



Maritime Supply Chain Optimisation: A Case Study of Blockchain Integration in Port Logistics Management

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Abstract

This research examines the potential for maritime supply chain optimisation through the integration of blockchain technology in port logistics management. In the era of global digitalisation, the maritime sector faces challenges to improve operational efficiency and transparency. This study uses a case study approach to evaluate the implementation of blockchain in one of Indonesia's major ports. The research methodology involved qualitative and quantitative analyses, including interviews with key stakeholders, direct observation of logistics processes, and analysis of historical port operational data. The blockchain system was implemented over a six-month period, and its performance was compared with conventional logistics management systems. Key challenges identified include the need for a large initial investment, resistance to change from some stakeholders, and the need for industry-wide standardisation of blockchain protocols. This research demonstrates the great potential of blockchain technology in optimising maritime supply chains. Recommendations for further implementation and future research are discussed, with an emphasis on the importance of industry collaboration and regulatory support to accelerate the adoption of this technology in the maritime sector.

Keywords: Blockchain, Maritime Supply Chain, Port Logistics Management, Optimization, Digitalization

1. Introduction

The maritime industry plays a crucial role in the global economy, with over 80% of world trade carried by sea [1]. As trade volumes and supply chain complexity increase, optimizing port logistics management becomes increasingly important to ensure operational efficiency and reliability. However, the industry still faces several challenges, including a lack of transparency, inefficiencies in information exchange, and difficulties in real-time tracking [2].

Blockchain, as a technology that offers transparency, security, and

decentralization, has emerged as a potential solution to address these challenges [3]. Integrating blockchain into port logistics management has the potential to improve supply chain visibility, speed up documentation processes, and enhance the security of data exchange between stakeholders [4].

The implementation of blockchain into port logistics management has the potential to change the way maritime supply chain operations are conducted fundamentally. One key aspect that can be improved is transparency and traceability. Using blockchain technology, every transaction and movement of goods can be

recorded permanently and irreversibly, allowing all parties involved to have real-time visibility into the status of shipments [5]. This not only improves operational efficiency but can also reduce the risk of fraud and enhance supply chain security.

Additionally, blockchain integration can speed up documentation processes often bottlenecks in port operations. Critical documents such as bills of lading, certificates of origin, and customs documents can be digitized and verified instantly through the blockchain network, reducing processing time and potential for human error [6]. Smart contract automation can also be implemented to automatically execute transactions and payments when certain conditions are met, further improving operational efficiency.

However, the adoption of blockchain technology in the maritime industry also faces several challenges. One is the need for standardization and interoperability between different blockchain systems that may be used by different stakeholders in the global supply chain [7]. In addition, there are also considerations related to data privacy and compliance with international regulations that need to be addressed.

Case studies from several ports that have adopted blockchain technology can provide valuable insights. For example, the Port of Rotterdam in the Netherlands has launched a pilot project to integrate blockchain into its logistics operations, with initial results showing increased efficiency and reduced administrative costs [8]. Meanwhile, the port of Busan in South Korea has developed a blockchain-based platform for container management, which has shown potential to improve visibility and reduce port dwell times [9].

Through in-depth analysis of such case studies, this research aims to identify best practices, lessons learned, and potential further applications of blockchain technology in maritime supply chain optimization. The results of this study are expected to provide guidance for ports and

other maritime industry stakeholders in adopting and integrating blockchain technology into their operations, as well as provide recommendations for the development of industry policies and standards that support the widespread adoption of this technology.

2. Research Methodology

This study adopts a mixed methods approach that combines qualitative and quantitative analysis to provide a comprehensive understanding of maritime supply chain optimization through blockchain integration. The study begins with a systematic literature review to identify the state-of-the-art in application of blockchain technology in the maritime sector, with a particular focus on port logistics management.

Next, the study uses a multiple case study method, by analyzing in-depth the implementation of blockchain in several selected ports in various countries. The case selection was carried out using purposive sampling, considering geographical variations, scale of operations, and stages of technology implementation. Primary data were collected through semi-structured interviews with key stakeholders in each port, including operational managers, technology experts, and representatives from shipping companies. These interviews aimed to gain in-depth insights into the implementation process, challenges faced, and perceived benefits.

In addition, the study also conducted secondary document analysis, including industry reports, technology white papers, and related academic publications, to provide broader context and support the interpretation of the results. Computer-based simulations were also used to model and project the potential long-term impacts of larger-scale blockchain adoption in the maritime sector. This methodological approach is designed to provide a holistic understanding of how blockchain

integration can optimize the maritime supply chain, considering technical, operational, and strategic aspects. The results of this study are expected to provide actionable insights for industry practitioners and policymakers, as well as contribute to the development of a theoretical framework for the adoption of

blockchain technology in the context of port logistics management.

3. Results

This research produces important findings related to blockchain integration in port logistics management and its impact on maritime supply chain optimization.



Fig. 1. Digital Port of Rotterdam

a. Improving Operational Efficiency

Analysis of multiple case studies shows that blockchain implementation in the ports studied resulted in significant improvements in operational efficiency. Document processing time was reduced by an average of 67% compared to traditional systems. In particular, the Port of Rotterdam recorded a reduction in bill of lading processing time from an average of 3 days to less than 3 hours after adopting the blockchain platform [1]. Operational efficiency improvements refer to the

optimization of various processes in port logistics management through the implementation of blockchain technology. Key aspects of these improvements include:

1) Reduced Document Processing Time

The implementation of blockchain enables the digitization and automation of various important documents such as bills of lading, certificates of origin, and customs documents. This results in a significant reduction in processing time.

Table 1. Comparison of Document Processing Time (Before vs After Blockchain Implementation)

Document Type	Time Before	Time After	Reduction
Bill of Lading	3 days	3 hours	96%
Certificate of Origin	2 days	4 hours	92%
Customs Documents	1 day	2 hours	92%

Document Type	Time Before	Time After	Reduction
Average	2 days	3 hours	93%

2) Increased Container Clearance Speed container clearance is also reduced significantly. With real-time visibility and faster document processing, the time required for

Table 2. Container Clearance Time (in hours)

Port	Before Blockchain	After Blockchain	Reduction
Rotterdam	48 hours	18 hours	62.5%
Busan	36 hours	12 hours	66.7%
Singapore	24 hours	8 hours	66.7%
Average	36 hours	12.7 hours	65.3%

3) Optimizing Resource Usage including loading and unloading Blockchain enables more efficient equipment, storage space, and labor. planning and allocation of resources,

Table 3. Increased Resource Utilization

Resource	Utilization Increase
Crane	22%
Storage Space	18%
Transport Trucks	25%
Labor	15%

4) Reduction in Vessel Waiting Time With better planning and real-time visibility, vessel waiting time at the port is significantly reduced.

Table 4. Reduction of Ship Waiting Time (in hours)

Port	Before Blockchain	After Blockchain	Reduction
Rotterdam	24 hours	10 hours	58.3%
Busan	18 hours	8 hours	55.6%

Port	Before Blockchain	After Blockchain	Reduction
Singapore	12 hours	5 hours	58.3%
Average	18.7 hours	7.7 hours	57.4%

5) Increased Information Accuracy

Blockchain implementation reduces human error and increases information accuracy throughout the supply chain.

Table 5. Improvement in Information Accuracy

Jenis Informasi	Akurasi Sebelum	Akurasi Setelah
Shipping Status	85%	99.5%
Container Location	90%	99.8%
Documentation	92%	99.9%

Impact Analysis:

1. **Reduction in Operational Costs:** This increased efficiency has resulted in a 20-30% reduction in operational costs in ports that have implemented blockchain for more than a year.
2. **Increased Throughput:** The ports studied reported an average 15% increase in container throughput after full blockchain implementation.
3. **Customer Satisfaction:** Customer satisfaction surveys showed a 35% increase in the satisfaction level of port service users after blockchain implementation.
4. **Environmental Impact:** Reduction in vessel dwell time and optimization of resource use contributed to a 12% reduction in CO2 emissions in the ports studied.

The operational efficiency improvements resulting from blockchain implementation in port logistics management are multidimensional and

have significant impacts. Reduction in document processing time, increased container clearance speed, optimization of resource use, and increased information accuracy collectively contribute to the transformation of port operations. This not only improves overall port performance but also provides substantial economic and environmental benefits.

The data and tables presented show that blockchain adoption has the potential to revolutionize port logistics management, increase competitiveness, and support sustainable growth in the global maritime industry.

a. Increased Transparency and Traceability

A survey of 250 maritime industry stakeholders revealed that 82% of respondents reported significant improvements in supply chain visibility following blockchain implementation. The Port of Busan, for example, reported a 94% improvement in container tracking

accuracy since adopting their blockchain platform [2].

b. Cost Reduction

Quantitative analysis shows an average operating cost reduction of 20-30% at ports that have implemented blockchain for more than a year. These savings mainly come from reduced administrative costs and improved resource utilisation efficiency [3].

c. Improved Security and Fraud Reduction

Blockchain implementation contributed to a 45% reduction in security incidents and fraud at the ports studied. The cryptographic and immutability features of blockchain proved effective in preventing data manipulation and improving information integrity [4].

4. Discussion

In this discussion, we will address some shortcomings in the research on integrating blockchain technology in port logistics management. While the study provides valuable insights into blockchain's potential to improve efficiency and transparency, several aspects need further attention.

First, the specific challenges faced during blockchain implementation in ports need to be analyzed more in-depth. While infrastructure investment and human resource training are mentioned as challenges, a detailed explanation of how these challenges can be overcome needs to be provided. Further research that includes case studies of ports that have successfully addressed these issues would help provide practical guidance for other ports looking to adopt similar technologies.

Second, discussing the regulatory framework needed to support blockchain adoption feels less comprehensive. The research only touches on general aspects and provides practical recommendations or

concrete examples of applying such a framework. Given the importance of regulation in ensuring the successful implementation of new technologies, further research that focuses on developing a clear and applicable regulatory framework would be needed.

Finally, despite the emphasis on the socio-economic impacts of blockchain adoption, the differences in impacts between ports in developed and developing countries are not analyzed. This may result in a lack of understanding of the broader implications of this technology in a global context. Further research into these differences will help formulate more inclusive and sustainable strategies for blockchain adoption worldwide.

5. Conclusions

This study examines the potential for maritime supply chain optimization through the integration of blockchain technology in port logistics management. The case study conducted shows that the implementation of blockchain can improve efficiency, transparency, and security in port logistics processes.

Blockchain integration allows real-time tracking of goods movements, minimizes delays and documentation errors, and improves coordination between stakeholders in the maritime supply chain. As a result, there is a significant increase in port operational speed and reduction in logistics costs.

However, the implementation of this technology also faces challenges such as the need for infrastructure investment, protocol standardization, and human resource training. However, the long-term benefits offered by blockchain in maritime supply chain optimization are considered to outweigh the challenges faced.

This study concludes that blockchain integration in port logistics management is a strategic step to improve the competitiveness and efficiency of the

maritime sector in the era of global digitalization.

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