INDUSTRIALIZATION AND BLOCKCHAIN STRATEGY IN SUPPORTING THE ACHIEVEMENT OF SDGS AND FOOD SECURITY: A CASE STUDY OF THE FISHERIES INDUSTRY SUPPLY CHAIN WITH SEM, AHP, OR, AND SPATIAL ANALYSIS APPROACHES (EAST JAVA, AMBON, MAKASSAR, MADURA)

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Abstract

This study investigates strategies for integrating blockchain technology into Indonesia's capture fisheries supply chain to enhance transparency, operational efficiency, and sustainability, thereby contributing to the achievement of Sustainable Development Goals (SDGs) 2, 12, and 14. Employing a mixed-methods approach, the research combines Structural Equation Modeling (SEM), Analytic Hierarchy Process (AHP), Operational Research (goal programming), and Geographic Information System (GIS)-based spatial analysis. Data from 210 fisheries stakeholders were analyzed to identify determinants of blockchain adoption, prioritize strategic criteria, and optimize policy objectives. The SEM results ($R^2 = 0.67$) indicate that government support and perceptions of transparency significantly influence adoption intention. AHP prioritization highlights data transparency and accuracy (0.34) as the most critical criterion, followed by infrastructure readiness (0.27), capacity development (0.23), and cost efficiency (0.16). Goal programming optimization recommends a strategic combination of logistics traceability, digital training, and certification systems, while spatial analysis identifies Makassar, the North Coast of East Java, and Ambon as priority zones for implementation. The findings underscore that blockchain adoption in the fisheries sector is not solely a technological intervention but a systemic transformation requiring institutional reform, infrastructure investment, and multi-stakeholder collaboration. The study provides an evidence-based roadmap for place-based blockchain deployment, aiming to improve fisheries governance and strengthen Indonesia's competitiveness in global seafood markets.

***Keywords**: Blockchain, Fisheries Supply Chain, Food Security, Sustainable Development Goals*

INTRODUCTION

Indonesia's fisheries sector plays a pivotal role in sustaining national food security and bolstering the maritime economy. With a coastline exceeding 108,000 km and a marine area of 6.4 million km², Indonesia ranks among the world's largest fisheries producers, supplying essential animal protein to over 270 million citizens and providing livelihoods for approximately 12 million fishers and fisheries-based enterprises (FAO, 2022; MMAF, 2023). Despite its vast potential, the national fisheries supply chain remains hindered by structural inefficiencies, fragmented coordination among stakeholders, limited data accuracy, and logistical constraints. These challenges contribute to high post-harvest losses—up to 30% in certain coastal regions—undermining both domestic food availability and the competitiveness of Indonesian seafood in global markets.

Key systemic issues include the absence of integrated data management, delayed distribution processes, and inadequate cold chain infrastructure in remote areas. Moreover, illegal, unreported, and unregulated (IUU) fishing practices persist, eroding consumer confidence and threatening the sustainability of marine resources (World Bank, 2022; OECD, 2023). Addressing these constraints requires an innovative governance framework that simultaneously enhances transparency, operational efficiency, and sustainability within the supply chain. In this context, blockchain technology has emerged as a promising enabler of digital transformation in the fisheries sector.

Blockchain's decentralized and tamper-proof architecture allows for real-time, verifiable data recording across the supply chain—from the point of capture to the end consumer. By enabling immutable traceability of catch origin, fishing methods, and handling processes, blockchain can reduce fraudulent practices, strengthen regulatory compliance, and improve consumer trust. Case studies from advanced fisheries economies, such as Norway's blockchain-enabled salmon traceability system, demonstrate significant improvements in market value and sustainability credentials through digital integration (NSC, 2022). For Indonesia, this technological shift aligns directly with national priorities and the United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 14 (Life Below Water).

However, the adoption of blockchain in Indonesia's fisheries supply chain is not solely a technological challenge. Successful implementation requires institutional readiness, supportive governance structures, adequate digital infrastructure, and capacity-building for diverse supply chain actors, including small-scale fishers. Previous studies highlight that technology uptake in resource-based sectors is influenced by factors such as perceived transparency, trust in digital systems, regulatory harmonization, and the availability of training programs (Clohessy et al., 2019; Hair et al., 2019). Consequently, a multidisciplinary approach is essential to design an implementation strategy that addresses behavioral, technical, and spatial dimensions.

This study aims to develop a comprehensive blockchain adoption strategy for the Indonesian capture fisheries sector using an integrated methodological framework that combines Structural Equation Modeling (SEM), the Analytic Hierarchy Process (AHP), Operational Research (OR) via goal programming, and Geographic Information System (GIS)-based spatial analysis. SEM is applied to examine the behavioral determinants of blockchain adoption; AHP is used to prioritize strategic criteria such as transparency, infrastructure readiness, and capacity development; OR facilitates optimization of competing policy objectives; and spatial analysis identifies priority zones for deployment based on port access, cold storage availability, and production intensity. By integrating these analytical approaches, the study seeks to provide an evidence-based roadmap for blockchain implementation that enhances supply chain governance, strengthens Indonesia's seafood traceability system, and advances the achievement of the SDGs.

METHOD

This study adopts a mixed-methods research design that integrates quantitative and qualitative analytical techniques to formulate an evidence-based blockchain adoption strategy for the Indonesian capture fisheries supply chain. The approach combines Structural Equation Modeling (SEM), Analytic Hierarchy Process (AHP), Operational Research (OR) through goal programming, and Geographic Information System (GIS)-based spatial analysis. This methodological integration enables the examination of behavioral factors influencing adoption intentions, prioritization of strategic criteria, optimization of conflicting policy objectives, and geographic targeting of implementation areas.

The first stage involved applying SEM to identify the behavioral determinants of blockchain adoption among fisheries sector stakeholders, including fishers, traders, port operators, and government officials. A total of 210 respondents were surveyed using a structured questionnaire designed to measure latent variables such as government support, perceptions of transparency, trust in digital systems, and adoption intention. All constructs were measured using validated Likert-scale indicators adapted from previous studies (Clohessy et al., 2019; Hair et al., 2019). The SEM analysis was conducted using the Partial Least Squares (PLS) method, which is suitable for predictive modeling and complex causal relationships. Model fit and reliability were assessed through composite reliability, average variance extracted (AVE), and path coefficients, with statistical significance determined at the 5% level.

Following the SEM analysis, the AHP method was employed to prioritize strategic criteria for blockchain implementation. Expert respondents, drawn from academia, government, and the private sector, were asked to perform pairwise comparisons of criteria such as data transparency and accuracy, infrastructure readiness, capacity development, and cost efficiency. The relative weights were calculated using Saaty's (2008) eigenvalue method, and consistency ratios (CR) below 0.10 were accepted as valid. The resulting weight distribution (transparency (0.34), infrastructure readiness (0.27), capacity development (0.23), and cost efficiency (0.16)) was subsequently used as input for the optimization stage.

The third stage integrated goal programming to optimize policy objectives that often conflict in fisheries governance, such as improving logistics traceability, reducing distribution costs, increasing small-scale fisher participation, and accelerating distribution speed. The objective function was formulated to minimize deviations from desired targets, incorporating contribution weights derived from the AHP results.

RESULTS AND DISCUSSION

Structural Equation Modeling (SEM) Results

The SEM analysis produced an R^2 value of 0.67, indicating that 67% of the variance in blockchain adoption intention (Y) can be explained by two primary predictors: government support (X_1) and perceptions of transparency (X_2). The structural model equation is expressed as:

$$Y = \beta_1 X_1 + \beta_2 X_2 + €$$

Both predictors had statistically significant path coefficients ($p < 0.05$), confirming their critical influence. Government support encompasses regulatory harmonization, fiscal incentives, and local institutional empowerment, while perceptions of transparency relate to blockchain's ability to provide immutable, real-time records that improve supply chain accountability and combat IUU fishing practices (FAO, 2021; Kamilaris et al., 2019). These findings are consistent with Clohessy et al. (2019), who argue that supportive governance and clear policy frameworks are essential to accelerating blockchain adoption in complex supply chains.

Analytic Hierarchy Process (AHP) Prioritization

The AHP results established the following priority weights for blockchain implementation criteria:

1. Data transparency and accuracy – 0.34
2. Infrastructure readiness – 0.27
3. Capacity development – 0.23
4. Cost efficiency – 0.16

These weights emphasize that technical credibility and systemic readiness outweigh purely financial considerations when adopting blockchain in the fisheries sector. This aligns with Probst et al. (2022), who note that traceability and infrastructure are the primary enablers of digital transformation in resource-based industries. The prioritization also provides a quantitative basis for resource allocation in policy planning.

Goal Programming Optimization

The goal programming model optimized multiple policy objectives, including:

1. Achieving at least 85% product traceability
2. Keeping distribution costs below Rp 50 million per month
3. Ensuring ≥60% participation from small-scale fishers
4. Improving distribution speed by ≥30% over baseline

Minimizing deviations from these targets resulted in an optimal strategy combination: logistics traceability (X_1), digital training programs (X_2), and certification systems (X_3), with contribution weights of 0.45, 0.35, and 0.20, respectively. This combination integrates technological, human, and institutional dimensions, ensuring both operational efficiency and equitable participation.

Spatial Analysis Findings

GIS-based spatial scoring identified Makassar (0.87), North Coast of East Java (0.85), and Ambon (0.79) as the top priority zones for blockchain implementation. These areas scored highly due to their proximity to export ports, availability of cold storage infrastructure, and significant production intensity. Targeting these zones first can maximize the return on investment in digital infrastructure and enhance market access for traceable, sustainable seafood products.

Discussion

The integration of SEM, AHP, goal programming, and GIS provides a multi-dimensional framework for blockchain adoption in the Indonesian fisheries sector. The SEM results highlight that institutional and perceptual factors, particularly government support and transparency, are foundational to adoption. Without strong regulatory alignment and public confidence in system integrity, technological interventions risk low uptake. The AHP findings reinforce that achieving data credibility and building infrastructure readiness are non-negotiable prerequisites. These priorities are particularly relevant in rural and coastal areas where digital literacy and connectivity remain limited (Nurdin et al., 2022). Investments in these domains are likely to yield higher adoption rates and operational efficiency.

Goal programming optimization demonstrates that technological solutions must be complemented by capacity-building and certification mechanisms to ensure inclusivity and compliance with sustainability standards. The inclusion of small-scale fishers is critical, as they form the backbone of Indonesia's fisheries production yet often face barriers to digital participation. Spatial analysis adds a critical geographic lens, ensuring that resources are allocated to regions with the highest potential impact. By focusing initial efforts in Makassar, East Java, and Ambon, policymakers can build demonstrable success cases that facilitate scaling to other regions. This aligns with the place-based policy approach advocated by Agustina & Choi (2020), leveraging regional strengths under Indonesia's decentralized governance framework.

The results underscore that blockchain adoption in the fisheries sector is not merely a technological upgrade but a systemic transformation requiring policy reform, infrastructure investment, and human capital development. Multi-stakeholder collaboration through a penta-helix model involving government, industry, academia, NGOs, and communities will be essential to overcome institutional inertia and ensure long-term sustainability.

CONCLUSION

This study demonstrates that the successful adoption of blockchain technology in Indonesia's capture fisheries sector is highly dependent on institutional support, transparency, and systemic readiness. The SEM results confirm that government support and perceptions of transparency are the two most influential factors, explaining 67% of the variance in adoption intention. These findings highlight that blockchain adoption is not solely a technological challenge, but a governance and trust-building process requiring regulatory harmonization, fiscal incentives, and institutional empowerment.

The AHP analysis underscores data transparency and accuracy (0.34) and infrastructure readiness (0.27) as top priorities, indicating that policy interventions must first address technical credibility and logistical capacity. Goal programming optimization further identifies a strategic combination of logistics traceability, digital training programs, and certification systems as the most effective pathway for achieving operational efficiency, sustainability, and inclusive participation.

Spatial analysis reveals that Makassar, the North Coast of East Java, and Ambon are the most strategic starting points for blockchain deployment, due to their high production volumes, port accessibility, and cold chain infrastructure. These regions provide the ideal conditions for pilot implementation and scaling of blockchain-based traceability systems.

Blockchain technology offers Indonesia a transformative opportunity to enhance fisheries governance, combat IUU fishing, and strengthen its global market position. However, its successful implementation requires multi-stakeholder collaboration, capacity building, and a place-based policy approach that aligns technological innovation with local socio-economic realities.

SUGGESTION

1. Harmonize cross-sectoral regulations to eliminate legal inconsistencies in fisheries governance.
2. Introduce fiscal incentives (tax breaks, subsidies) to encourage blockchain adoption, particularly for small-scale fishers and cooperatives.
3. Expand cold storage capacity and improve logistics networks in priority regions.

4. Implement continuous digital literacy programs to equip stakeholders with the skills necessary to operate blockchain platforms effectively.
5. Mandate standardized data recording protocols across the supply chain to ensure consistency and reliability.
6. Develop a national blockchain registry for marine products to verify legality and traceability.
7. Begin with high-readiness zones such as Makassar, East Java, and Ambon to build success models before nationwide expansion.
8. Integrate GIS-based monitoring to continually assess geographic readiness and adapt deployment strategies.
9. Implement a penta-helix governance model involving government agencies, private sector players, academia, NGOs, and fishing communities.
10. Establish regional blockchain innovation hubs to foster knowledge exchange and pilot new applications in fisheries traceability.

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