Vol. 15 | No. 1: 73 - 84
Mei, 2026
Peer-Reviewed ☑

AMANISAL - Jurnal Teknologi dan Manejemen Perikanan Tangkap
(E-ISSN 2988-3172, P-ISSN 2085-5109)
URL: https://ojs3.unpatti.ac.id/index.php/amanisal/index
https://doi.org/10.30598/amanisal.v15i1.25339

Optimalisasi Pemanfaatan Pelabuhan Perikanan sebagai Strategi Pengelolaan Perikanan Kepulauan untuk Mendukung Keberlanjutan Industri Tuna, Cakalang, dan Tongkol (TCT) di Provinsi Nusa Tenggara Timur, Indonesia

(Navigating Archipelagic Fisheries Through An Optimization Strategy For Fisheries Port Utilization To Support The Sustainable Tuna, Skipjack, And Tongkol (Tct) Fisheries Industry In Ntt Province, Indonesia)

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☑ **Article Info :**
Recived : 07 April 2026
Accepted : 02 Mei 2026
Online : 28 Mei 2026

Article type

	Review Article
	Commin Serv. Articel
✓	*Research Article*

🕮 **Keyword :**
Archipelagic Logistics, Fishery Port Optimization, Mixed Methods, NTT Province, Port Infrastructure, Sustainable Fisheries, TCT Industry

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Abstract

Despite the considerable potential of the tuna, skipjack, and tongkol (TCT) fisheries in East Nusa Tenggara (NTT) Province, their economic contribution remains stagnant due to the underutilization of port facilities. This study evaluates the utilization of fishing port facilities at PPI Oeba and PPP Tenau in Kupang City, identifies operational constraints, and formulates strategic optimization plans for the long-term development of the TCT fisheries industry. A mixed-methods approach was employed, integrating quantitative surveys from 180 respondents comprising fishermen, logistics providers, processing entrepreneurs, and port managers with qualitative in-depth interviews with key stakeholders. Stakeholder perceptions were assessed using a five-point Likert scale and the instrument was subjected to validity and reliability testing prior to full deployment. Findings reveal that while primary facilities at PPI Oeba are relatively functional (mean score: 4.03), PPP Tenau faces critical challenges arising from infrastructure aging dating to 1977 and severely limited operational capacity relative to current TCT industry demand. Key obstacles identified include non-functional cold chain systems, weak institutional governance, inadequate waste management, and low stakeholder participation in policy-making. Strategic recommendations encompass infrastructure revitalization, institutional governance reform, digitalization through GIS-based monitoring, investment facilitation, and implementation of the Eco-Fishing Port concept. This study underscores the imperative of transforming fishing ports from passive landing sites into integrated maritime–industrial hubs to enhance the regional value chain and ensure long-term sustainability of archipelagic fisheries.

INTRODUCTION

The fisheries sector constitutes a vital pillar of Indonesia's blue economy, with tuna, skipjack, and tongkol (TCT) commodities representing among the highest-value export categories in the national fisheries portfolio. At the global level, efforts to optimize fisheries productivity are aligned with Sustainable Development Goal (SDG) 14, particularly Target 14.4, which calls for the regulation of harvesting and the restoration of fish stocks to biologically sustainable levels (United Nations, 2015). In Indonesia, the Ministry of Maritime Affairs and Fisheries (Kementerian Kelautan dan Perikanan, KKP) has reinforced this commitment through the Penangkapan Ikan Terukur (regulated fishing) policy, facilitation of export access to key markets including Japan, development of international certification through the Marine Stewardship Council (MSC), and inclusion of TCT among the 14 priority capture fisheries commodities in the KKP Grand Design for Marine and Fisheries Development (Kementerian Kelautan dan Perikanan, 2021).

East Nusa Tenggara (NTT) Province is strategically positioned as a major contributor to national TCT production, with a marine area exceeding 151,000 km² that encompasses the productive waters of Fisheries Management Areas (WPP) 714 and 715. TCT production recorded a significant increase from 33,291 tonnes in 2019 to 334,536 tonnes in 2020 and reached a peak of 404,797 tonnes in 2021, before recovering to 397,135 tonnes in 2023 following a decline in 2022 (Kementerian Kelautan dan Perikanan, 2025). Despite this productive potential, the contribution of the fisheries sub-sector to NTT's Gross Regional Domestic Product (GRDP) at current prices (ADHB) has followed a stagnant and declining trajectory: from 5.73% in 2020, peaking at 6.19% in 2022, and declining to a projected 5.84% in 2024 (Kementerian Kelautan dan Perikanan, 2025). This divergence between high production volume and limited economic contribution reflects a structural underutilization of production output — a central concern of this study.

Fishing ports serve as critical nodes in the fisheries value chain, functioning as centers for fish landing, auctioning, processing, cold storage, and export logistics (Lubis, 2012). The National Fisheries Port Master Plan (RIPPN), regulated under Ministerial Decree No. 132 of 2023, designates NTT Province as a priority development area with 26 planned fishing port locations across three categories: 2 Coastal Fishing Ports (PPP), 18 Fish Landing Ports (PPI), and 6 Fishing Ports (PP), to be developed between 2024 and 2028. This is reinforced by the NTT Province 2025–2045 Long-Term Development Plan (RPJP), which identifies marine and fisheries sectors — including TCT commodities — as strategic priorities for primary sector development. The integration between RIPPN and the NTT Grand Design is therefore of paramount importance: RIPPN furnishes the infrastructure framework and port classification, while the Grand Design promotes these ports as pivotal nodes for TCT downstreaming and industrialization.

However, empirical evidence reveals a significant gap between policy intent and operational reality. Research by Mau et al. (2024) highlighted the strategic importance of PPI Oeba Kupang in the processing and marketing of tuna products in NTT, while also underscoring the need for improved handling infrastructure. Iksan et al. (2021) demonstrated that deficiencies in cold chain facilities — including ice factories and cold storage — constitute major barriers to fish quality maintenance and value addition at fishing ports in eastern Indonesia. Sitanggang et al. (2025) found that port facility utilization at PPP Tenau Kupang remained suboptimal, with damaged and incomplete facilities constraining operational performance despite relatively good fish landing and marketing activity. More broadly, Agustian et al. (2023) have shown that an ecosystem approach to fishing port management is essential for achieving sustainable fisheries governance, a perspective reinforced by Widiastuti et al. (2024), whose INFINITY framework demonstrates that the integration of port information systems with green port principles measurably improves governance outcomes. At the national level, the Ministry of Maritime Affairs and Fisheries (KKP, 2020) identified strengthening fishing ports as a strategic priority for downstreaming and the development of capture fisheries industry centers.

Building on these findings, this study seeks to bridge the gap between normative-strategic policies and empirical field realities through evidence-based analysis. The research focuses on PPI Oeba and PPP Tenau — the two primary active fishing ports in Kupang City — with the aim of assessing current port facility utilization, diagnosing operational constraints, and

formulating actionable optimization strategies for the sustainable TCT fisheries industry in NTT Province.

RESEARCH OBJECTIVES

This study pursues three primary objectives:

- To analyze the current utilization of fishing port facilities at PPI Oeba and PPP Tenau in supporting the TCT fisheries industry.
- To identify and describe the key obstacles and constraints in the utilization of fishing port facilities at both port locations.
- To formulate evidence-based optimization strategies for sustainable fishing port utilization in support of the TCT industry in NTT Province.

RESEARCH METHODS

Research Location and Period

This research was conducted at two fisheries ports in Kupang City, NTT Province: PPI Oeba and PPP Tenau. These locations were selected through purposive sampling based on their strategic relevance to TCT fisheries operations and their contrasting profiles. PPI Oeba is an active, moderate-capacity port serving as the primary fish landing site within Kupang City, with strategic access to local and regional markets; while supporting facilities are not yet fully optimized, the port maintains relatively consistent operational activity. PPP Tenau is the largest active fisheries port in NTT Province in terms of production volume, possessing comparatively more comprehensive infrastructure; however, it faces significant constraints in export integration and cold chain logistics, and is also designated for elevation to Pelabuhan Perikanan Nusantara (PPN) status under the National Fisheries Port Master Plan (RIPPN). Data collection was conducted over a six-month period from May to November 2025.

Research Design

This study employs a mixed-methods research design (Creswell & Plano Clark, 2018), integrating quantitative and qualitative approaches to generate a comprehensive understanding of fishing port utilization and optimization strategies. The quantitative component measures stakeholder perceptions and satisfaction levels regarding port infrastructure and services through a structured Likert scale questionnaire. The qualitative component involves in-depth interviews and participatory observation with key informants — including officials from the Provincial Marine and Fisheries Service (DKP), port managers, TCT industry operators, and fisheries extension workers — to explore operational realities, institutional dynamics, and policy barriers. Integration of both approaches occurs at the analytical and strategy formulation stages, where quantitative findings are contextually interpreted through qualitative narratives.

Population and Sampling

The target population comprises all parties directly involved in fishing port operations and the TCT fisheries industry chain at PPI Oeba and PPP Tenau, including TCT fishermen, port managers and staff, fish processing entrepreneurs, logistics and port support service providers, and technical officials from the NTT Provincial Marine and Fisheries Service. Non-probability sampling techniques were applied: purposive sampling to select respondents with direct involvement in port activities and the TCT value chain, and snowball sampling to reach additional respondents in cases where direct access was limited. The minimum target was set at 30 respondents per port location, with the total reaching 180 respondents across six ports in the broader Bapperida NTT research project from which this article draws its primary data.

To ensure the representativeness of perceptions captured from the 30 respondents per port, the Likert-scale questionnaire was subjected to validity and reliability testing prior to full deployment. Construct validity was examined through Pearson product-moment correlation between each item score and the total score for each indicator block, with items retained when r-count exceeded the r-table value at $\alpha = 0.05$. Reliability was assessed using Cronbach's Alpha for each indicator block, with a threshold of $\alpha \geq 0.60$ considered acceptable for exploratory descriptive-evaluative research. A preliminary trial was conducted with a select

group of fishermen and port operators at PPI Oeba prior to the main survey. The mixed-methods design compensates for quantitative sample limitations through in-depth interviews and participatory observation (Sugiyono, 2019).

Data Collection

Primary data were collected through three instruments: (1) structured questionnaires using a five-point Likert scale administered to respondents across both port locations; (2) semi-structured in-depth interviews with key informants, including DKP officials, port managers, and fisheries industry operators; and (3) direct field observation of port facility conditions, operational activities, and environmental management practices (Siregar, 2013). Secondary data were sourced from the Ministry of Maritime Affairs and Fisheries (KKP), the Central Statistics Agency (BPS), the NTT Provincial Marine and Fisheries Service, and port management units, encompassing port facility profiles and fisheries statistics. A systematic literature review was also conducted in accordance with the criteria of relevance, currency, and originality proposed by Sugiyono (2019) and supplemented by non-interactive documentation methods as described by Sutopo (1988).

Data Analysis

Quantitative data were analyzed using descriptive statistics to produce frequency distributions, mean scores, and category-based interpretations of stakeholder perceptions. The Likert scale interpretation scheme applied is as follows:

Table 1. Likert Scale Interpretation Scheme

Interpretation	Score	Descriptive Meaning
STS – Very Low	1	Respondents express strong dissatisfaction. Conditions or facilities are considered wholly inadequate or non-functional.
TS – Low	2	Respondents express mild disagreement. Weaknesses are present but the overall situation is not entirely negative.
N – Neutral/Moderate	3	Respondents are uncertain or indifferent, often due to insufficient information or limited direct experience.
S – Agree	4	Respondents report satisfactory conditions with room for improvement. Overall satisfaction is evident.
SS – Strongly Agree	5	Respondents express full satisfaction. Conditions are excellent with no notable complaints.

Source: Adapted from Sugiyono (2019)

Qualitative data from interviews and observations were analyzed thematically to identify recurring patterns, operational challenges, and governance gaps. Both data types were subsequently integrated at the interpretation stage to produce a holistic analysis and formulate context-specific optimization strategies.

RESULTS AND DISCUSSION

Existing Infrastructure Conditions at PPI Oeba and PPP Tenau

Primary Facilities

An assessment of primary facilities was conducted in accordance with Ministerial Regulation on Marine Affairs and Fisheries No. PER.08/MEN/2012, which classifies fishing port facilities into three categories: primary (pokok), functional (fungsional), and supporting (penunjang). At PPI Oeba, the primary facilities are in generally good operational condition. The majority of structures were constructed between 2000 and 2003 and are now over 20 years old, necessitating systematic preventive maintenance. Field observations revealed that while the port maintains routine landing activity, several drainage channels are blocked by accumulated waste and certain technology infrastructure units are non-functional.

Table 2. Primary Facilities at PPI Oeba

Primary Facilities	Year	Condition
Breakwater (1)	2001	Good Condition
Breakwater (2)	2000	Good Condition
Revetment	2001	Good Condition
Wharf/Dock	2000	Good Condition
Groin	N/A	Good Condition
Mooring Poles	2022	Good Condition
Navigation Channel	2000	Good Condition
Access Road	2000	Good Condition
Open Drainage	2000	Good Condition – requires maintenance
Perimeter Fence	2003	Good Condition

Source: Bapperida Provinsi NTT (2025); KKP Portal Data (https://portaldata.kkp.go.id), processed 2025

At PPP Tenau, the primary facilities present a considerably more critical picture. A direct comparison between the original 1977–1999 design capacity and current operational requirements illustrates the magnitude of the revitalization gap. The Tenau dock was originally designed to accommodate vessels of up to 30 GT with a daily fish-handling throughput of approximately 3–5 tonnes and an ice supply of about 5 tonnes/day; however, the current demand from the TCT industry necessitates capacity for vessels of 50–100 GT (consistent with the planned upgrade to PPN status under RIPPN), a daily throughput of 15–25 tonnes during peak season, an ice supply of at least 20–30 tonnes/day, and cold-storage capacity of no less than 100 tonnes to support export-grade tuna handling. In practical terms, the dock length and draft must be extended by approximately 40–60 meters and 1–2 meters respectively, ice production capacity must be expanded four- to sixfold, and cold-storage volume must increase fivefold. Key concerns also include insufficient basin area to accommodate larger-tonnage vessels and the need for navigation channel re-survey.

Table 3. *Primary Facilities at PPP Tenau*

Primary Facilities	Year	Condition
Breakwater (1)	2016	Minor Rehabilitation Needed
Breakwater (2)	2016	Minor Rehabilitation Needed
Breakwater (3)	2016	Minor Rehabilitation Needed
Wharf/Dock (main)	2010	Severely Damaged
Wharf/Dock (old)	1999	Requires Major Repair
Wharf/Dock (original)	1977	Requires Revitalization
Groin	2014	Functional
Basin/Harbor Pool	1999	Silted – requires dredging
Navigation Channel (1)	2016	Functional
Navigation Channel (2)	1977	Requires Re-survey

Source: Bapperida Provinsi NTT (2025); KKP Portal Data (https://portaldata.kkp.go.id), processed 2025

Functional Facilities

A comparative analysis of functional facilities at both ports reveals contrasting operational profiles. PPI Oeba possesses a more diversified and operational-oriented set of functional facilities, directly supporting core port functions including fish auction, cold chain management, fuel supply, and fish processing. PPP Tenau's functional facilities are comparatively fewer but are oriented toward ancillary port support functions within the Kupang fisheries system.

Table 4. Comparative Functional Facilities at PPI Oeba and PPP Tenau

Port Location	Facility	Construction Year
PPP Tenau	Fish Auction Site (TPI)	1996 / 2016 (Rehabilitation)
	Fish Market	2001
	Navigational Beacon	1996
	Telephone Line	1982
	SSB Radio Communication	1978
	Internet Connectivity	2014
	Port Services Building	1997
PPI Oeba	Fish Auction Site (TPI)	N/A
	Fish Market	2001
	Fish Processing Facility	2010
	Internal Road Network	2000
	Water Supply (PDAM)	2015
	Water Supply (Alternative)	2015 / 2006
	PLN Electrical Connection	2012
	Fuel Storage Tank	2000
	Ice Storage	2008
	Ice Crusher Unit	2012
	Ice Factory (1)	2011
	Ice Factory (2)	2004
	Port Administrative Office	2000
	Waste Collection Facility	N/A

Source: Bapperida Provinsi NTT (2025); KKP Portal Data (https://portaldata.kkp.go.id), processed 2025

Supporting Facilities

A comparative review of supporting facilities at both ports reveals that PPI Oeba has security posts and information technology infrastructure — albeit largely underutilized — while PPP Tenau maintains a more diverse range of utility and administrative support facilities, though many date back to the 1970s and require significant modernization.

Table 5. Comparative Supporting Facilities at PPI Oeba and PPP Tenau

Port	Facility	Year/Units	Condition
PPI Oeba	Security Post	2 units	Functional
	IT/Information Center (computers)	8 units / 2006	Functional, underutilized
	IT/Information Center (workstations)	20 units / 2000	Functional, underutilized
PPP Tenau	Internal Road (1)	2016	Functional
	Internal Road (2)	1977	Functional
	PDAM Water Connection	1995	Aging – functional
	Borehole Well (1)	2011	Functional
	Borehole Well (2)	2005	Functional
	Shallow Well	2011	Functional
	Water Treatment Unit	2014	Functional
	Electrical Power Supply	1983	Aging – requires upgrading
	Generator House	1977	Functional
	Ice Factory	1977	Non-functional / abandoned
	Port Administrative Office	1978	Functional
	Fisheries Authority Office	1995	Functional
	Harbor Master Office	1978	Functional
	Waste Management Facility	N/A	Functional but inadequate

Source: Bapperida Provinsi NTT (2025); KKP Portal Data (https://portaldata.kkp.go.id), processed 2025

Stakeholder Perception Analysis

Fishermen's Perceptions

The average perception score among fishermen at PPI Oeba was 4.03, placing it in the 'Agree' (satisfactory) category. Respondents at both ports expressed high satisfaction with fish auction site accessibility, ice and cold storage availability, and the economic profitability of fish products. However, the lowest-scoring indicator at both ports was stakeholder participation in port policy-making (Oeba: 2.64; Tenau: 2.55 — both in the 'Low' category), indicating that governance processes are largely non-participatory. To translate this finding into operational practice, the optimization framework integrates a set of public-engagement instruments designed to give the fishing community a verifiable voice in port governance: (i) a quarterly Multi-Stakeholder Forum (Forum Pemangku Kepentingan Pelabuhan), chaired by the UPT and including representatives of fishermen's cooperatives (KUB), processing entrepreneurs, logistics providers, and the DKP; (ii) an annual port-development consultation modeled on the Musrenbang method, ensuring fishermen's priorities are integrated into the APBD planning cycle; (iii) a complaint-and-suggestion mechanism combining a physical drop-box at the landing site with a WhatsApp/SMS hotline managed by the UPT with a 14-working-day response commitment; and (iv) participatory monitoring of cold-chain and waste-handling indicators by selected community observers reporting monthly to the UPT. These instruments are expected to elevate the 'active in policy-making' perception score towards the 'Agree' range over the medium term.

Table 6. Fishermen's Perception Scores at PPI Oeba and PPP Tenau

No.	Indicator	Score (PPI Oeba)	Score (PPP Tenau)
1	Adequacy of basic port infrastructure	3.91	4.27
2	Accessibility and operation of fish auction site (TPI)	4.45	4.45
3	Availability of ice supply and cold storage	4.36	4.36
4	Accessibility and capacity of fuel supply	4.00	3.91
5	Quality of port administrative services	4.00	4.36
6	Availability of basic utilities (water, electricity)	4.09	4.00
7	Economic profitability of fisheries products	4.73	4.73
8	Participation in port policy-making processes	2.64	2.55
9	Facility contribution to improved livelihoods	4.27	4.36
10	Overall satisfaction with port services	3.83	3.82
	Average Score	4.03	4.08

Source: Primary data, processed 2025

Logistics Providers' Perceptions

Logistics providers at PPI Oeba reported notable difficulties with transportation accessibility (score: 3.20) and logistic demand stability (3.40), suggesting weak integration between port operations and broader supply chain networks. At PPP Tenau, the primary concern was the efficiency of infrastructure-to-distribution flow (3.00), indicating bottlenecks in the movement of goods within and beyond the port area. The overall average scores were 3.96 at Oeba and 4.17 at Tenau.

Table 7. Logistics Providers' Perception Scores at PPI Oeba and PPP Tenau

No.	Indicator	Score (PPI Oeba)	Score (PPP Tenau)
1	Adequacy of logistic support facilities	3.80	4.63
2	Accessibility of transportation to/from port	3.20	4.75
3	Stability and regularity of logistic demand	3.40	4.25
4	Coordination with port management	5.00	4.63
5	Availability of ice and fuel supply	3.80	4.13
6	Impact of electricity and water on operations	3.80	4.00
7	Efficiency of infrastructure-to-distribution flow	4.00	3.00

No.	Indicator	Score (PPI Oeba)	Score (PPP Tenau)
8	Clarity of logistic regulations and procedures	3.60	4.00
9	Entrepreneurship climate and business potential	4.60	3.88
10	Overall operational satisfaction	4.40	4.38
	Average Score	3.96	4.17

Source: Primary data, processed 2025

Entrepreneurs and Fish Marketers' Perceptions

Entrepreneurs and fish marketers reported the lowest perception scores overall. At PPI Oeba, critical gaps were observed in primary facility conditions (2.33), understanding of the port as a distribution hub (2.67), institutional support (2.67), and training availability (2.33), all indicating systemic underperformance in the enabling environment for small-scale enterprises. At PPP Tenau, the main concern was the negative impact of financial limitations (2.00), suggesting that while facilities and coordination are relatively better, economic access remains a significant barrier. This finding is consistent with broader evidence on financial exclusion in small-scale fisheries (Pomeroy et al., 2020) and the role of institutional governance in determining port effectiveness (Yulisti et al., 2022).

Table 8. Entrepreneurs and Fish Marketers' Perception Scores at PPI Oeba and PPP Tenau

No.	Indicator	Score (PPI Oeba)	Score (PPP Tenau)
1	Condition of primary facilities	2.33	3.75
2	Optimality of port services	3.33	4.50
3	Inter-sector coordination	3.00	5.00
4	Regularity of vessel activities and catch availability	4.33	4.25
5	Accessibility of support inputs (ice, fuel)	3.67	5.00
6	Impact of financial limitations on business	4.33	2.00
7	Port understood as a product distribution center	2.67	4.00
8	Support from relevant government agencies	2.67	3.25
9	Availability of training and technical assistance	2.33	3.25
10	Degree of public-facing port optimization	3.67	3.50
	Average Score	3.23	3.85

Source: Primary data, processed 2025

OBSTACLES AND CHALLENGES IN PORT MANAGEMENT

Based on field research and stakeholder interviews, five principal categories of obstacles were identified:

Infrastructure Deficiencies

Both ports face critical infrastructure gaps. At PPI Oeba, these include the absence of functional cold storage, malfunctioning ice machines, and inadequate basic utilities (clean water and sanitation). At PPP Tenau, a narrow and shallow wharf creates severe vessel queuing during peak landing periods, with the gap between original design capacity and current operational requirements documented in Section 3.1.1. A comparable yet more limited discrepancy is evident at PPI Oeba, where the 2008 ice storage and 2011 ice factory facilities function at less than 60% of present daily demand from active TCT fishermen. These figures provide a tangible baseline for the port-modernization action plan and should guide investment phasing under the 2024–2028 RIPPN implementation period (Iksan et al., 2021; Sitanggang et al., 2025).

Human Resources and Institutional Weaknesses

Both ports suffer from a shortage of technical manpower and insufficiently trained personnel, with organizational structures characterized by daily executive arrangements without clearly defined structural positions or accountability frameworks. To address this gap, this study proposes a three-pillar professional port management strategy: (i) organizational

restructuring, in which each port adopts a formal Port Technical Implementation Unit (UPT) structure with clearly defined echelon-IV positions for a Port Master (Syahbandar), Head of Operations and Catch Recording, Head of Facilities and Cold-Chain Maintenance, and Head of Statistics and Information Systems; (ii) targeted recruitment, in which the NTT Provincial Marine and Fisheries Service initiates competitive recruitment for at least one certified Port Master and two Catch Recorders per port, in collaboration with the KKP and Politeknik Kelautan dan Perikanan Kupang; and (iii) continuous capacity-building through a structured annual training program covering log-book verification, VMS data interpretation, e-PIPP and SIPEPI reporting, cold-chain quality assurance, and occupational health and safety, with refresher certification required biennially.

Budget Constraints and Operational Costs

Limited budgetary allocations for routine maintenance have led to a progressive decline in service quality. Additionally, high operational logistics costs — particularly for fuel and cold chain supplies — create economic barriers for small-scale operators. The national adjustment of subsidized fuel prices in September 2022 led to an estimated 25–30% increase in operational cost per fishing trip for small and medium vessels operating out of PPI Oeba and PPP Tenau, reducing trip frequency and fishing-ground coverage for many operators.

Production Volatility and Market Uncertainty

TCT production is highly dependent on seasonal and meteorological conditions, resulting in supply instability. The production decline from 2022 to 2024 was exacerbated by several structural factors beyond weather: the implementation of the Penangkapan Ikan Terukur policy under Government Regulation No. 11 of 2023 introduced quota-based fishing zones requiring transitional adjustments in licensing and vessel registration that temporarily reduced volumes formally recorded at NTT ports; and regional logistics constraints — including limited cold-chain reefer container availability on the Kupang–Surabaya and Kupang–Makassar shipping routes and the rationalization of inter-island cargo schedules — increased post-harvest losses and discouraged shipments of fresh tuna-grade products. These structural factors reinforce the need for the optimization strategies discussed in Section 5 (Suman et al., 2020; Proctor et al., 2019).

Waste Management and Environmental Sanitation

Inadequate waste management infrastructure, combined with low environmental awareness among port users, results in unsanitary conditions across port perimeter areas that threaten both ecosystem sustainability and compliance with international food safety and export standards. As an integral component of the port-optimization strategy, this study recommends a structured waste-management system for PPI Oeba and PPP Tenau comprising: segregated waste bins (organic fish waste, plastic, metal, and hazardous/B3 categories) at every dock, fish-handling area, ice-loading bay, and TPI auction floor; construction of a Temporary Waste Storage Facility (TPS) within the port perimeter, integrated with the municipal waste-collection schedule of Kupang City; establishment of a small-scale fish-waste processing unit (rendering, fish meal, or silage) operated through a cooperative scheme; a scheduled clean-up program involving daily routine sweeping, weekly joint clean-ups (Jumat Bersih), and quarterly community campaigns; and a monitoring and enforcement mechanism incorporating sanitation compliance into port service-level standards (SOPs) with monthly reporting to the UPT. This package is essential to support the overarching 'Eco-Fishing Port' concept (Yulisti et al., 2022).

Strategic Recommendations for Port Optimization

Based on empirical findings and stakeholder consultations, the following integrated optimization strategies are recommended for PPI Oeba and PPP Tenau, structured across short-, medium-, and long-term horizons:

Short-Term: Infrastructure Revitalization and Cold Chain Development

Priority rehabilitation of cold chain systems — including ice machines and cold storage units — is urgently required at both ports to reduce post-harvest losses and maintain product quality for market and export. Port basin dredging and wharf extension, particularly at PPP Tenau, are critical to accommodate larger-tonnage vessels and reduce operational congestion. Systematic provision of basic utilities — clean water, stable electricity, and fuel — must be guaranteed to sustain uninterrupted port operations (KKP, 2020; Lubis, 2012).

Short-Term: Institutional Strengthening and Human Resource Development

Port governance should be strengthened through formalization of UPT structures and professionalization of staffing at both ports, as detailed in Section 4.2. Targeted capacity-building programs for technical personnel — harbor masters, production officers, and logistical coordinators — are essential to improve data accuracy, vessel management, and catch recording (Sitanggang et al., 2025). Port zoning — reorganizing landing, marketing, and logistics layouts — will improve loading and unloading efficiency and port cleanliness.

Medium-Term: Investment Facilitation and Business Ecosystem Development

Public–private partnership (PPP) schemes should be actively promoted to attract private sector investment into underutilized port facilities, reducing reliance on state budget allocations (APBD/APBN). Port status improvement — encouraging class upgrades from PPI to PPP for strategic locations serving vessels over 30 GT — will expand operational reach. Integration of processing and value-addition industries within or adjacent to port areas would capture greater economic value from TCT landings, enabling export of processed rather than raw products and enhancing the income multiplier effect for regional communities (Bailey et al., 2016; Bennett et al., 2021).

Medium-Term: Digitalization and Technological Innovation

The implementation of an integrated port information management system — incorporating digital logistic inventories, real-time catch monitoring, and vessel tracking — would significantly enhance operational transparency and decision-making efficiency. The INFINITY framework developed by Widiastuti et al. (2024) provides a directly applicable model for integrating fisheries port information systems with green port governance principles. GIS-based mapping of production potential across WPP 714 and 715 fishing grounds would provide data-driven support for resource management and strategic port planning (Kementerian Kelautan dan Perikanan, 2021).

Long-Term: Environmental Sustainability and Certification

The Eco-Fishing Port concept — as assessed by Yulisti et al. (2022) — should be adopted as the operational framework for both ports, integrating standardized liquid and solid waste management systems, sanitation infrastructure, and environmental monitoring mechanisms as described in Section 4.5. This is a prerequisite for compliance with international export standards. Fishermen and industry operators should be supported in obtaining sustainability certifications — such as the Marine Stewardship Council (MSC) certification — to enhance the competitive positioning of NTT's TCT products in premium global markets (United Nations, 2015; Halim et al., 2019). Product downstreaming — encouraging the development of fish processing industries around port areas — will enable NTT to export processed products rather than fresh or frozen fish alone, significantly increasing regional economic value added (Suharyanto et al., 2025).

CONCLUSION

This study concludes that despite the substantial fisheries potential of East Nusa Tenggara (NTT) Province in the TCT sector within WPP 714 and 715, port facility utilization at PPI Oeba and PPP Tenau remains significantly suboptimal due to four interrelated systemic factors: critical infrastructure deterioration (particularly in cold chain systems and aging wharfs); institutional governance deficits (staffing shortages, unclear organizational structures, and non-participatory policy processes); non-integrated supply chains that export raw rather than

processed fish, limiting regional value capture; and inadequate environmental management that threatens ecosystem sustainability and export compliance.

The mixed-methods analysis reveals that stakeholders across all groups consistently identify infrastructure and institutional weaknesses as primary barriers to port optimization, while simultaneously expressing relatively high satisfaction with basic port accessibility and the economic value of TCT commodities — suggesting that productive potential is constrained by remediable structural factors rather than fundamental market limitations.

The key transformation required is the repositioning of fishing ports from passive landing sites to integrated maritime–industrial hubs capable of supporting the full TCT value chain from landing through processing, cold storage, certification, and export. Achievement of this goal necessitates coordinated, multi-stakeholder action encompassing infrastructure investment, institutional reform, private sector engagement, digital innovation, and environmental stewardship. The optimization framework proposed in this study — grounded in evidence from 180 respondents across multiple stakeholder groups and triangulated through qualitative field interviews — provides a replicable, evidence-based model applicable to other archipelagic provinces with analogous structural challenges in the capture fisheries sector.

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