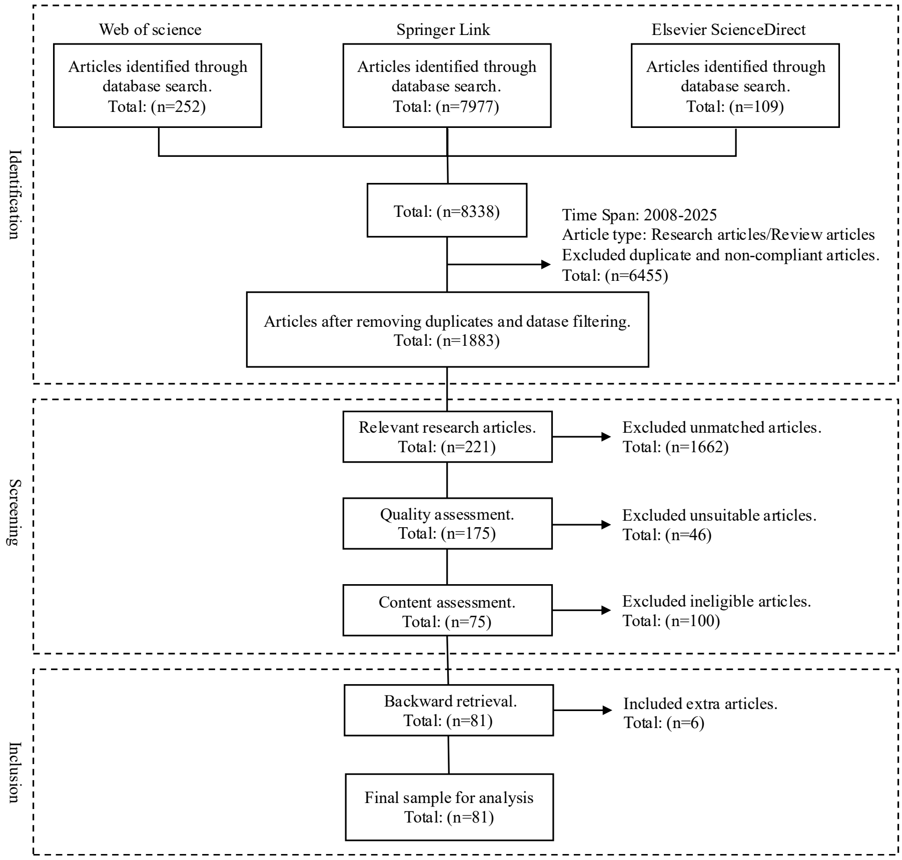


Figure 1. Literature search protocol.

3.1 Identification

The literature was retrieved from the Web of Science, Springer, and Elsevier databases. A search identified 6,563 publications (Table 2). The inclusion criteria were peer-reviewed articles from 2008 to 2025 in the SSCI or SCI. The exclusion criteria removed non-English articles, conference papers, books, and chapters. After screening, 1,353 articles remained for review.

Table 2. String inputted in the advanced search option of the databases.

Web of Science	TS= ("Blockchain" OR "Distributed ledger" OR "Smart Contract" OR "Bill of lading" OR "blockchain technology") AND TS= ("Shipping" OR "Maritime" OR "Port" OR "Liner" OR "vessel*")
Springer	("Blockchain" OR "Distributed ledger" OR "Smart Contract" OR "Bill of lading" OR "blockchain technology") AND ("Shipping" OR "Maritime" OR "Port" OR "Liner" OR "vessel*")
Elsevier	TITLE-ABS-KEY ("Blockchain" OR "Distributed ledger" OR "Smart Contract" OR "Bill of lading" OR "blockchain technology") AND TITLE-ABS-KEY ("Shipping" OR "Maritime" OR "Port" OR "Liner" OR "vessel*")

3.2 *Screening*

Screening and evaluation identified relevant literature through three steps: selection, quality assessment, and content evaluation. Selection analyzes publications at the title and abstract levels to determine relevance to the research topic. After screening, 221 articles remained. Quality assessment used Dybå and Dingsøyr' s (2008) structured questions to evaluate rigor, credibility, and relevance, as shown in Table 3. After this stage, 175 articles remained for review. Content evaluation was performed using the criteria in Table 3. Articles with any "No" answer were excluded, resulting in 75 articles.

Table 3 Evaluation Questions

	Purpose	Evaluation questions
Quality evaluation	To appraise the rigor of the study.	Was a thorough and appropriate approach applied to the key research methods in the study?
	To appraise the credibility of the study.	Are the findings well presented and meaningful?
	To appraise the relevance of the study.	How useful are the findings to the supply chain industry and the research community?
Content evaluation	Focus on blockchain technology applications rather than computational performance or design issues	Does the paper focus on issues related to blockchain technology applications?
	Theme of applying blockchain technology in the shipping industry	Is the paper set against a shipping industry background to discuss and analyze blockchain technology?
	Concentration on blockchain technology rather than integrated digital technologies	Does the paper's discussion primarily focus on blockchain technology?

3.3 *Inclusion*

To maximize the literature coverage, this study conducted a backward retrieval to address omissions. The search used predefined keywords (e.g., "Blockchain" AND "Maritime"). However, some publications might have used synonyms or broader terms, causing exclusion. Core literature often contains relevant citations that may not have emerged in keyword searches. By applying the same screening criteria to the articles identified through backward retrieval, six additional publications were identified. Thus, a final sample of 81 papers was analyzed. A list of the identified papers is compiled in Appendix A for reference.

3.4 *Analytical procedure*

This study employed a two-step analytical procedure to systematically analyze the 81 selected publications. First, the descriptive analysis provides an overview of the literature landscape. Next, an in-depth content analysis was conducted using thematic coding to address the three research questions.

Specifically, the coding process followed a structured thematic analysis approach. First, each article was read line-by-line to identify recurrent themes related to consortium blockchain adoption. Open codes were generated to capture key concepts, such as barriers, enablers, stakeholder roles, and outcomes. Second, the open codes were grouped into higher-order categories based on conceptual similarity. For instance, "inadequate infrastructure," "reliability concerns," and "high costs" were grouped under "foundational technical constraints." Third, the themes were integrated to construct theoretical constructs addressing the research questions.

For RQ1, themes were mapped onto the TOE framework: technical themes formed the "technological maturity spectrum"; organizational factors comprised the "organizational preparedness continuum"; regulatory and industry ecosystem factors constituted the "environmental enablement landscape." For RQ2, themes regarding implementation workflows and stakeholder collaboration were synthesized into a sequential process model—identity management, smart contract execution, and automated payment—derived from a cross-case comparison. For RQ3, the outcome themes were examined for paradoxical patterns. The final structure was validated using an iterative review. The findings from both steps are presented in Sections 4.1 to 4.4.

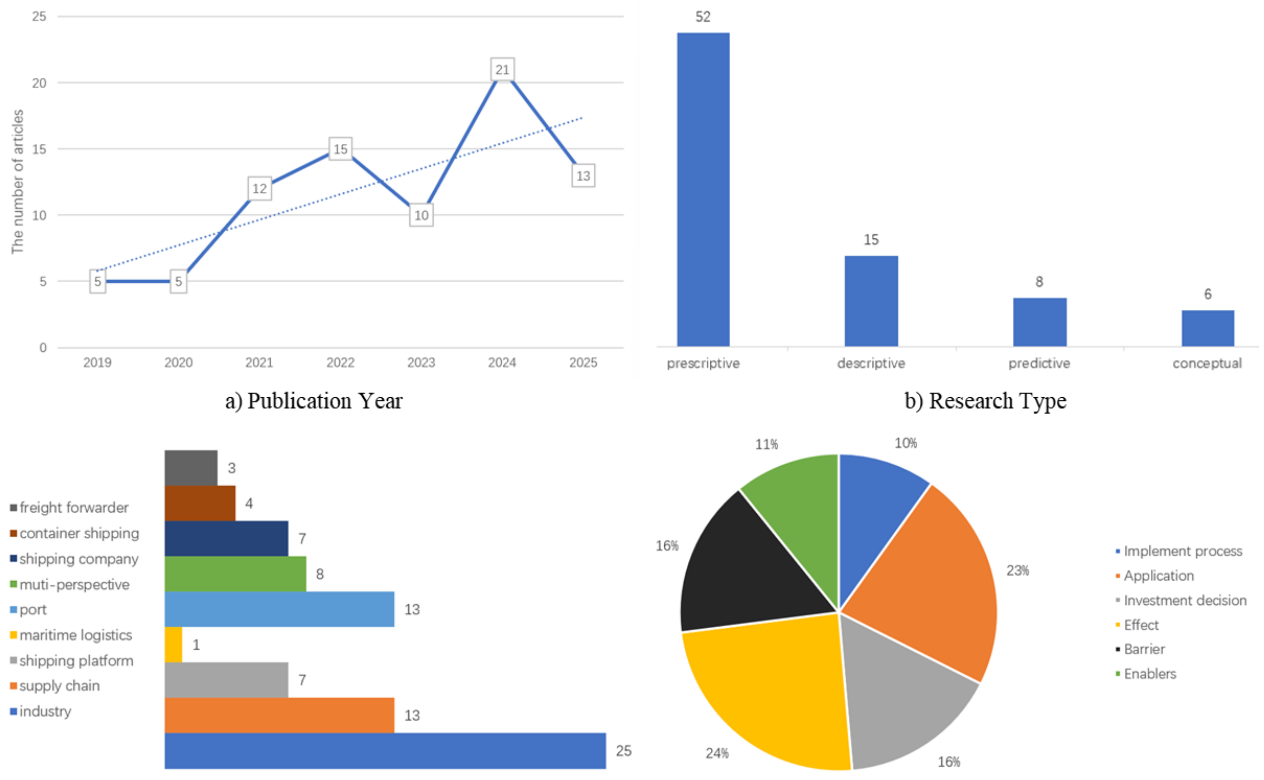
4. Review results

4.1 Descriptive results

The bibliometric analysis of the articles is shown in Figure 1. Figure 2(a) shows the publication growth from 2019 to 2025. A regression model was used to predict literature volume growth. Figure 2(b) illustrates literature categorization based on Wang ’ s(2019) categories: prescriptive, descriptive, predictive, and conceptual studies. 1) Prescriptive studies diagnose MSC problems and provide solutions for blockchain deployment. 2) Descriptive studies review blockchain research on MSCs. 3) Predictive studies explore potential applications of blockchain technology. 4) Conceptual studies examine the meaning of blockchain for MSCs. Among the 81 publications, prescriptive studies comprise 52 papers, demonstrating blockchain maturity. The descriptive studies included 15 papers exploring applications. Predictive (8 papers) and conceptual (6 papers) studies are increasing.

Existing research involves multiple stakeholders. Figure 2(c) shows the distribution of research perspectives, with 81 studies analyzed from two dimensions: industry and function, and core operational entities. The literature covers industries, maritime logistics, supply chains, and shipping platforms. From the operational entities dimension, research focuses on container shipping, shipping companies, ports, freight forwarders, and multi-perspectives. Studies from the "industry" perspective have the highest proportion (25 articles), reflecting academic attention to the application value of blockchain in the maritime industry. Research on "port" (13 articles) and "supply chain" (13 articles) is equally focused, while eight studies adopt "multi-perspective,” indicating a shift from single-subject to multi-stakeholder research.

Based on the content analysis, the 81 selected studies were categorized into six themes: effect, barrier, enabler, investment decision, application, and implementation process, as illustrated in Figure 2(d). Among them, 27% focus on the "effect" of blockchain applications, reflecting that the academic community prioritizes practical value realization after the technology’s implementation. Meanwhile, 25% of the studies explore "application" scenarios, indicating that the practical exploration of blockchain in specific fields of the shipping supply chain has emerged as a research hotspot. Overall, the existing research has formed a complete framework covering the entire logical chain of "barriers – enablers – decision-making – applications – implementation processes – effects.” Within this framework, barriers and enablers, investment decisions and applications, and effect evaluation constitute three core research directions, laying a solid foundation for further in-depth research on the application of blockchain in the shipping supply chain.



a) Publication Year b) Research Type

c) Research Perspective d) Research Content

Figure 2. Bibliometric analysis of the selected articles.

4.2 Antecedent Conditions: Decision-making influencers

According to existing research, this study adopts the TOE framework to integrate factors that affect consortium blockchain adoption decisions in MSCs, as shown in Table 4.

4.2.1 Technological maturity spectrum

4.2.1.1 Foundational technical constraints

Inadequate technological infrastructure. Current technological infrastructures cannot meet the computational demands for tracking large vessels (Nguyen, Chen, et al., 2023) because network latency impairs ledger synchronization. Older nodes may fail to process new transactions, and leading platforms cannot support high-frequency transactions (X. Li et al., 2024), increasing adoption decision risk.

Misgivings about reliability. Blockchain technology in maritime remains nascent, with skepticism about its reliability (Zhou et al., 2020). With increasing data, blockchain processing speed degrades, and integration with legacy systems faces standardization challenges (Papathanasiou et al., 2020), limiting adoption decision-making.

High adoption costs. Blockchain adoption incurs costs owing to its complexity. Platform deployment incurs expenses with prolonged returns (Balci & Surucu-Balci, 2021) and sunk-cost risks (Papathanasiou et al., 2020). The cost-benefit imbalance creates a "wait-and-see" attitude among shipping enterprises (Zhou et al., 2020). Nguyen (2023) found disparities among stakeholders in evaluating cost risks; early adopters may monopolize value, while smaller participants face costs with limited benefits, affecting strategies.

4.2.1.2 Inherent technical capabilities

End-to-end traceability. Blockchain provides end-to-end traceability (Papathanasiou et al., 2020) and drives the adoption of shipping enterprises (Lin, 2025). Asymmetric encryption enables secure transmission (X. Li et al. 2024) found that blockchain encryption protects data (Singh, Chakraborty, et al., 2024) and prevents forgery (Papathanasiou, 2020).

Testability and observability. Testability refers to the ability of a blockchain to conduct pilots for low-cost validation. Observability denotes the visibility of blockchain outcomes and the perception of their advantages (Singh, Chakraborty, et al., 2024). The verifiability of efficiency and transparency reduces adoption risks and enhances stakeholder confidence (X. Li et al., 2024).

4.2.1.3 Technological integration and deployment

Smart contracts. Blockchain technology enables automated reengineering via smart contracts for maritime adoption (Singh, Pratap, et al., 2024), eliminating intermediaries (Lin, 2024) and triggering payments (X. Li et al., 2024). Smart contracts translate bill clauses into code, using IoT sensors to validate data and monitor cargo (Irannezhad & Faroqi, 2023), thereby reducing disputes and enhancing trust.

e-Bill of Lading and standardization. Papathanasiou (2020) noted that blockchain enables unified e-Bill of Lading and standardizes terminology across borders. Standardization reduces document costs by 30%, eliminating paper expenses. Standardized operations reduce complexity and address interoperability issues (X. Li et al., 2024), and enhancing blockchain adoption (Yang, 2019).

4.2.2 Organizational preparedness continuum

4.2.2.1 Organizational Awareness

Knowledge and awareness gap. The maritime industry lacks blockchain expertise, which limits enterprises' understanding and delays decisions (Guan et al., 2023). SMEs often confuse blockchain technology with cryptocurrency (Balci and Surucu-Balci, 2021). Management's digital awareness and shareholder support aid resource allocation, driving adoption (Singh, 2024).

Perception of data security. Cyberattacks in shipping (such as the 2017 NotPetya ransomware attack on Maersk) have intensified skepticism regarding blockchain security. The governance flexibility of private blockchains raises concerns regarding data control (Balci & Surucu-Balci, 2021). Despite consortium blockchain encryption, concerns exist regarding the privacy leaks of sensitive commercial information (Lin, 2024).

Data value allocation. Internal ambiguity regarding data ownership rights and value distribution from data sharing diminishes the willingness to participate in blockchain-enabled data ecosystems (Y. Xiao et al., 2023). The absence of standardized data protocols impedes cross-departmental collaboration and analyses (Guan et al., 2023).

Table 4 Influence factors in consortium blockchain adoption decision

TOE	Dimension	Sub-dimension	Barriers	Enablers	Reference
Technology maturity spectrum	Foundational technical constraints	Inadequate technological infrastructure	✓		Balci & Surucu-Balci, 2021; Nguyen, Chen, et al., 2023; Zhou et al., 2020; X. Li et al., 2024
		Misgivings about reliability	✓		Zhou et al., 2020; Papathanasiou et al., 2020
		High adoption costs	✓		Balci & Surucu-Balci, 2021; Papathanasiou et al., 2020
	Inherent technical capabilities	End-to-end traceability		✓	Papathanasiou et al., 2020; Lin, 2025; X. Li et al., 2024
		Testability and observability		✓	Singh, Chakraborty, et al., 2024; X. Li et al., 2024
	Technological integration and deployment	Smart contracts		✓	Singh, Pratap, et al., 2024; Lin, 2024; Papathanasiou et al., 2020; X. Li et al., 2024
		e-Bill of Lading and standardization		✓	Yang, 2019; Papathanasiou, 2020; X. Li et al., 2024
Organizational preparedness continuum	Organizational awareness	Knowledge and awareness gap	✓		Zhou et al., 2020; Papathanasiou et al., 2020; Kapnissis et al., 2022; Guan et al., 2023; Balci and Surucu-Balci, 2021
		Perception of data security	✓	✓	Balci & Surucu-Balci, 2021; Lin, 2024; Nguyen, Chen, et al., 2023; Zhou et al., 2020)
		Data value allocation	✓		Y. Xiao et al., 2023; Guan et al., 2023
	Organizational motivation	Strategic alignment		✓	X. Li et al., 2024
		Collaboration Imperative		✓	Lin, 2024; Lin, 2025; X. Li et al., 2024
		Conservative corporate culture	✓		Guan et al., 2023; Papathanasiou et al., 2020; Zhou et al., 2020; Balci & Surucu-Balci, 2021; Singh, 2024
	Organizational capability	Resource-based capability		✓	Zhou, 2020; X. Li et al., 2024; Lin, 2024
		Reliance on information asymmetry	✓		Balci & Surucu-Balci, 2021; Papathanasiou et al., 2020
Environmental enablement landscape	Formal regulatory environment	Lack of overarching regulations	✓		Nguyen, Chen, et al., 2023; Papathanasiou et al., 2020; Y. Xiao et al., 2023; Nguyen, Chen, et al., 2023
		Local legislative facilitation		✓	Zhou, 2020; X. Li et al., 2024; Singh, Pratap, et al., 2024
	Informal industry ecosystem environment	Lack of critical stakeholders	✓		Balci & Surucu-Balci, 2021; Guan et al., 2023; Zhou et al., 2020
		Competitive Pressure		✓	X. Li et al., 2024; Kapnissis et al., 2022; Singh, Pratap, et al., 2024; Singh, Pratap, et al., 2024
		Third-party service support		✓	Zhou et al., 2020

4.2.2.2 Organizational Motivation

Strategic alignment. Blockchain adoption is driven by how blockchain capabilities align with defined corporate strategies (e.g., cost efficiency vs. green shipping). If an enterprise emphasizes "cost reduction and efficiency," blockchain should lower costs through digital documentation and smart contracts. If an enterprise prioritizes "green shipping," blockchain should support sustainable practices such as carbon emission tracking and energy optimization (X. Li et al., 2024).

Collaboration Imperative. The MSC requires partner coordination for blockchain adoption (Lin, 2024). Joint blockchain platform development by upstream and downstream participants enables cost and risk sharing, whereas customer acceptance drives implementation (X. Li et al., 2024). Compliance requirements from suppliers, clients, and governments can drive shipping enterprises to adopt blockchain technology (Lin, 2025).

Conservative corporate culture. Structural inertia in the shipping industry's organizational culture impedes blockchain adoption, with resistance to new technologies (Guan et al., 2023). This resistance is prominent in family owned businesses with rigid hierarchies that follow conventional models (Balci and Surucu-Balci, 2021). Singh (2024) suggests that an open culture fosters blockchain applications within MSC.

4.2.2.3 Organizational Capability

Resource-based capability. The financial resources and infrastructure compatibility of an organization are fundamental enablers of blockchain adoption (X. Li et al., 2024). Moreover, knowledge absorption capacity, defined as the ability to identify and apply blockchain knowledge, correlates with higher willingness to adopt (Lin, 2024).

Reliance on information asymmetry. Shipping data involve transactions of significant value and require client confidentiality protection. Shipping enterprises, including freight forwarders, capitalize on information asymmetry, particularly among family owned companies that resist transparency owing to concerns about losing bargaining leverage(Balci & Surucu-Balci, 2021).

4.2.3 Environmental enablement landscape

4.2.3.1 Formal regulatory environment

Lack of overarching regulations. Legal frameworks and blockchain technology face compatibility issues. Coordinating multinational legislation is essential (Nguyen, Chen, et al., 2023) because regulatory discrepancies pose compliance risks (Papathanasiou et al., 2020). Unclear regulations and a lack of standards increase blockchain adoption costs (Y. Xiao et al., 2023), limit compensation avenues, reduce investment incentives, and risk technical lock-in (Nguyen, Chen, et al., 2023).

Local legislative facilitation. Local legislation, including electronic bill of lading recognition, cross-border data flow framework, service provider certification, and government testing platforms, can support implementation (Zhou, 2020). Furthermore, government compliance frameworks and subsidies incentivize the willingness to adopt blockchain technology (Singh, Pratap, et al., 2024).

4.2.3.2 Informal industry ecosystem environment

Scarcity of Pioneer and benchmarks. The maritime industry lacks early adopters and blockchain benchmarks. While pioneers like Maersk exist, many shipping enterprises take a "wait-and-see" approach awaiting technology maturation (Balci & Surucu-Balci, 2021). Established institutions, particularly freight forwarders facing business model disruptions, have not adopted consortium blockchains (Guan et al., 2023). Without blockchain expert partners and consensus, information silos limit the network effects of blockchain (Zhou et al., 2020).

Competitive Pressure. Market competition drives enterprises to pursue innovation for strategic advantage (X. Li et al., 2024; Zhang & Wu, 2025). The adoption of blockchain by industry participants creates a "catch-up effect," compelling others to expedite implementation (Singh, Pratap, et al., 2024). External uncertainties, including customer preferences, technological disruption, geopolitical conflicts, and oil prices, drive blockchain implementation (X. Li et al., 2024).

Third-party service support. Professional support is crucial for developing collaborative ecosystems and facilitating blockchain adoption. Consulting and technical assistance from third-party institutions, like maritime advisory firms, offer technical customization and risk assessment services. These services address enterprises' knowledge gaps during initial deployment(Zhou et al., 2020).

4.2.4 An Analytical Synthesis: Resource-Value-Institution Nexus of Stakeholder Dynamics

Stakeholder attitudes, from large shipping lines' pioneering stance to freight forwarders' skepticism, stem from the differing capacity to absorb costs versus capturing value in the blockchain ecosystem. Large shipping companies have organizational resources (O), including capital and IT infrastructure, to incur technological costs (T). Their market position influences consortium alliance governance (E), enabling value capture through supply chain optimization and digital services (Zheng & Jiang, 2024). Conversely, for intermediaries like freight forwarders, whose business models rely on information asymmetry (O), transparency capability (T) poses an existential threat. Without regulatory or governance frameworks (E) guaranteeing their value proposition in a transparent ecosystem, their resistance protects competitive advantage (Balci & Surucu-Balci, 2021). Thus, the perceived opportunity for some represents a threat to others, based on their positions within the supply chain power structure.

Furthermore, the institutional and governance environments shape the technological and strategic decision-making available to stakeholders. The lack of international regulations (E) creates a governance vacuum, heightens risk, and encourages a wait-and-see approach. This vacuum incentivizes the formation of permissioned consortium blockchains (T) as a private governance solution to build trust among a limited number of participants (Zhou et al., 2020). However, this creates a paradox: while solving the trust issue among insiders, such consortia can erect new barriers to entry, potentially reinforcing the market power of large incumbents and excluding smaller players. This shows that consortium blockchain technology responds to institutional gaps, and its governance model determines broader ecosystem inclusion or exclusion.

In summary, the dynamic decision-making of consortium blockchain adoption in MSCs is understood through the resource-value-institution nexus. Stakeholders' strategies respond to their assessment of the nexus. Understanding blockchain adoption requires an analysis of how these factors shape power structures and economic incentives within the industry.

4.3 The Core Processes of Implementing Blockchain

4.3.1 Decision-making attitudes of stakeholders

The blockchain adoption framework involves stakeholders such as the government, shipping firms, ports and terminal operators, and freight forwarders. Their adoption attitudes and strategies vary by efficiency, relationships (Xin et al., 2022), costs (Ju et al., 2024; Zhang & Wu, 2025), and transparency in MSC.

Governments act as policymakers and drivers of blockchain adoption through policies and subsidies. Shipping firms are the primary investors (Li et al., 2025), influenced by economic scale and time costs (Ju et al., 2024), where large firms show the strongest investment willingness. Ports adopt consortium blockchains based on government policies and market demand, with decisions based on efficiency (Xin et al., 2022). In competitive environments, ports lead investments according to adoption costs (Sun et al., 2025). Specifically, in low-cost environments, they collaborate with shipping lines; however, under high costs, they may free-ride (Ju et al., 2024). Terminal operators follow shipping lines' choices to avoid sunk costs and invest when technology matures (H. Li et al., 2024). Finally, freight forwarders remain skeptical due to business model concerns, investing only when the technology matures (Nguyen, Chen, et al., 2023).

4.3.2 Core application areas and technical architecture

Two core applications of MSC are digital document automation and process execution using Internet of Things (IoT) data. In digital documentation, such as e-BLs, blockchain enables real-time data synchronization and automated creation, signing, and amendment via smart contracts. Transactions are encrypted, immutably chained, and require consensus for changes, which prevents forgery. Customs can directly verify authenticity, avoiding cargo detention, and banks can trigger automated releases, improving efficiency, as shown at the Port of Livorno (Amico & Cigolini, 2024). The second domain translates contractual clauses into self-executing, smart contracts. These use IoT sensor data to validate conditions, monitor cargo status (temperature and location), and trigger actions, such as payments, based on rules. This reduces manual intervention, disputes, and audits, enhancing system trust with applications in port cold chain logistics (Irannezhad & Faroqi, 2023).

Blockchain technology is primarily applied to container management, maritime transportation and port supply chain systems within MSCs. It reduces empty container turnover by sharing real-time container data between the consignees and shippers. Blockchain timestamps ensure that delivery meets demand windows (Mhiri et al., 2024). The maritime system creates a secure platform with a coordinated architecture for shared data. Implementations include: 1) Decentralized ledger. Blockchain's immutability ensures data consistency (Zhang et al., 2022); 2) Trusted identity authentication; and verification of vessels, drones, and servers to prevent intrusion (Kumar & Ali, 2024) and ensure privacy (Gai et al., 2022); 3) dynamic trust collaboration. It uses a VRF-based consensus with reputation evaluation; 4) Event traceability. Blockchain records can be used to track transportation anomalies (Zhang et al., 2022). The system achieves trusted sharing using RBACP, regulatory nodes, and smart contracts (Gao et al., 2022).

4.3.3 Operational workflow and implementation mechanisms

Consortium blockchain adoption in MSC involves identity management, contract execution, data collaboration, and disintermediated payments. This restructures MSC collaboration, solving information lag, trust issues, and redundancy, and forms a digital ecosystem, as shown in Figure 3.

Identity Management and Permission Control. This process enables blockchain technology to establish a trusted digital identity. 1) Identity registration and verification. Participants submit applications to a Certificate Authority (CA) for a User ID, digital certificate (Cert), and pseudonymous identity (PID) on the blockchain (Gai et al., 2022). 2) Dynamic keys and access controls. Communication uses a dynamic key agreement, whereas smart contracts verify identity to prevent unauthorized access (Kumar & Ali, 2024). 3) Permission hierarchy and data isolation. The CA assigns role-based permissions through peer nodes, ensuring that shippers can create orders but not modify their status, while agencies can view data without operational authority (Ni & Irannezhad, 2024).

Create Contract and Data Collaboration. This process digitizes the trusted flow of key documents, specifically electronic bills of lading. 4) Creates an electronic bill on the chain and encrypts cargo data before blockchain upload with a unique hash. Contract payment ratios are set for advance payment, cash, and credit (Lin, 2025). 5) Multiparty verification occurs. The exporter signs with a private key, the bank verifies the payment, and customs accesses the data. 6) Transfer of ownership and cargo release. The importer verifies bill ownership, the smart contract triggers the release, and the port releases the goods (Amico & Cigolini, 2024). 7) Recorded on a distributed ledger, with consensus ensuring data immutability (Ni & Irannezhad, 2024).

Transportation Monitoring and Contract Execution. This process ensures automatic execution of transportation terms and automated supervision. 8) Codification of terms. It begins with the activation and monitoring of IoT devices. Transportation begins after IoT devices self-check, and during transit, the sensors upload the temperature, location, and door status data in real time (Irannezhad & Faroqi, 2023). 9) Automatic execution and arbitration. If the data comply with the terms, the contract executes the next steps; if the data violate the terms, the contract terminates the transportation and triggers a refund. The receiver must verify and take delivery within the time limit; otherwise, penalties apply (Hasan et al., 2019).

Disintermediated Payment and Settlement. This process addresses settlement through automated payments linked to logistics. 10) Automated phase payments. After confirmation, reservation payment is transferred to the contract account, triggering shipping (Lin, 2025). When goods arrive and are verified, the contract notifies the buyer for cash payment and transfers funds to the supplier (Zhang et al., 2022). After the credit period, the contract deducts the payment from the buyer's account (Raj et al., 2022). 11) Dispute resolution. If the inspection shows anomalies, the contract freezes payment and initiates claims; if the balance is insufficient, it triggers notifications (Raj et al., 2022).

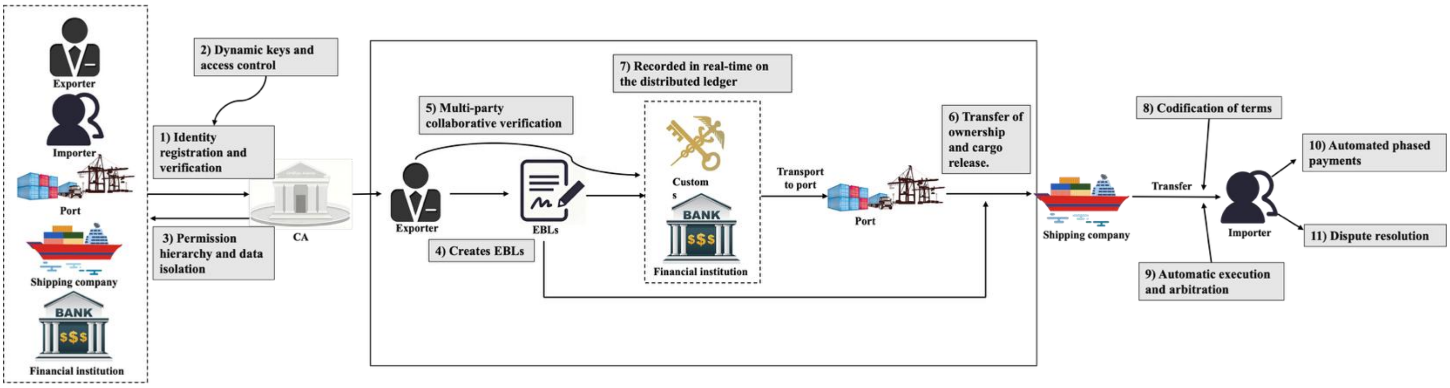


Figure 3. Implementation process

4.4 Outcome Dynamics: Dual-effects in Evaluating Consortium Blockchain's impact on MSCs

4.4.1 The Dual-Effect of Transparency: Trust Builder versus Power Imbalance

Blockchain technology's transparency introduces a fundamental shift in MSC information sharing, yielding collaborative and coercive outcomes. Transparency is a powerful force for building trust, enhancing sustainability, and improving social welfare. It builds trust by reducing information asymmetry and fraud risk, creating a reliable foundation for collaboration. Its precise tracking extends to environmental metrics, supporting carbon emission monitoring and energy optimization, which are crucial for green shipping. Moreover, the visibility provided by blockchain can serve as a tool to reduce corruption and enhance social welfare by promoting accountability in MSCs. Conversely, it can generate negative consequences that inhibit cooperation and create risks. From an organizational perspective, this can lead to "one-way visibility" where powerful actors, such as cargo owners, gain excessive monitoring capabilities over their agents, such as logistics providers. This imbalance can erode trust and discourage cooperation, particularly among stakeholders such as freight forwarders, whose business models rely on information asymmetry and who may resist transparency.

4.4.2 The Dual-Effect of Automation and Efficiency: Optimizer versus Source of Rigidity

Smart contracts drive efficiency gains while introducing new vulnerabilities that challenge the operational flexibility. The dual nature of automation manifests in streamlining processes while creating dependencies on predetermined algorithmic logic.

Automation offers benefits in terms of cost, efficiency, and resilience. Real-time data processing allows "just-in-time" vessel arrivals, reducing fuel use and idle time. Document processing is transformed through digitalization, especially with e-BL. Optimization improves logistics routes and workflows, thereby ensuring seamless cargo movement. Automation also boosts supply chain resilience by shortening financing cycles and enhancing capital access for SMEs while improving demand forecasting to mitigate bullwhip effects. However, smart contracts, which are efficient for standard scenarios, lack flexibility for unforeseen or complex cases, potentially turning minor issues into major disputes as systems follow preset paths without context. Moreover, unequal cost-benefit distribution among supply chain participants can worsen the power imbalances in the maritime ecosystem.

4.4.3 The Dual-Effect on Market Structure: Ecosystem Enabler versus Concentration Driver

Blockchain technology generates contradictory forces that reshape information flows and redefine value capture mechanisms, creating tension between inclusive ecosystem development and exclusive power consolidation. Blockchain enables collaborative ecosystems and market democratization through benefit distribution models that align stakeholder incentives. It lowers barriers to entry by providing small and medium enterprises with access to operational data previously monopolized by large players. This data democratization creates a more level competitive field where innovation can prevail over the scale advantage. However, countervailing forces drive toward market concentration. The resources required for blockchain development naturally advantage large players, particularly major shipping lines and port operators. This early mover position risks value monopolization and potentially exacerbates existing market power differentials. Additionally, intermediaries, such as freight forwarders and family owned shipping businesses, may resist adoption, seeing transparency as a threat to their business models that depend on information asymmetry.

4.4.4 The Dual-Effect on Sustainability: Green Enabler versus Implementation Challenge

Blockchain technology presents a paradox for sustainable development in MSCs, offering environmental progress potential while creating implementation challenges that affect ecological and social dimensions. The positive environmental impacts of blockchain implementation are substantial and build on its core capabilities. Through paperless operations and digital documentation, blockchain reduces resource consumption and carbon emissions from traditional paperwork processes. This technology enables the precise tracking of environmental metrics, particularly carbon emissions, across supply chains. These applications result in shorter shipping times, reduced vessel congestion, and lower greenhouse gas emissions in MSCs. However, these benefits are counterbalanced by the challenges of social sustainability. Social risks emerge from cost and benefit distribution, with the potential for unfair cost transfer to consumers and technology misuse within global supply chains. The realization of blockchain's sustainability potential faces organizational resistance rooted in conservative corporate cultures and reluctance to adopt new frameworks. Regulatory uncertainty increases implementation costs and risks, thereby hindering widespread adoption.

5. Conclusion and Contributions

5.1 Conclusion and Conceptual Closure

This study systematically reviews 81 studies to establish a holistic framework delineating the antecedent conditions, core implementation processes, and dual-effect outcomes of consortium blockchains in maritime supply chains. This research closes existing conceptual gaps by framing blockchain adoption not as a one-time technological decision, but as a strategic, stakeholder-driven, and institutionally embedded process. The conceptual closure is achieved through three integrated insights, as shown in Figure 4.

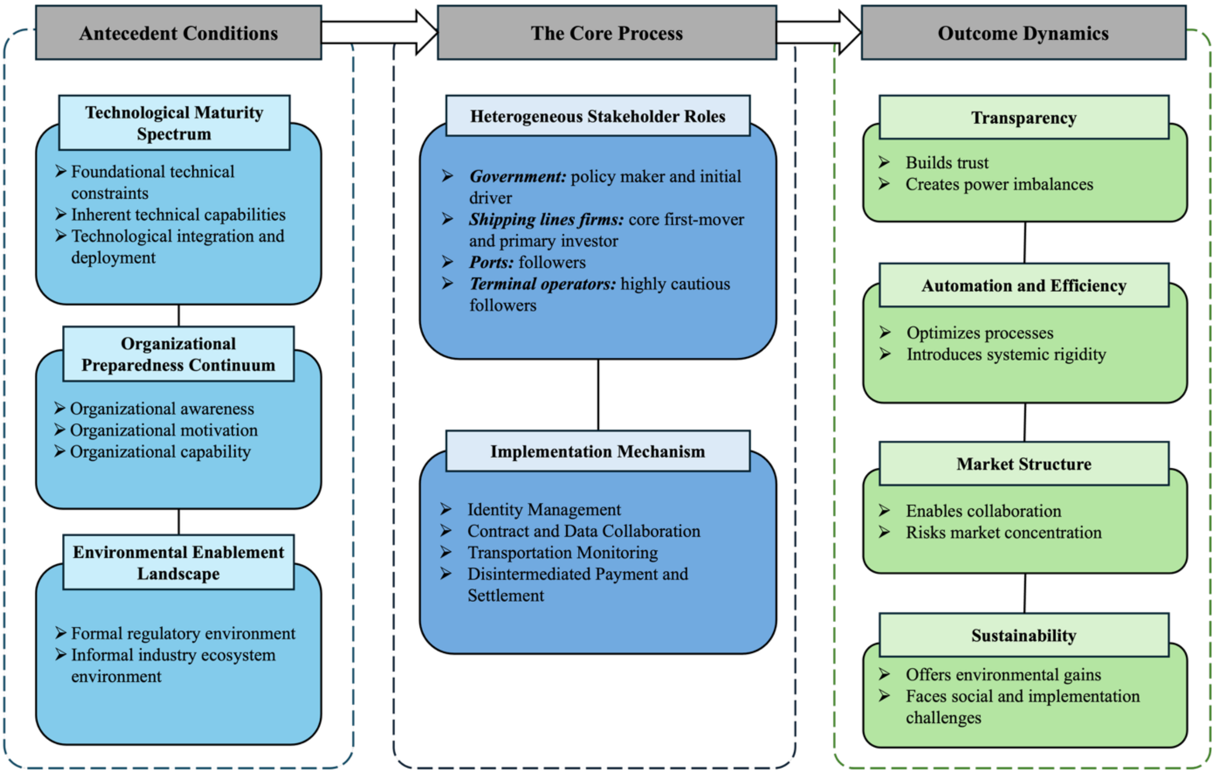


Figure 4. Conceptual Closure

First, the TOE framework combined with the resource–value–institution nexus explains why heterogeneous stakeholders assume divergent roles in blockchain adoption as drivers, pioneers, followers, or skeptics based on their cost-absorptive capacity and value-capture potential. This resolves the theoretical ambiguity regarding stakeholder incentives for consortium governance (Zheng & Jiang, 2024; Zhou et al., 2020). The adoption of consortium blockchain in maritime supply chains is not merely a cost-benefit calculation but a strategic positioning game shaped by stakeholders' relative capacity to absorb costs versus capture value within the emerging ecosystem.

Second, the multi-stage operational workflow, from identity authentication and smart contract collaboration to automated settlement, demonstrates how blockchain transforms technical feasibility into governed, cross-stakeholder collaboration. This procedural view fills the gap between technological potential and real-world operationalization (Ju et al., 2024; Nguyen, Chen, et al., 2023; Lin, 2025). The transition from technical feasibility to operational sustainability requires not only technological capability but also robust governance mechanisms that align differentiated stakeholder incentives within a shared digital infrastructure.

Third, the identified dual effects, such as transparency versus power imbalance, automation versus rigidity, inclusion versus concentration, and green gains versus implementation challenges, provide a balanced, paradoxical understanding that avoids technological determinism. Together, these insights form a closed conceptual framework that explains not only what affects blockchain adoption but also how and why it reshapes the maritime supply chain (Balci & Surucu-Balci, 2021; Irannezhad & Faroqi, 2023; X. Li et al., 2024; Xiao et al., 2023). In line with this, technology-enabled transparency and efficiency gains are inherently coupled with power redistribution and structural rigidity, suggesting that the net impact of blockchain technology depends on the governance context in which it operates.

Ultimately, this study concludes that consortium blockchain revolutionizes maritime supply chains not merely through digital efficiency or transparency, but through its ability to restructure trust, redistribute value, and reconfigure institutional governance among competing stakeholders. Therefore, the framework developed herein provides a theoretically grounded and practically relevant lens for understanding the long-term structural impact of blockchain on the maritime industry.

5.2 Contributions

This study makes three contributions. First, this study explicates the dynamic and strategic nature of consortium blockchain adoption decisions by heterogeneous stakeholders in MSCs. Moving beyond the static factor listings prevalent in prior research, this study reveals that adoption is not a binary choice but a dynamic game. By applying the TOE framework, the study demonstrates how the interplay of technological constraints/capabilities, organizational resources/motivations, and environmental pressures/facilitators drives stakeholders—governments, shipping lines, ports, and freight forwarders—to assume distinct strategic roles as "drivers," "pioneers," "followers," or "skeptics." This analysis provides a nuanced understanding of how divergent attitudes are formed within an emerging blockchain ecosystem. Second, this study identifies and synthesizes the core operational mechanisms that enable the transition from a technical feasible platform to a fully functional system. This research delineates implementation not as a single event but as a multi-stage process. It details the sequential workflow that illustrates how these technical mechanisms restructure collaboration to solve information lags and build trust. More importantly, it links these technical processes to critical governance and strategic choices, explaining how the effective orchestration of stakeholder roles and responsibilities is essential for moving from feasibility to sustainable operation. Third, this research provides a systematic analysis of the dual-effects of consortium blockchain implementation. The study confirms the positive impact of blockchain on efficiency, cost reduction, and resilience but significantly enriches the literature by critically highlighting its paradoxical outcomes. This critical perspective on the dual-edged nature of value creation, particularly regarding sustainability and social equity, provides a more balanced and realistic assessment of the overall impact of blockchain technology on MSCs, cautioning against overly optimistic or technologically deterministic views.

5.3 Future Direction

Although this study constructed a systematic analytical framework, several limitations exist. First, the literature sample was constrained by database selection and keywords, potentially omitting relevant studies. Second, the research insufficiently analyzes the impacts of regional disparities, firm-size heterogeneity, and segmented scenarios, which may weaken practical guidance. Third, the synergistic effects of blockchain with other technologies, such as IoT and AI, have not been fully incorporated, limiting the potential for technology integration. Further research can focus on three aspects: first, developing dynamic assessment models incorporating carbon tariff policies and geopolitical risks to assess the impact of blockchain on supply chain resilience; second, conducting comparative studies across shipping modes, firm sizes, and regional markets to understand technology adoption barriers and develop implementation strategies. In addition, proposing qualitative expert interviews or surveys is a recommended direction for future empirical research to build upon the synthesized framework of the current study.

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