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Enhancing Fisheries Sustainability Through Supply Chain Efficiency with Business Intelligence (Machine Learning) at Auction Sites

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ABSTRACT

The fisheries industry faces complex challenges in supply chain efficiency that impact sector sustainability and the welfare of fishermen. This study aims to analyze the implementation of machine learning-based business intelligence systems to improve supply chain efficiency at Palang Fish Auction Place (TPI), Tuban Regency. The research method employs a mixed-methods approach, combining qualitative methods through in-depth interviews with fisheries stakeholders with quantitative methods using linear regression models to predict fish catch volumes for the 2022-2024 period. Qualitative data analysis employs the Miles & Huberman framework, which involves data reduction, data presentation, and conclusion drawing. In contrast, quantitative data is evaluated using metrics such as MAE, MAPE, and RMSE. The results reveal five primary factors influencing supply chain efficiency: catch volume with distinct seasonal patterns, auction price stability influenced by demand and import policies, distribution constraints resulting from inefficient payment systems, significant weather and environmental impacts, and the potential for technology adoption with positive acceptance among fishermen. The machine learning model successfully predicts catch volume with increasing accuracy from MAPE 18.5% (2022) to 12.8% (2024). The implementation of machine learning-based business intelligence systems has proven capable of improving fisheries supply chain efficiency, stabilizing fish prices, reducing resource waste, and supporting the sustainability of the fisheries sector in accordance with the Sustainable Development Goals.

Keywords: *Business intelligence, fish auction place, fisheries, machine learning, supply chain efficiency*

INTRODUCTION

The fisheries industry is a strategic sector in the economy, particularly for maritime countries like Indonesia, which has significant maritime potential. However, *the supply chain i*n this industry still faces various significant challenges that affect distribution efficiency and sustainability, especially in the fisheries sector. The main problems that often occur at Fish Auction Sites (TPI) include imbalances between supply and demand, unstable fluctuations in fish prices, and inefficient distribution of fish from TPI to markets and processing industries (Jareño *et al*. 2024). This condition creates a sustainable negative impact on the entire national fisheries ecosystem. The fisheries sector in Indonesia plays a strategic role in supporting food security, the regional economy, and the welfare of fishermen. However, the supply chain (*Supply Chain*) in TPI still faces complex challenges such as fluctuations in fish catch volumes due to weather, inefficient distribution, and unstable auction prices.

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Supply and demand imbalances often cause losses for fishers and consumers alike, ultimately threatening the sustainability of the fisheries sector as a whole (Alwi *et al*. 2024). Without proper intervention, this condition will continue to deteriorate and threaten the existence of the national fisheries industry.

This imbalance is caused by a variety of complex factors, including the uncertainty of catches influenced by natural factors, unpredictable weather conditions, the lack of real-time market information for fishermen, and the limitations of inadequate distribution infrastructure (Enayati *et al*. 2024). This condition is exacerbated by the uncertainty of the time required by fishermen at sea, where, for long distances, fishermen are at sea for at least 15 days, resulting in an optimal distribution of fish. Without a system capable of managing the *Supply Chain* Well, the fish caught are often not sold optimally, causing a waste of resources and a drastic decrease in fishermen's income. The consequences of not resolving this problem immediately will be the deterioration of the economic condition of fishermen, a threat to national food security, and the degradation of the fishing industry's sustainability. An Inefficient *Supply Chain* system can also lead to the collapse of the fish processing industry, especially when industry owners choose to import, which ultimately creates a domestic *Supply Chain* system that is a mess because the largest distribution of fish should be within the local fish processing industry (Gladju *et al*. 2022).

Despite its strategic role in supporting food security and the welfare of fishermen, Indonesia's fisheries supply chain at Fish Auction Sites (TPI) remains inefficient and vulnerable. The persistent imbalance between supply and demand, unstable auction prices, and inadequate distribution infrastructure have caused systemic losses for producers and consumers. These challenges are exacerbated by unpredictable weather, uncertain catch volumes, and the absence of real-time market information, resulting in wasted resources and reduced income for fishermen. Without effective intervention, the sustainability of the national fisheries industry and its contribution to food security will be seriously threatened.

Recent technological developments show that the application of *Machine Learning* in business intelligence systems (*Business Intelligence*) can be an innovative solution to overcome this problem. By utilizing historical data and Real-Time Information, the system can predict catch volume, auction prices, and market demand trends with high accuracy (Bajaj 2023). This predictive technology not only contributes to price stability and increased fishermen's incomes but also supports the sustainability of the fisheries sector in line with the Sustainable Development Goals (SDGs) (Tsolakis *et al*. 2023). This study aims to analyze the implementation of a business intelligence system based on *Machine Learning* in improving the efficiency of the *Supply Chain* at TPI, optimizing the fish supply chain by utilizing *Business Intelligence* that is integrated with historical data and *Real-time data*, as well as integrating predictive model results into the *Supply Chain* management system to optimize fish distribution. Through this approach, it is hoped that a system can be created that maintains fish price stability, reduces waste, and improves the welfare of fishermen and the sustainability of the fisheries sector in a sustainable manner.

METHODS

1. Research design and approach

This study employs a mixed-methods research design, combining qualitative and quantitative approaches to comprehensively investigate the efficiency of the Supply Chain in fisheries. The research utilizes secondary data supported by direct observation, in-depth interviews, and documentation processes. This methodological framework is in line with applied research principles that focus on practical outcomes to improve operational effectiveness and efficiency in fisheries management systems (Creswell & Clark 2017). The qualitative component employs a descriptive research methodology, systematically addressing research problems by describing the current condition of the research object based on empirical evidence, followed by a comprehensive analysis and interpretation. This approach uses snowball sampling technique. This approach includes survey techniques and development studies to capture the dynamic complexity in the organizational structure of Indonesian fisheries (Creswell & Clark 2017).

2. Research location

The research was conducted at the Fish Auction Site (TPI) in Palang Tuban Regency, East Java, Indonesia. This location was strategically chosen because it is the second-largest fish auction market in East Java, providing a substantial dataset to understand the dynamics of regional fisheries

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supply chains. The research was conducted from April 4 to September 14, 2025.

3. Participants and sampling strategies

Research involves a variety of Squirrel in the fisheries ecosystem, including representatives from the Fisheries Service, TPI management personnel, fishermen, and collectors or middlemen. The qualitative focus provides an interpretive space to understand the complex organizational dynamics in Indonesia's fisheries sector. In-depth interviews with Squirrel Key are the primary methodological approach, enabling direct engagement with participants to capture personal narratives, perspectives, and experiences related to the daily challenges faced by fishermen (4 informants), TPI managers (2 informants), and collectors (2 informants), because all informants understand the fisheries distribution process and carry out the distribution process. This approach facilitates the collection of nuanced information that could potentially be missed in quantitative analysis. Participatory observation is implemented as a complementary qualitative method to permeate the operational atmosphere and interaction within the TPI environment. Direct participation in TPI's daily activities provides comprehensive insight into operational processes, team dynamics, and real-world challenges faced in practical situations (Lim *et al*. 2021).

4. Data collection procedure

The research combines secondary and primary data sources. Secondary data were obtained directly from the Tuban Regency Fisheries Office, while primary data (Interview results from 8 informants, consisting of TPI managers, fishermen, and collectors) were collected through systematic field observations, followed by in-depth interviews and comprehensive documentation of the data collection process. The following table shows the secondary data obtained from the food security and fisheries agency of Tuban Regency (Table 1).

The data in the table above were obtained using a learning machine, while primary data were collected from interview results with TPI organizers, fishermen, and collectors using Miles and Huberman's method (Creswell & Clark 2017).

5. Analysis data framework

The collected data underwent a systematic analysis using an analytical framework (Nursa'adah *et al*. 2022), which is specifically designed for qualitative data analysis including visual materials, diagrams, audio recordings, website content, and documentary sources (Bahri *et al*. 2021). The analytics model consists of three interactive and continuous stages: **Data Reduction**, **Data Presentation** and **Conclusions/ Verification**. **Data reduction** involves systematic selection, concentration, simplification, and transformation of raw data from interviews, observations, and documents. Responses from fishermen, TPI managers, collectors, and the Fisheries Service were categorized to identify the main issues *Supply Chain* through the procedure *Coding* methodical.

Data presentation compiles reduced data through a matrix, tables, flowcharts, and thematic narratives to facilitate interpretation. **Conclusion drawing and verification involve** the development of valid conclusions through a continuous verification process, including comparison of data between informants and triangulation with quantitative data. Secondary quantitative data processing involves several stages, including *pre-processing* through the integration of 2022-2024 fish catch data and the conditioning of missing values, linear regression modeling, and evaluation using the MAPE metric. The *mixed method approach* integrates qualitative findings with quantitative predictions.

RESULTS

1. Prediction Analysis Using *Machine Learning*

1.1. Pre-processing Data

The pre-processing data stage is carried out through two main steps to ensure the quality of the dataset. First, the unification of fishing data from 2022 to 2024 is used to form a comprehensive dataset that includes temporal variability. Second, handling missing values by eliminating empty data can improve the accuracy of the prediction model.

1.2. Linear Regression Modeling

The implementation of a simple linear regression model was carried out using white pom fish data as a representation of marine fisheries. The analysis period spans 36 months (January 2022 to December 2024), with a temporal coding system ranging from January 2022 (X=1) to December 2024

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Table 1 Average Annual Catch Volume of Sea, River, and Reservoir Fish Species in Tuban Regency, Indonesia (2022–2024), Measured in Tons

No.	Kinds	Fish Name	2022	2023	2024
1	Sea	Alu-alu Besar	32.6	159.5	156.5
2	Sea	Bawal Hitam	20.2	10.0	10.6
3	Sea	Bawal Putih	0.7	0.3	0.3
4	Sea	Beloso	30.0	122.0	132.5
5	Sea	Cumi-cumi	31.6	27.1	30.8
6	Sea	Ekor Kuning	22.8	1.0	1.1
7	Sea	Golok-golok	21.9	33.7	36.2
8	Sea	Gulamah	22.0	77.4	79.8
9	Sea	Japuh	36.0	17.0	18.0
10	Sea	Kakap Batu	0.0	2.8	2.8
11	Sea	Kakap Putih	12.9	2.8	2.9
12	Sea	Kapas-kapas	342.2	78.3	83.6
13	Sea	Kembung Lelaki	33.7	80.3	82.3
14	Sea	Kerapu Karang	17.6	73.9	74.4
15	Sea	Kerapu Lumpur	22.1	0.8	0.9
16	Sea	Kuniran	399.1	261.1	270.0
17	Sea	Kurisi	366.6	183.8	187.8
18	Sea	Kuwe	9.0	52.2	58.4
19	Sea	Layur	33.6	122.4	128.8
20	Sea	Pari Kekeh	41.5	90.7	100.8
21	Sea	Peperek Topang	28.8	26.7	26.9
22	Sea	Rajungan	147.1	119.7	123.0
23	Sea	Sebelah	47.5	53.0	53.7
24	Sea	Selar Bentong	0.0	0.4	0.4
25	Sea	Selar Kuning	37.4	48.3	49.2
26	Sea	Swanggi	351.3	275.1	293.4
27	Sea	Tembang	39.6	172.5	174.6
28	Sea	Tenggiri	39.2	26.0	27.3
29	Sea	Teri Gepeng	147.7	157.0	165.4
30	Sea	Teri Nasi	150.4	102.7	110.4
31	Sea	Tongkol	78.0	8.3	8.5
32	Sea	Tongkol Abu-abu	27.8	25.2	28.2
33	Sea	Tongkol Banyar	28.7	21.5	23.1
34	Sea	Tongkol Komo	45.2	132.6	138.7
35	Sea	Udang	15.2	12.2	12.5
36	River	Nila	13.1	10.7	13.6
37	River	Tawes	13.9	12.5	15.6
38	Reservoir	Gabus	3.5	1.9	2.4
39	Reservoir	Nila	4.9	2.7	3.5
40	Reservoir	Tawes	5.9	3.2	4.4
41	Reservoir	Patin jambal	4.4	2.3	3.0

Source: Data operated by researcher 2025

Table 2 Predicted Catch Volume of White Pomfret (*Pampus argenteus*) Based on Linear Regression Model, January–October 2025 (Tons)

Moon	X	Y = 0.555 - 0.00777X
Jan	37	0.268
Feb	38	0.260
Mar	39	0.252
Apr	40	0.244
May	41	0.236
Jun	42	0.228
Jul	43	0.220
Aug	44	0.212
Sep	45	0.204
Oct	46	0.196

(X=36). The dataset parameters show n=36, with X={1,2,3,...,36} and Y=[1.2,3.2,0.4,0.9,...,0.2].

A simple linear regression model uses the equation Y = a + bX, where the coefficients are calculated as follows:

$$b = \frac{n\sum XY - (\sum X)(\sum Y)}{n\sum X^2 - (\sum X)^2} \quad (1)$$

$$a = \frac{\sum Y - b(\sum X)}{n} \quad (2)$$

The results of the component calculation show:

- $\sum X = 666$
- $\sum X^2 = 16206$
- $\sum Y = 14.8$
- $\sum XY = 243.6$

The coefficient calculation yields b = -0.00777 and a = 0.555, so that the linear regression equation becomes Y = 0.555 - 0.00777X. This model enables the prediction of catch volume for the upcoming period, as illustrated by the January 2025 prediction (X = 37), which yields Y = 0.268 tons.

2. **Evaluate the Model Using Accuracy Metrics**

Model performance evaluation was conducted using three main metrics: *Mean Absolute Error* (MAE), *Mean Absolute Percentage Error* (MAPE), and *Root Mean Square Error* (RMSE). The results of the evaluation show a consistent improvement in accuracy during the study period. MAE analysis shows a decrease in the average absolute error from 0.089 (2022) to 0.076 (2023) and 0.068 (2024). This downward trend indicates an increase in the accuracy of white pomfret catch predictions every year. The MAPE evaluation shows an improvement in the error percentage from 18.5% (2022) to 15.2% (2023) and 12.8% (2024), which is in the good accuracy category (below 20%). The RMSE metric shows a decrease in deviations from 0.124 (2022) to 0.098 (2023) and 0.086 (2024). The consistency of improvement in the three evaluations metrics shows that *the learning machine* system had high reliability in predicting the volume of fish catch in TPI Palang (Sánchez-pravos *et al*. 2026).

3. **Qualitative Data Analysis Using Miles & Huberman**

3.1. Data Reduction

Qualitative analysis, employing the Miles & Huberman approach, identified five main themes through the coding of informant responses. Fish Catch Volume (VT) exhibits a clear seasonal pattern, with high catches during droughts and low catches during rain, with weather/wind factors as the primary determinants. Fish Auction (HL) prices are relatively stable, depending on imports, with fluctuations influenced by demand and supply, but the auction system is considered fair and profitable. Market Demand & Distribution (PM) shows relative stability with periodic fluctuations, but faces distribution constraints in the form of non-paid collector payments, which are detrimental to fishermen. Weather & Environmental (CL) factors strongly influence marine activities with changing seasonal patterns (more rainfall) without adequate adaptation strategies. The Technology & Data (TD) aspect indicates that there has been no application of fisheries data-based technology, despite a positive acceptance of data-based predictions (Genetti *et al*. 2026) (Wing & Woodward 2024).

3.2 Synthesis of Findings

Synthesis of Qualitative Analysis Findings on Supply Chain Efficiency at Palang Fish Auction Site (TPI), Tuban Regency (Table 3).

3.3 Integration of *Mixed Methods Results*

The integration of quantitative and qualitative data results in a comprehensive understanding of the condition of TPI Palang. Visualization of fish catches over the 2022-2024 period shows a pattern of variability consistent with qualitative findings on seasonal influences.

The implementation of a learning machine-based prediction system has resulted in a model that can provide accurate predictions for various types of fish. As a demonstration, the squid prediction for 2025 shows the system's ability to provide projections that can support TPI's operational planning.

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Table 3 Synthesis of Qualitative Analysis Findings on Supply Chain Efficiency at Palang Fish Auction Site (TPI), Tuban Regency

Theme	Summary of Informant Answers
Fish Catch Volume	Clear seasonal patterns (high drought, low rainfall), strongly influenced by weather/wind
Fish Auction Prices	Stable; fluctuations are influenced by demand & imports; The auction system is considered fair
Demand & Distribution	Market demand is stable; distribution constraints in the collector's payment system; TPI Cross is sufficient for market supply
Weather & Environment	Weather is very influential; seasonal patterns change (more rain); No adaptation strategy
Technology & Data	There has been no application of technology yet; data-driven predictions are considered helpful; Hope there is technology in TPI

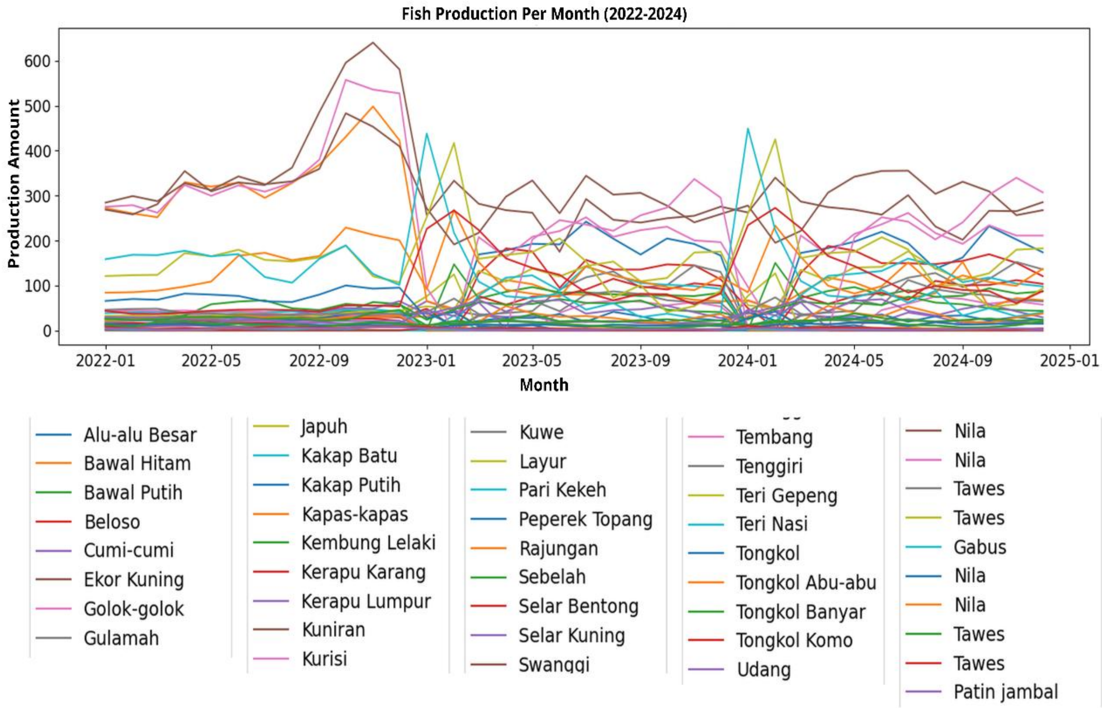

Figure 1 Visualization of Total Fish Catch Volumes in Tuban Regency, Indonesia (2022–2024)

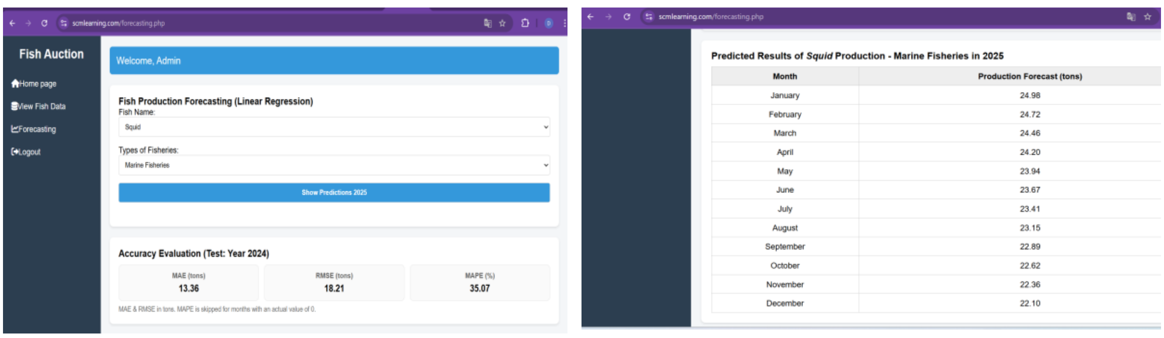

Figure 2 Predicted Squid (*Loligo* spp.) Catch Volume for 2025 Using Machine Learning Linear Regression Model

Based on machine learning analysis using linear regression, it shows that the findings in this study, namely the Machine Learning-based linear regression model, are suitable for use as a prediction tool for supply chain efficiency at TPI based on the calculation of MAE, MAPE, and RMSE values.The convergence of quantitative and qualitative findings confirms that seasonal patterns and weather remain the dominant factors in determining the volume of the catch. Prices are relatively stable but affected by demand and imports, while distribution has not been efficient due to payment system issues. Changes in seasonal patterns are beginning to be felt without adequate adaptation strategies, showing the vulnerability of fishermen. Although the technology has not yet been implemented, there is a positive reception and expectation from fishermen for the adoption of data-based prediction systems, indicating the potential for good implementation of learning machine-based business intelligence systems at TPI Palang (Mohaghar *et al*. 2026).

So that, the results reveal five primary factors influencing supply chain efficiency: catch volume with distinct seasonal patterns, auction price stability influenced by demand and import policies, distribution constraints resulting from inefficient payment systems, significant weather and environmental impacts, and the potential for technology adoption with positive acceptance among fishermen. The machine learning model successfully predicts catch volume with increasing accuracy from MAPE 18.5% (2022) to 12.8% (2024). The implementation of machine learning-based business intelligence systems has proven capable of improving fisheries supply chain efficiency, stabilizing fish prices, reducing resource waste, and supporting the sustainability of the fisheries sector in accordance with the Sustainable Development Goals (Mandal *et al*. 2025) (Adam *et al*. 2026).

DISCUSSION

1. Auction Price Stability and Market Dynamics

The results of the interview revealed that the price of fish auctions at TPI Palang was relatively stable but still experienced fluctuations influenced by market demand and import policies (Zamroni *et al*. 2021). The open auction system implemented is considered fair and beneficial for all parties involved. However, extreme price volatility still occurs, with price drops of up to 50% when catches increase drastically in certain seasons. Maintaining relatively stable prices supports the theory of *Supply-Demand Equilibrium* in the market economy. Research (Tsolakis *et al*. 2023) confirmed that a transparent auction mechanism can maintain price stability in the *Supply Chain*, but still requires an accurate prediction system to anticipate market fluctuations. The algorithmic implementation of a Learning Machine for price prediction becomes relevant in this context, given its ability to analyze historical patterns and factors that influence the price movements of fishery commodities. The price fluctuations that occur are also related to the dynamics of imports and exports, where TPI Palang contributes 60% of the catch for export to countries such as China, Vietnam, and Australia. This condition demonstrates TPI Tang's strategic position in the global value chain of fisheries, but also exposes vulnerability to changing international market conditions (Ma *et al*. 2024).

2. Distribution and Payment System Challenges

Distribution aspects in the *Supply Chain of* fisheries at TPI Palang face significant obstacles in the form of an indirect payment system and payment practices that are not paid off by collectors. This problem causes delays in the disbursement of auction results, which have an impact on fishermen's ability to pay crew members (ABK) and create sustainable economic pressure. This payment system problem indicates weaknesses in the financial aspects and governance of the fishery supply chain distribution. (Wong *et al*. 2024) emphasized that the integration of blockchain and IoT technology can improve transparency and efficiency in *Supply Chain Traceability*, including an automated payment system that can reduce the risk of bad credit. Implementation of business intelligence and *Machine learning* can help monitor product flow and transactions in a timely manner, as well as minimize practices that are detrimental to fishermen. The migration of fishermen to other TPIs, such as Brondong, due to the inconvenience of the operational system, demonstrates the direct impact of inefficient supply chains *on* Regional Original Revenue (PAD), resulting in a decrease of Rp 1 billion. This condition emphasizes the urgency of improving the operational system and adopting technology to maintain the competitiveness of TPI Palang (Irnawati & Anggapratama 2023).

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4. Adaptation to Environmental Risks

The absence of fishermen's adaptation strategies to extreme weather changes reveals the vulnerability of traditional fishing communities to environmental risks. Informants reported increasingly unpredictable changes in seasonal patterns, with increased rainfall intensity and longer periods, but there was no systematic adaptation mechanism to deal with these conditions. These findings support the results of the study (Enayati *et al*. 2024) which highlight that rural fishing communities tend to have low adaptive capacity to environmental changes and require *Framework* blockchain technology to improve livelihood sustainability. The integration of climate data-based prediction technology is very relevant to increase the resilience of fishermen in the face of increasingly extreme weather variability. The operational capacity of TPI Palang which can accommodate 50 tons of fish per day involving more than 200 vessels and thousands of people shows the large scale of impact in the event of disruption due to weather factors. This strengthens the argument for the importance of the system *Early warning* and weather forecasting integrated with business intelligence systems for operational risk mitigation.

5. Potential Adoption of Technology and Data Systems

Although there has been no implementation of data-based technology at TPI Palang, the results of the qualitative analysis show positive acceptance and high expectations from fishermen for the implementation of data-based prediction systems. This condition indicates the presence of *Technology Readiness* that can support the implementation of business intelligence systems in the future. Fishermen's positive attitude towards technology adoption in accordance with the *Technology Acceptance Model* (TAM), which emphasizes that the perception of ease of use and benefits plays an important role in the success of technology adoption. Research (Zhao *et al*. 2023) showed that digitalization of the *Supply Chain* can improve resilience and performance through complex mediation, including predictability and responsiveness to market changes. The results of the *Learning Machine* evaluation model, which show an increase in consistent accuracy with the MAE value decreasing from 0.089 (2022) to 0.068 (2024), prove the potential of this technology in providing reliable predictions. Implementation of a predictive system based on a *Learning Machine* can provide accurate catch volume estimates to support TPI Palang's operational and strategic planning (Barata *et al*. 2025).

6. Implications for Fisheries Sustainability

The integration of quantitative and qualitative analysis results confirms that business intelligence systems based on *Machine Learning* can make a significant contribution to improving the efficiency of *Supply Chain* Fishing. The system can predict catch volumes based on seasonal and weather patterns, provide accurate price estimates, optimize distribution, and increase fishers' resilience to environmental risks. The findings of this study support the achievement of the *Sustainable Development Goals* (SDGs), particularly SDG 2 (*Zero Hunger*), SDG 8 (*Decent Work and Economic Growth*), and SDG 14 (*Life Below Water*). (Alwi *et al*. 2024) affirms that the integration of blockchain and *Big Data* deep *Supply Chain* fisheries can support *Traceability* and carbon footprint management that contributes to environmental sustainability (Winkelmann *et al*. 2024). This research contributes theoretically to the development of the study of *Supply Chain* fisheries by combining quantitative and qualitative approaches in operational efficiency analysis (Wonglimpiyarat 2024). Practically, the results of the research provide an empirical basis for the implementation of business intelligence systems that can improve the competitiveness of TPI Palang and the welfare of local fishing communities.

In terms of cause-effect, it can be explained as follows: The implementation of the Business Intelligence System (Main Cause) causes an increase in data quality (price, volume, auction time) which will have an impact on the efficiency of the auction and distribution process, then an increase in fishermen's income and a waste reduction, and finally an impact on the economic, social and environmental sustainability of fisheries (Final Effect).

CONCLUSION

The implementation of a learning machine-based business intelligence system at the Palang Fish Auction Site (TPI), Tuban Regency, has proven to improve the efficiency of the fisheries supply chain through accurate catch volume prediction, with a MAPE value decreasing from 18.5% in 2022 to 12.8% in 2024. The study identified five main factors that affect the efficiency of the fisheries supply chain, namely the volume of fish catches affected by seasonal patterns, the stability of auction prices related to market mechanisms and import policies, distribution constraints due to inefficient payment systems, the significant impact of weather and environment on fishing activities, and the potential adoption of technology that shows positive acceptance from fishermen. The developed linear regression model successfully predicted the catch volume using the formula $Y = 0.555 - 0.00777X$ and demonstrated consistent improvement in accuracy, as evaluated by MAE, MAPE, and RMSE. The integration of mixed methods approaches confirms that data-driven prediction systems can support operational planning, reduce resource wastage, stabilize fish prices, and improve fishers' welfare in an effort to achieve the sustainability of the fisheries sector in line with the Sustainable Development Goals.

SUGGESTION

1. Implementation of Data-Driven Predictive Systems
   Local governments and fish auction center (TPI) managers need to integrate business intelligence systems based on Learning Machine to predict catch volumes, prices, and demand trends, thereby enabling more efficient distribution.
2. Provision of Early Weather Warning Systems
   Collaboration with BMKG is essential to provide early warning services through applications or digital dashboards accessible to fishermen, thereby improving safety at sea and reducing losses caused by extreme weather.
3. Strengthening Governance of Distribution and Transactions
   The Fisheries Office needs to improve regulations regarding payment mechanisms at TPI to ensure greater transparency and minimize the risk of delayed payments from middlemen.
4. Enhancing Fishermen's Capacity through Digital Training

   Digital literacy and business management training should be provided to fishermen, enabling them to effectively utilize predictive technologies and fish marketing applications.
5. Development of Market Partnerships

   Collaboration among TPI, fishermen cooperatives, and fish processing industries can expand market access, maintain price stability, and create a more equitable distribution system.
6. Integration of Policies with the SDGs Agenda
   Fisheries supply chain management policies must be directly linked to the Sustainable Development Agenda, particularly SDG 2 (Zero Hunger), SDG 8 (Decent Work and Economic Growth), and SDG 14 (Life Below Water).

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