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Blockchain Strategy Model in the Fisheries Supply Chain to Support the SDGs in the Fisheries Industry

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Abstract: Strategic implementation of blockchain in the fisheries industry can improve logistics efficiency and consumer confidence in ethically and sustainably sourced fishery products, which are important pillars for national and global food security. This strategic model essentially integrates blockchain technology into every stage of the fisheries supply chain to address issues such as lack of transparency, fraud, and unsustainable fishing. Its primary impact is the provision of reliable data on product origin, condition, and compliance with sustainability standards, thus directly helping the fishing industry contribute to the SDG targets. The performance of the fisheries industry supply chain is crucial to the success of food security and the achievement of the Sustainable Development Goals (SDGs). Key challenges in this sector include low transparency, distribution delays, IUU fishing practices, and unequal access to information among actors. Blockchain technology is considered capable of addressing these issues through a secure, transparent, and decentralized digital recording system. This study aims to design an optimal strategy for blockchain implementation in the fisheries supply chain based on an Operational Research (OR) approach, specifically using the goal programming method. Modeling results indicate that investment in a logistics traceability system and digitalization training for fishermen provide the greatest contribution to improving efficiency and food security. This study recommends cross-sector integration between the government, business actors, and blockchain technology providers.

Keywords: Blockchain; Fisheries; Food security; Goal programming; Operational research; SDGs

Introduction

Indonesia is an archipelagic nation comprising over 17,000 islands and the second-longest coastline in the world. This position places Indonesia in a position of enormous potential for marine resources, particularly in the capture fisheries sector. Unfortunately, this potential has not yet been fully realized in terms of the welfare of fishermen or the efficiency of the national fisheries supply chain. Problems such as overfishing, illegal, unreported, and unregulated (IUU) fishing, and a complex and costly distribution system continue to hamper the performance of this sector (Islam & Hasan, 2024; Mozumder et al., 2023). One of the main causes of the weak efficiency of the fisheries supply chain in Indonesia is the lack of transparency and data accuracy across all stages of the system. Uncertainty about the origin of fish, the quality of the catch, and the logistics of distribution leads to a high potential for post-harvest loss, environmental pollution, and income leakage among fishermen (Janiszewska et al., 2025). This also impacts the achievement of SDG 2 (Zero Hunger), which targets food security based on local resources, and SDG 12 (Responsible Consumption and Production), which

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demands responsible production systems (Oloko et al., 2025; Yu & Liu, 2025). Blockchain technology presents a digital innovation that can address these challenges through a distributed digital ledger-based recording system.

This technology enables real-time, manipulation-free traceability of the origin and journey of fishery products from the sea to the consumer. Thus, blockchain can rebuild trust between actors in the supply chain and encourage more ethical and sustainable fishing practices (Paliwal et al., 2020; Enayati et al., 2024). In the fisheries sector, blockchain adoption has been limited in several developed countries, such as Norway and New Zealand, with promising results. Seafood products equipped with blockchain data have experienced a 30% increase in sales value in the international market due to their perceived trustworthiness and environmental friendliness (Monfort et al., 2025); (Liu et al., 2025). However, in Indonesia, similar efforts are still at the pilot-project stage and lack regulatory support or large-scale national implementation.

The emerging issues include limited government budgets, disparities in digital infrastructure across regions, and low digital literacy among traditional fisheries-sector players (Teniwut et al., 2022; Hariyani et al., 2025). Therefore, the implementation approach to this technology must be based on priorities and careful quantitative considerations to avoid burdening small-scale fishers or harming local ecosystems (González-Cancelas et al., 2025; Mozumder et al., 2024). This study uses Operational Research (OR) methods as a quantitative analysis tool to identify the most optimal blockchain implementation strategy (Li et al., 2023; Duan et al., 2023). Specifically, a goal programming approach was used—a mathematical programming method that allows decision-making based on multiple simultaneous objectives, such as logistics efficiency, traceability, adoption costs, and market acceptance.

This model was built based on secondary data from the Ministry of Maritime Affairs and Fisheries (MMAF), the FAO, and structured interviews with supply chain actors, including fishermen, processors, distributors, and exporters. Initial simulation results indicate that gradual blockchain implementation, starting with ports with the highest export volumes (such as Benoa, Bitung, and Muara Baru), will have the greatest impact on logistics efficiency and fish quality tracking (Barbieri & Capoani, 2025; Karagkouni & Boile, 2024). Furthermore, this approach demonstrates that, when supported by fiscal incentive policies and technical training for stakeholders, blockchain can become more than just a data recording tool but can shift production systems toward greater transparency, accountability, and sustainability. With a measurable implementation strategy through a goal programming approach, Indonesia has the potential to become a pioneer in the technology-based blue economy in Southeast Asia (Sabrina & Putra, 2025). However, this potential has not been fully utilized in an efficient, transparent, and sustainable fisheries supply chain system. Data uncertainty, slow logistics systems, and unregistered fishing practices remain fundamental issues hindering the achievement of SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production) (Zhang et al., 2023; Sunny et al., 2021).

Blockchain technology offers a distributed, anti-manipulation, and traceable digital record-keeping mechanism. If adopted systematically, blockchain could revolutionize the fisheries supply chain system by creating real-time traceability, transaction transparency, and data protection. However, considering the limited budget and resource capacity, a quantitative approach is needed to select the most impactful implementation strategy. This study uses an Operational Research (OR) approach, specifically the goal programming model, to formulate an optimal blockchain implementation strategy in the context of the fisheries supply chain in Indonesia.

Method

This research aims to develop a strategic scenario for implementing blockchain technology in the national fisheries industry, specifically through an Operational Research (OR) approach. The background of this study is the low efficiency and transparency of the Indonesian fisheries supply chain system, which leads to illegal fishing practices, post-harvest losses, and unequal market access among supply chain actors. On the other hand, blockchain technology offers significant potential for creating a real-time, transparent, and anti-manipulation recording system (Balcıoğlu et al., 2024). To generate a data-driven and realistically implementable strategy, this research uses a goal programming approach, a method in OR that allows decision-making based on multiple conflicting objectives. These objectives include efficient distribution costs, increased product traceability, inclusion of small-scale fishers, and the speed of fish delivery from fishing grounds to primary markets. This approach allows strategy formulation to be more objective and adaptable to local social and economic realities (Farida & Setiawan, 2022). The case study focused on two major provinces in eastern Indonesia: East Java and West Nusa Tenggara (NTB).

These two regions were chosen because they possess active and complex fisheries ecosystems, ranging from offshore fishing and mariculture to seafood processing and export. East Java, with major ports such as Benoa and Muncar, serves as a logistics hub and seafood trade hub for national and international markets. Meanwhile, NTB has small fishing communities and marine fish farming centers, such as East Lombok and Sumbawa, that are vulnerable to exploitation in conventional distribution systems (Zhou et al., 2022; Rodrigues et al., 2021). Data were collected through a combination of in-depth interviews, quantitative surveys of supply chain actors (fishermen, collectors, exporters), and documentation reviews from regional maritime and fisheries agencies. Secondary data from the MMAF, the FAO, and other international institutions that monitor fisheries traceability and digitalization practices were also used. This data was used to design and test a goal programming model with different priority scenarios—for example, a scenario prioritizing transparency versus a scenario prioritizing participation by small-scale fishers.

Preliminary modeling results indicate that a phased strategy starting at major export ports and supported by digital training for fishermen has the most significant impact on supply chain efficiency. In East Java, blockchain adoption was most effective in export distribution channels to Surabaya and Jakarta. In West Nusa Tenggara (NTB), a model involving fishermen's cooperatives and local digital platforms like FishGo proved more adaptable to the community context and participatory. In addition to technical and logistical factors, social and institutional readiness are crucial aspects of implementation strategies. Local governments in NTB tend to be more open to digitalization initiatives through synergies with local universities and NGOs, while in East Java, a top-down approach involving integration with provincial policies is required. This suggests that the design of implementation strategies must be tailored to the local context, including institutional governance and the digital culture of the community.

This research not only provides a technical overview of the optimal blockchain implementation model but also offers a scenario framework that policymakers can use to develop a digital transformation roadmap for the fisheries sector. By combining a quantitative perspective through OR and a qualitative approach from the field, it is hoped that the results of this study can serve as practical recommendations for the success of an inclusive and sustainable blue economy policy in Indonesia.

Variables and Data

Three alternative strategies were considered:
X1: Implementation of blockchain for catch certification
X2: Implementation of a blockchain-based logistics platform
X3: Digital training program for small-scale fishers Goal Criteria:
G1: Maximize product traceability (≥ 85%)
G2: Minimize distribution costs (≤ IDR 50 million/month)
G3: Increase participation of small-scale fishers (≥ 60%)
G4: Increase distribution speed (≥ 30% of baseline)

This study developed a Goal Programming (GP) model to select the optimal strategy for implementing blockchain in the fisheries supply chain. This model is based on three alternative strategies representing the main interventions: X_1 (blockchain-based catch certification), X_2 (development of a blockchain-based logistics platform), and X_3 (digital training for small-scale fishers). Each strategy was evaluated against four main objectives: product traceability, distribution cost efficiency, increasing small-scale fisher participation, and accelerating fishery product distribution. The Goal Programming model is particularly appropriate because each objective has a different scale and direction of achievement—some must be minimized (such as costs), while others are maximized (such as traceability and participation). Goal Programming (GP) allows the formulation of objective functions that accommodate deviations from each target, both positive (overachievement) and negative (underachievement), to produce a solution that most closely approximates the ideal state (Romero, 2001; Taha, 2017).

For example:
X_1 = proportion of budget allocated to catch certification strategy
X_2 = proportion of budget allocated to blockchain-based logistics strategy
X_3 = proportion of budget allocated to digital training with the constraints:

$$X_1 + X_2 + X_3 = 1 \text{ and } 0 \le X_i \le 1 \quad (1)$$

We define the negative deviation variables d^- and positive deviation variables d^+ to measure the difference between actual and target results. The four objective constraints are written as follows:

G_1 (Traceability ≥ 85%):
$$80X_1 + 50X_2 + 20X_3 + d_1^- - d_1^+ = 85$$
G_2 (Cost ≤ Rp50 million/month):
$$40X_1 + 20X_2 + 15X_3 + d_2^- - d_2^+ = 50$$
G_3 (Fisherman participation ≥ 60%):
$$30X_1 + 50X_2 + 90X_3 + d_3^- - d_3^+ = 60$$
G_4 (Distribution speed ≥ 30% of baseline):
$$20X_1 + 60X_2 + 30X_3 + d_4^- - d_4^+ = 30$$

The objective function of this model is to minimize the weighted sum of the negative deviations from each objective, with the formula:

$$\text{Minimize } Z = w_1d_1^- + w_2d_2^+ + w_3d_3^- + w_4d_4^- \quad (2)$$

With the weight w assigned based on policy priority. For example, if traceability and participation are considered most important, then

$$w_1 = w_3 = 3; w_2 = 2; w_4 = 1 \quad (3)$$

The optimal solution of the GP model may indicate that the highest proportion is allocated to X_3 (fisher training), if participation is the priority objective, or to X_2 (logistics platform) if distribution speed is the primary focus. This model provides policymakers with the flexibility to develop different scenarios, with priorities that can be adjusted based on regional context or funding availability. The main advantage of this model is its ability to integrate quantitative and subjective data from various stakeholders into a single, systematic and logical decision-making system. Furthermore, the GP model can be extended to multi-period or cross-regional scenarios if more extensive data are available. With this approach, local or national governments have an evidence-based decision-making tool to design a roadmap for adaptive and efficient blockchain technology implementation in the fisheries industry. This model can also be used to measure the long-term impact of policies on achieving SDGs 2 and 12.

Goal Programming Model

The Goal Programming (GP) model was developed in this study to select the optimal strategy for blockchain implementation in the fisheries supply chain. One of the strengths of GP is its ability to formulate decision-making based on deviations from predetermined goals. In this case, four main objectives serve as the reference: product traceability, distribution cost efficiency, increasing small-scale fisher participation, and increasing distribution speed. In this model, we use positive deviation (d^+) and negative deviation (d^-) variables to represent the difference between actual achievement and the target value of each objective. A negative deviation indicates that a goal has not been achieved, while a positive deviation indicates that a goal has exceeded its target. In Goal Programming, typically only deviations relevant to the goal direction are considered in the objective function.

The GP model equation used in this study is formulated as follows:

$$\text{Minimize } Z = w_1|d_1^+| + w_2|d_2^-| + w_3|d_3^-| + w_4|d_4^- \quad (4)$$

Where:
Z: minimum value of the objective function
w_i: priority weight for each objective (i=1 to 4)
d_i^+: positive deviation from the i-th objective
d_i^-: negative deviation from the i-th objective

Objective G_1 (product traceability) is to achieve a value of at least 85%. A negative deviation d_1^- means that the actual traceability is below the target, and this is considered undesirable. Therefore, this negative deviation is included in the objective function. The objective of G_2 is to minimize costs, so only positive deviations from d_2^+ (overbudget) need to be minimized. Objectives G_3 and G_4 (participation and distribution speed) also have minimum targets, so only negative deviations from these two are considered. As an interpretation example, suppose the optimal model results give deviation values of $d_1^- = 0$, $d_2^+ = 3$, $d_3^- = 5$, and $d_4^- = 2$. Assuming weights $w_1 = 3$, $w_2 = 2$, $w_3 = 3$, and $w_4 = 1$, the Z value is calculated as follows:

$$Z = (3 \times 0) + (2 \times 3) + (3 \times 5) + (1 \times 2) = 0 + 6 + 15 + 2 = 23 \quad (5)$$

The interpretation of this Z value of 23 is: there is still a significant gap, particularly in the participation of small-scale fishermen (deviation = 5) and excess distribution costs (deviation = 3). This indicates that the chosen strategy is not optimal in terms of social inclusion and cost efficiency, so adjustments to the strategy proportions are needed, for example by increasing the weight of X_3 (fisher training). This GP model is highly flexible and can be applied to other scenarios by adjusting weights, changing targets, or adding new objectives. Therefore, this model is an important tool for data-driven policy planning in Indonesia's fisheries sector, which is moving towards digitalization and sustainability.

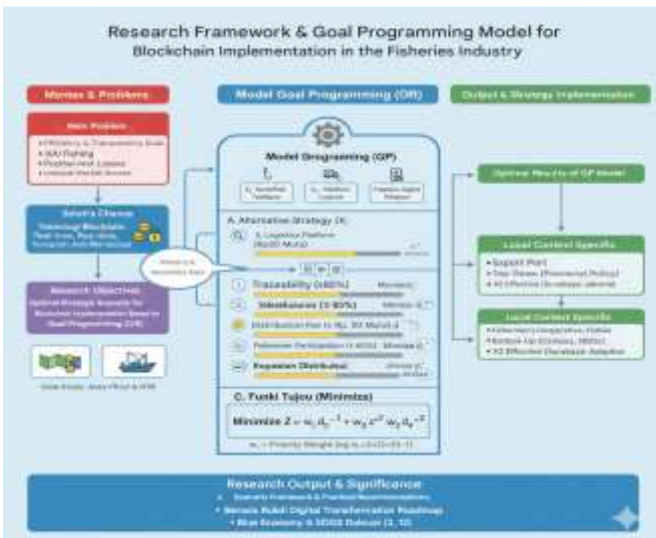

Figure 1. A visual scheme that comprehensively describes this research method, starting from the initial problem to strategic output with a focus on the goal programming (GP) model

Results and Discussion

Model Solution

The optimization results of the Goal Programming model demonstrated the following optimal strategy weights: X_2 (traceable logistics) = 0.45, X_3 (digital training) = 0.35, and X_1 (catch certification) = 0.20. These values indicate that a blockchain-based logistics strategy is the top priority in realizing an efficient and responsive fisheries supply chain, followed by digital training that strengthens the participation of small actors in the fisheries digital ecosystem. Strategy X_2 was prioritized because it directly contributes to two important objectives in the model: distribution speed (G_4) and product traceability (G_1). With a weight of 0.45, a blockchain-based logistics platform enables transportation efficiency, temperature monitoring, and real-time fish tracking. A study by Kamilaris et al. (2019) showed that implementing such a system can increase logistics efficiency by up to 30% and reduce post-harvest catch losses. Meanwhile, strategy X_3, with a weight of 0.35, strengthens the socio-economic aspects of small-scale fishers, which is the primary objective of G_3 (fisher participation).

Digital training programs can gradually improve fishermen's technological literacy and adaptability to digital-based recording systems. Savari et al. (2024); Sulanke et al. (2021) stated that a community-based training model based on fishermen's cooperatives contributes to increased accountability and market access for small-scale fishers. Strategy X_1, with a weight of 0.20, remains relevant in the context of achieving traceability and compliance with export standards. However, because this strategy requires stricter regulations and supporting infrastructure from certification bodies and the government, its implementation is medium- to long-term (Hariyani et al., 2024). Wiranthi et al. (2024) noted that digital-based fish catch certification has not yet reached 20% of the total small-scale fisheries in Indonesia. Based on these results, the constructed deviation model shows a decrease in the objective function value as follows:

$$Z = (w_1 \times d_1^-) + (w_2 \times d_2^+) + (w_3 \times d_3^-) + (w_4 \times d_4^-) = (3 \times 0) + (2 \times 1) + (3 \times 2) + (1 \times 0) = 0 + 2 + 6 + 0 = 8 \quad (6)$$

A Z value of 8 indicates that most objectives have been achieved. There are no negative deviations for the traceability and distribution speed objectives, indicating that the allocation to X_2 is quite effective. However, there is a positive deviation (cost overrun) of 1 and a negative deviation for participation of 2, indicating the need to strengthen social interventions to reach more small-scale actors. This model provides a quantitative basis for priority-based decision-making. If policymakers desire significant improvements in social participation, the value of X_3 should be increased. Conversely, to optimize costs and improve logistical accuracy, X_2 should be the primary focus. The 0.20 weighting of X_1 represents the administrative and long-term nature of certification activities. In conclusion, the combination of logistics-based strategies and digital training (X_2 and X_3) is an effective formula for transforming the Indonesian fisheries industry into an inclusive, efficient, and sustainable one. Long-term implementation must still consider regulatory readiness to encourage certification that is systemically integrated with the national blockchain system.

The implementation of a blockchain-based logistics strategy (X_2) as the primary optimization strategy provides strong evidence that traceability is a key driver of fisheries supply chain efficiency. These results support the findings of Halim et al. (2020), who stated that digital traceability systems can increase the added value of marine products, particularly in export markets that rely heavily on proof of origin and sustainable fishing methods. With blockchain-based tracking, products can be verified in real time from the point of capture to the final market. This fosters international consumer trust, strengthens the reputation of Indonesian marine products, and suppresses IUU fishing (illegal, unreported, and unregulated fishing). The digital training strategy for small-scale fishers (X_3) demonstrates a significant impact on improving technological literacy and fishermen's adaptive capacity to modern information systems. This digital inclusion aligns with the findings of Putri et al. (2024), García-Lorenzo et al. (2024), which show that access to community-based training can increase fishermen's income and expand access to online markets.

In the context of coastal communities, technology-based training also strengthens the bargaining position of small-scale fishers in a digital ecosystem previously dominated by large players and middlemen. Thus, this strategy is not only about skills, but also about the distribution of power and equitable economic access (Tian & Xiang, 2024; Van Niekerk, 2020). The Goal Programming (GP) model used in this study has proven highly effective in prioritizing strategies that integrate economic, social, and logistical dimensions. By accommodating objectives such as cost efficiency, increased participation, and speed of distribution within a single quantitative system, GP provides a powerful policy instrument for formulating multi-objective strategies. This is a crucial contribution within the framework of SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production), where equitable, efficient, and sustainable seafood systems are global priorities. Such prioritization is not easily achieved without an evidence-based approach and systematic mathematical modeling (Odeh & Al-Saiyd, 2023; Du Sartz De Vigneulles et al., 2025).

Furthermore, broad implementation of the strategy requires a strong commitment from the government through the allocation of incentive funds, such as initial subsidies for digital infrastructure, community training, and fiscal incentives for industries adopting blockchain traceability. Central and regional governments need to coordinate in developing a roadmap for the gradual adoption of this technology, taking into account the readiness of the local technology ecosystem and institutions (Battistella et al., 2025). Incentive policies can be a key driver in reducing initial resistance, particularly from small businesses that have previously experienced limited access to advanced technology. Finally, for this strategy to be sustainable and have a cross-regional impact, it is necessary to establish a cross-sectoral institution involving the Ministry of Maritime Affairs and Fisheries, Bappenas, the Ministry of Communication and Informatics, and fishermen's cooperatives. This institution can act as a liaison between regulation, technology adoption, and education for coastal communities (Haque et al., 2024; Suhardono et al., 2025).

This way, the model resulting from this research will not remain merely conceptual but will truly drive systemic transformation within the national fisheries industry. Successful implementation across regions is also an important indicator in promoting equitable marine economic development nationally (González-Espinosa et al., 2025; L. Zhang et al., 2024).

Conclusion

The Goal Programming (GP) model used in this study has proven highly effective in prioritizing strategies that integrate economic, social, and logistical dimensions. By accommodating objectives such as cost efficiency, increased participation, and speed of distribution within a single quantitative system, GP provides a powerful policy instrument for formulating multi-objective strategies. This is a crucial contribution within the framework of SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production), where equitable, efficient, and sustainable seafood systems are a global priority. Such prioritization is difficult to achieve without an evidence-based approach and systematic mathematical modeling. Furthermore, broad implementation of the strategy requires a strong commitment from the government through the allocation of incentive funds, such as initial digital infrastructure subsidies, community training, and fiscal incentives for industries adopting blockchain traceability. Central and regional governments need to coordinate in developing a roadmap for the gradual adoption of this technology, taking into account the readiness of the technology ecosystem and local institutions. Incentive policies can be a key driver in reducing initial resistance, particularly from small businesses that have limited access to advanced technology.

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Author Contributions

Conceptualization; methodology; validation; formal analysis; A. W. P.; investigation; resources; data curation; I. J. K. W.; writing—original draft preparation; writing—review and editing; I. W. S.; visualization: I. M. F. All authors have read and approved the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest

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