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A Cost Calculation Framework for Fuel Transport Tariffs Using Multi-Vessel Waterway Operations in Remote and Underdeveloped Areas of Indonesia

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Abstract

Fuel distribution in remote and underdeveloped regions of Indonesia faces significant challenges due to complex geographical conditions, diverse transportation modes, and inconsistent tariff calculation mechanisms. These challenges may affect the efficiency, transparency, and sustainability of the national fuel supply system, particularly within the BBM Satu Harga program. This study aimed to develop a standardized cost calculation framework for fuel transportation tariffs using multi-vessel waterway operations to support more accurate, equitable, and risk-based tariff determination. The research employed a mixed-method approach combining qualitative and quantitative methods through regulatory analysis, field data collection, route identification, cost component assessment, and simulation modeling. Data were obtained from service providers, operational regions, and relevant institutional sources, followed by the development of a Microsoft Excel-based tariff calculation framework. The results showed that the proposed framework successfully integrated six major cost components, including vessel costs, own-use fuel consumption, packaging, human resources, administrative and certification costs, and overhead expenses. The framework also incorporated load factor mechanisms, route-based adjustment factors, and safety incentives to accommodate operational risks and geographical variations. Simulation results across several regions demonstrated that the proposed tariffs were generally consistent with existing contract tariffs, while differences were primarily attributed to incomplete cost structures, negotiation-based pricing, and variations in vessel specifications. This study concluded that the developed framework provided a comprehensive and transparent approach for standardizing fuel transport tariffs and improving distribution efficiency in remote areas of Indonesia.

INTRODUCTION

PT Pertamina Patra Niaga, as the entity responsible for the Subholding Commercial & Trading segment within Indonesia’s downstream energy sector, plays a strategic role in ensuring national energy supply security. This responsibility extends to the most remote and geographically challenging regions, including the so-called 3T areas (Tertinggal or

Underdeveloped, Terdepan or Frontier, and Terluar or Outermost), where fuel availability and affordability are critical to achieving national economic equity and social welfare. To fulfill this mandate, PT Pertamina Patra Niaga deploys various transportation modes, including tank trucks, vessels (tankers, SPOBs, barges, wooden vessels, and others), and aircraft, to ensure fuel distribution reaches all regions of the country. Indonesia's archipelagic geography makes island-based fuel logistics inherently vulnerable to weather uncertainty, vessel availability constraints, and fragmented distribution networks, a gap that recent systematic literature mapping identifies as still under-addressed for Southeast Asian contexts (Suswaini et al., 2026). Optimization approaches for multi-vessel oil distribution across Indonesia's regional clusters have shown that coordinated fleet allocation and routing can substantially reduce operational costs while maintaining service reliability (Sirait et al., 2025).

A key national policy supporting equitable fuel access is the BBM Satu Harga (One-Price Fuel) program, which ensures that fuel is sold at a uniform price nationwide, regardless of the remoteness of the distribution location (Prasongko & Pambudi, 2023; Purwanto et al., 2019). Empirical evidence on the program's short-term effects shows that transportation-cost reductions are strongest within a 15-kilometre radius of subsidized fuel outlets, while villages farther from distribution points experience little measurable benefit (Simatupang, 2024). This pattern is consistent with broader findings that Indonesia's commodity-based energy subsidy design tends to leave geographically and socially marginalized households with persistent access gaps, reinforcing the case for cost-based rather than negotiation-based distribution pricing in remote regions (Gobel et al., 2024). Fuel distribution to non-regular distributors in 3T areas is managed through service contractors engaged under fixed-term contracts. For waterway and air transportation modes, distribution is conducted using various approaches tailored to the geographical conditions of each region. However, variations in transportation methods, route characteristics, and regional risk levels have created significant disparities in tariff structures, resulting in non-standardized tariff calculation methodologies across contracts, a problem mirrored in the broader shipping literature, where freight rates are frequently shaped more by negotiation, contract terms, and market structure than by transparent cost decomposition (Ke et al., 2024).

These tariff disparities reduce the efficiency and effectiveness of fuel distribution and may threaten the sustainability of the BBM Satu Harga program. Therefore, standardizing transportation cost structures is essential to establish a more accurate, equitable, and transparent tariff system. To address this issue, PT Pertamina Patra Niaga initiated a comprehensive study in collaboration with a research institution to develop a standardized tariff framework for waterway fuel transportation. This study aimed to: (1) standardize the tariff calculation formula across regions; (2) develop calculation guidelines as a reference for multi-modal waterway transportation tariffs; and (3) introduce safety-related cost components and incentives to improve safety standards in vessel operations.

The scope of this study covered seven multi-modal distribution schemes (A through G) implemented across PT Pertamina Patra Niaga's operational network. Schemes A through E involved waterway distribution using vessels such as SPOBs, barges, ferries, and tank trucks, while Schemes F and G involved air transportation using ATR aircraft and packaged cargo. This paper focused specifically on waterway transportation modes. Land-based fuel distribution using tank trucks faces comparable route, maintenance, and crew-related cost drivers, underscoring the need for standardized costing approaches across transportation modes (Hanafiah et al., 2025). More broadly, inland freight transportation costs in Indonesia have been shown to be driven by geographic dispersion, trip length, congestion, and imbalanced freight movement, factors that similarly constrain waterway operations in remote regions (Anas et al., 2022; Zega et al., 2023). Table 1 presents a summary of the seven distribution schemes.

Table 1. Summary of Multi-Modal Fuel Distribution Schemes

Scheme	Name	Process Description	Mode
A	SPOB/Barge Transport	Fuel Terminal → Tank Truck → Pier → Small SPOB/Barge → Destination Port → Tank Truck → Distributor	Water
B	Ferry – Tank Truck on Deck	Fuel Terminal → Tank Truck → Port → Tank Truck boards Ferry → Destination Port → Distributor	Water
C	Ferry – Drum/IBC Packaging	Fuel Terminal → Tank Truck → Port → Fuel transferred to Drum/IBC → Ferry → Destination Port → Pickup Truck → Distributor	Water
D	Direct SPOB Backloading	Fuel Terminal → direct backloading to SPOB/Barge → Destination Port → Ground Tank of Distributor	Water
E	Ship-to-Ship Transfer (STS)	Fuel Terminal → SPOB/Barge → Destination waters → Ship-to-Ship transfer to floating storage at Distributor	Water
F	ATR Aircraft	Fuel Terminal → Tank Truck → Airport → ATR aircraft fuel tank → Destination Airport → IBC/Drum → Distributor	Air
G	Packaged Air Cargo	Fuel Terminal → Drum packaging → Airport → Aircraft → Destination Airport → Truck → Distributor	Air

The study scope was bounded by several constraints: it focused exclusively on water transportation modes, excluded evaluations of existing service provider performance, excluded fuel distribution costs from distributors to end consumers, and did not account for external force majeure factors. The study covered small vessel types commonly used for fuel distribution and considered only cost components directly related to the waterway distribution process.

METHOD

The development of the standardized tariff framework followed the Stufenbau legal hierarchy theory developed by Hans Kelsen, which provided a structured basis for establishing consistent and hierarchical references in tariff standardization. Table 2 presents the reference hierarchy adopted in this study.

Table 2. Reference Hierarchy for Tariff Standardization

Level	Reference Type	Description	Example
1 (Highest)	Government Regulations	National legal instruments with highest legal force; mandatory when available and relevant	Laws (UU), Government Regulations (PP), Presidential Decrees (Perpres)
2	Association / Industry Standards	Technical standards established by national or international associations, widely accepted by industry	SNI (Indonesian National Standards), ISO

Level	Reference Type	Description	Example
3	Academic Papers / Textbooks	Academically verified sources: textbooks, journals, research reports; used when no regulatory or industry standard is available	Peer-reviewed journals, scientific research
4	Pertamina Internal Standards (STK)	Internal operational and technical standards developed by the company; used when external references are unavailable	Pertamina STK Guidelines
5 (Lowest)	Primary Data Collection	Field data, questionnaires, interviews, observations, FGDs; used only when all other reference sources are unavailable	Survey, FGD, field observation

The research methodology was conducted through the following sequential steps: (1) identifying water transport distribution routes; (2) clustering routes based on safety aspects, route conditions, and geographical characteristics; (3) determining recommended vessel types for each route cluster; (4) identifying cost components, including direct costs (vessel purchase or rental, maintenance, crew wages, fuel consumption, port services, loading and unloading, packaging, insurance, and certification) and indirect or overhead costs; (5) identifying distributors receiving multi-modal deliveries across eight major regions (MOR I–VIII); (6) identifying transport service providers, including PT Elnusa Petrofin, PT Pertamina Patra Logistik, Pelita Air Service, and other related providers; and (7) analyzing existing tariff structures applied across the Pertamina Group.

Data were collected from service provider headquarters in Jakarta and supplemented by field surveys in selected regional areas. The financial calculation methodology used a nominal value approach rather than a net present value (NPV) approach to ensure that all costs incurred by transport service providers were covered through the proposed tariff. The framework generated standardized tariff formulas with unit tariffs expressed in IDR/liter, incorporating key variables such as vessel type, transport capacity, distance, and fuel price. The calculation outputs were implemented through a Microsoft Excel-based worksheet tool designed to support practical use by regional operators.

Each critical methodological decision, including the selection of the nominal value approach, establishment of reference prices from vendors, and determination of sampling results for investment and maintenance costs, was documented in formal minutes signed by PT Pertamina Patra Niaga and the research institution (LAPI ITB). This documentation ensured traceability and accountability throughout the research process.

RESULTS AND DISCUSSION

Existing Cost Structure

Review of existing tariff contracts across all PT Pertamina Patra Niaga regions revealed a standard cost structure comprising five main components. Table 3 presents this standard existing cost structure, while Table 4 shows the proposed cost structure with expanded components.

Table 3. Existing Cost Structure – Standard (All Regions)

Code	Cost Component	Sub-Components
A	Vessel Costs	Vessel rental; own-use fuel (sailing, loading/unloading, berthing); fresh water; lubricant; routine maintenance
B	Packaging Costs	Drum costs
C	Human Resource Costs	Captain salary; crew (ABK) salary; admin salary; crew consumption
D	Administrative Costs	Vessel maneuvering permit; fuel loading/unloading permit; vessel certificate endorsement
E	Other Costs	Security coordination costs

In several regions, two additional cost categories were identified: (i) indirect operational costs (overhead), and (ii) special transport costs. The existing cost structure lacks several important components such as cargo insurance, docking maintenance, overhead costs, PSA certification incentives, and comprehensive crew training costs. These gaps result in underestimation of true operational costs in many contracts.

Proposed Cost Structure

The proposed cost structure expands the existing framework to six main components, with each sub-component explicitly categorized as either a fixed cost or a variable cost. Fixed costs remain constant regardless of volume carried, while variable costs scale with trip duration, distance, or quantity. Table 4 presents the complete proposed cost structure.

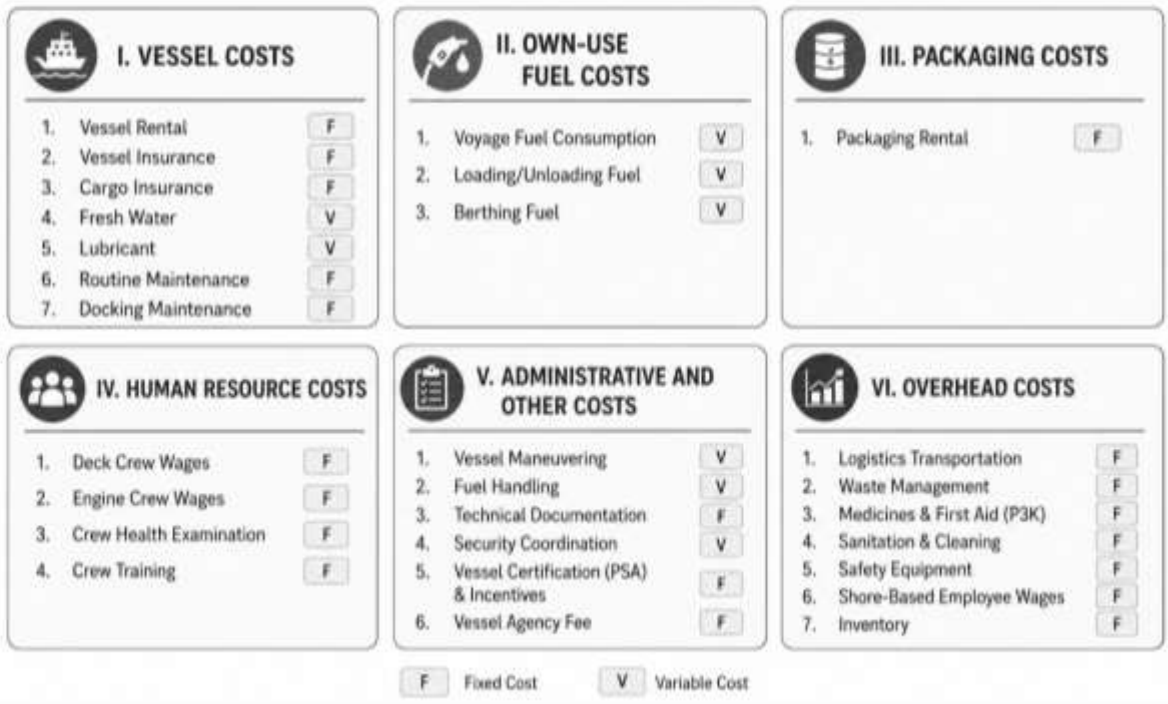

Table 4. Proposed Cost Structure for Water Mode Fuel Transport

No.	Sub	Cost Component	Category
1		**VESSEL COSTS**	
	1	Vessel Rental	Fixed cost
	2	Vessel Insurance	Fixed cost
	3	Cargo Insurance	Fixed cost
	4	Fresh Water	Variable cost
	5	Lubricant	Variable cost
	6	Routine Maintenance	Fixed cost
	7	Docking Maintenance	Fixed cost
2		**OWN-USE FUEL COSTS**	
	1	Voyage fuel consumption	Variable cost
	2	Loading/Unloading fuel	Variable cost
	3	Berthing fuel	Variable cost
3		**PACKAGING COSTS**	
	1	Packaging Rental	Fixed cost
4		**HUMAN RESOURCE COSTS**	
	1	Deck crew wages (incl. consumption & insurance)	Fixed cost
	2	Engine crew wages (incl. consumption & insurance)	Fixed cost
	3	Crew health examination	Fixed cost
	4	Crew training	Fixed cost
5		**ADMINISTRATIVE AND OTHER COSTS**	
	1	Vessel maneuvering costs	Variable cost
	2	Fuel handling costs	Variable cost
	3	Vessel technical documents	Fixed cost
	4	Security coordination	Variable cost
	5	Vessel certification (PSA) and incentive	Fixed cost
	6	Vessel agency fee	Fixed cost
6		**OVERHEAD COSTS**	
	1	Logistics transportation	Fixed cost
	2	Waste management	Fixed cost
	3	Medicines and first aid (P3K)	Fixed cost
	4	Sanitation and cleaning	Fixed cost
	5	Safety equipment	Fixed cost
	6	Non-vessel employee wages	Fixed cost
	7	Inventory	Fixed cost

Vessel Cost Calculations

Vessel costs represent the largest component of the total tariff. They are computed using a loan amortization approach (annuity scheme) reflecting real-world vessel acquisition practices. The vessel price depends on type and size, with standard reference prices established from shipyard data and external market sources. Table 5 presents the method used for standard price determination, while Table 6 shows estimated 2025 vessel prices by category.

Table 5. Vessel Price Standard Determination Method

Vessel Type	Reference	Calculation Method
Motor Tanker	External references: marineships, Made-in-China, Alibaba vessel listings, ships-for-sale	Comparison with SPOB price ratio; linear regression integration
SPOB	Ratson Shipyard data	Linear regression modelling based on shipyard information
Tugboat + Barge	External references; buy/sell transaction data regression	Linear regression modelling
Standard Design Vessel	Vessel design team data	Based on design specifications
LCT	Ratson Shipyard data	Linear regression modelling based on shipyard information
Wooden Vessel	Historical data	Based on historical transaction records

Vessel rental cost per month is calculated as: Rental Cost/Month = (Load Factor × Vessel Value) / (Useful Life in Years × 12). The vessel acquisition value under a credit scheme is determined using: Vessel Price = Down Payment + (Annual Installment × Tenor). A 30% down payment, 4-year tenor, 12% interest rate, 10% residual value (per PM No.10/2021), and 20-year useful life (per Ministerial Decree No.59/KMK.6/2013) are adopted as standard assumptions. Table 7 provides a worked example of the SPOB credit installment scheme.

Vehicle insurance is calculated at 1.75% of the credit vessel value per year (median of PM No.55/2019 range), while cargo insurance is set at 0.3% of total cargo value per month (per UU No.17/2008 and market references). Routine maintenance uses empirical coefficients shown in Table 8; docking maintenance uses age and GT factors shown in Table 9, an age- and condition-based approach broadly consistent with recent calls to shift maritime maintenance planning toward more systematic, data-informed scheduling to reduce unplanned repair costs (Simion et al., 2024). Own-use fuel consumption is derived from: Fuel Consumption (tons/day) = MCR × Engine Power × SFOC × Inefficiency Factor × Conversion Factor × Leakage Factor, where MCR = 0.7, SFOC = 185 g/HP/hr, and inefficiency factor = 1.0476. This empirical, engine-parameter-based approach reflects the physics-based category of fuel consumption estimation methods, which remains widely used in operational settings even as data-driven estimation techniques continue to be developed in the wider maritime literature (Marijan et al., 2025).

Table 6. Routine Maintenance Parameters

Parameter	Value
Coefficient k1	0.0035
k2 – Diesel Engine 2-stroke	105
k2 – Diesel Engine 4-stroke	125
k2 – Steam Turbine	75

Packaging and Human Resource Costs

Packaging costs apply to distribution routes where fuel is carried in drums or IBC containers. The cost per trip is calculated as: Packaging Cost/Trip = (Package Price/Unit ÷ Package Lifespan) × Units Required per Trip. Table 10 presents the packaging parameters used in the framework.

Human resource costs cover deck crew, engine crew, health examinations, and training. Crew numbers are determined by vessel GT and engine power per PM No.26/2022 and PM No.KM.65/2009. The daily crew cost formula is: Daily Crew Cost (IDR/day/person) = (Daily Wage + Daily Consumption) × (1 + Insurance Factor). Ensuring adequate crew compensation is not only a cost factor but also a determinant of decent working conditions at sea, as seafarers' perceptions of fair pay have been linked to broader indicators of occupational wellbeing such as safety, rest periods, and access to healthcare (Yildirim et al., 2022).

Table 7. Standard Crew Numbers and Daily Wage Rates

GT / kW	Cargo Capacity (kL)	Crew Positions (Sea Route / River Route)
GT > 10,000	> 24,029	Captain(1/1), 1st Officer(1/1), 2nd Officer(2/1), Skilled Deck Sailor(1/0), Helmsman(3/3), Seaman(1/0), Cook(1/0), Steward(1/0)
GT 7–34	17–82	Captain(1/1), 1st Officer(1/1), Helmsman(2/1)
kW ≥ 7,500	-	Chief Engineer(1/1), 2nd Engineer(1/1), Engineers(2/1), Electrical Officer(1/0), Oiler(3/3)
750 – 3,499 kW	-	Chief Engineer(1/1), 2nd Engineer(1/1), Engineer(1/1), Oiler(3/2)
kW ≤ 749	-	Chief Engineer(1/1), 2nd Engineer(1/1), Engineer(1/1), Oiler(1/1)

Administrative, Certification, and Overhead Costs

Vessel maneuvering costs (olah gerak) include port dues, berth fees, pilotage, towage, and navigation beacon fees, each calculated per PM No.22/2018 using GT-based PNBP rates multiplied by number of voyages and load factor. Security coordination costs are calculated based on the number of security personnel required (1 person per 25 kL of cargo, per Bank Indonesia escort standards), regional security index, and standard police escort rates (Norma Indeks Polri 2025). Overhead costs include logistics transport, waste management (IDR 250/kg waste, reference: Port Receiving Facility Tanjung Priok), medicines, safety equipment, non-vessel staff wages, and inventory.

A key innovation in the proposed framework is the Pertamina Safety Approval (PSA) incentive structure. Non-PSA-certified vessels represent a risk of operational losses to Pertamina. The incentive compensates certified vessel operators by estimating the cost savings they generate through reduced accident probability. This rationale is consistent with bibliometric evidence showing that certification, training, and management-related factors remain among the most extensively studied contributors to marine accident risk (Cao et al., 2023), and with statistical analyses indicating that vessels operating outside recognized safety regimes disproportionately account for accident-related fatalities and losses (Eliopoulou et al., 2023). Because human error continues to be implicated as a major upstream cause of maritime accidents, incentive structures that reward certified, better-managed operations are increasingly seen as a practical lever for improving safety outcomes (Dominguez-Péry et al., 2021). Table 8 presents the five PSA incentive components and their basis.

Table 8. PSA Incentive Components and Basis

No.	Incentive Component	Percentage	Basis
1	Material loss for fuel cargo	5% of cargo insurance cost	PM 11/2023; Lloyd's Register: certified vessels have lower accident risk
2	Regulatory violation fines	2.5% of maximum fine (IDR 100 million)	UU No. 17/2008 and UU No. 66/2024; conservative estimate for certified vs. non-certified
3	Vessel damage	20% of routine maintenance cost	Marine Engineering Economics: unserviced vessels may incur 14–25% higher maintenance costs
4	Insurance premium increase after accident	20% of vessel insurance cost	Tugu Insurance, Jasindo, Lloyd's: 10–30% premium difference between certified/non-certified
5	Company image recovery cost	1% of total image recovery cost	Oliver Wyman, IPR, COSO/PwC, HBR studies on reputation risk; includes PR, CSR, infrastructure recovery, and revenue loss

Multiplication Factors

To capture the operational variability and difficulty of different distribution routes—which are not fully reflected in direct cost components—the framework introduces a composite multiplication factor. Including a company image recovery component within the PSA incentive structure follows an emerging line of risk modeling that treats reputational loss as a quantifiable extension of operational loss, since reputational consequences of an incident can substantially exceed the direct financial loss if left unmodeled (Eckert & Gatzert, 2017). This factor is computed as a weighted sum of seven route/environmental parameters. Each parameter receives a weight reflecting its frequency, risk severity, and magnitude of cost impact. Table 9 summarizes the multiplication factor parameters, their weights, and value ranges.

Table 9. Multiplication Factor Parameters, Weights, and Value Ranges

Parameter	Weight	Classification Range	Factor Range
River Current Speed	12.5%	Following very fast (>1 m/s) to opposing very fast (>1 m/s)	0.80 – 1.20
Berth Facility Access	10.0%	Permanent concrete pier (1.0) to requires small boat/pontoon (1.3)	1.00 – 1.30

Parameter	Weight	Classification Range	Factor Range
Season & Water Level	15.0%	High tide (1.1), Normal (1.0), Low tide (1.2)	1.00 – 1.20
Number of Destinations	12.0%	1 destination (1.0) to >5 destinations (1.25)	1.00 – 1.25
Regional Security	15.0%	Class A – Fully Safe (index 0.18–0.28) to Class G – Unsafe (>0.85)	1.00 – 1.30
Wind Speed	12.5%	Calm air (<1 knot) to Strong breeze (22–27 knots)	0.95 – 1.25
Wave Height	10.0%	Glassy calm (0 m) to Phenomenal (>14 m); Douglas Scale	0.90 – 1.80
Vessel PSA Status	(see Table 14)	Certified vessel receives PSA incentive; non-certified does not	(incentive-based)

The composite multiplication factor is applied to the total tariff (excluding own-use fuel): Final Tariff = (Total Cost Excluding Own-Use Fuel × Multiplication Factor + Profit & Risk Margin) / Monthly Throughput + Own-Use Fuel Tariff. This design ensures own-use fuel is separately tracked for monitoring purposes, as it constitutes one of the largest cost elements.

Route Identification and Vessel Recommendation

For each distribution route, the framework identifies the optimal vessel type based on five route/berth parameters: berth length, draft at berth and channel, river width, current speed, and maximum wave height. The largest vessel that satisfies all five constraints is recommended, an approach consistent with heuristic route-assignment methods shown to reduce distribution distance and cost in Indonesian logistics settings by matching vehicle or vessel capacity to route characteristics (Siswanti & Fitrina, 2025). Table 10 presents the key specifications for each vessel type, and Table 11 defines the four route clusters.

Table 10. Vessel-Route Specifications by Vessel Type (Selected)

Vessel Type	Min. Berth Length (m)	Draft – Berth & Channel (m)	Min. River Width (m)	Max Current (m/s)	Max Wave Height (m)	Cluster
Barge 1	35.0	1.91	175.0	1.03	1.70	1
Barge 2	65.0	3.43	325.0	1.23	3.50	2
LAPI Design	32.71	1.73	130.85	2.00	1.32	1
LCT 1	22.5	1.28	112.5	1.54	1.75	1
LCT 4	90.68	4.33	453.42	1.84	5.10	2
SPOB 1	36.5	1.49	176.5	1.45	3.25	1
SPOB 3	50.0	2.98	250.0	1.67	5.50	3
Motor Tanker 1	100.0	5.10	500.0	2.47	9.00	3
Motor Tanker 5	266.45	13.59	1,332.25	3.15	24.23	4

Table 11. Route Cluster Definitions

Cluster	Description	Location	River Width	Current & Wave	Vessel Types
1: Small River	Narrow river, short pier, shallow draft	River	Narrow	Light wave	Barge 1, LAPI Design, LCT 1, LCT 2, SPOB 1
2: Medium-Large River/Industrial	Wide enough river, medium-large pier, medium-deep draft	River	Medium/Wide	Light wave	Barge 2, LCT 3, SPOB 2, LCT 4
3: Shallow-Medium Sea	Sea, medium-wide pier, shallow-medium draft	Sea	Wide	Light-medium wave	SPOB 3–5, Motor Tanker 1
4: Deep Sea/Large Terminal	Sea, wide pier, deep draft	Sea	Wide	High wave	Motor Tanker 2–5

Cluster 1 (Small River) applies to narrow rivers with short piers and shallow draft, served by Barge 1, LAPI Design vessel, LCT 1–2, and SPOB 1. Cluster 2 (Medium-Large River) covers wider rivers with medium draft. Cluster 3 (Shallow-Medium Sea) covers coastal and sea routes with light-to-medium waves, served by SPOB 3–5 and Motor Tanker 1. Cluster 4 (Deep Sea/Large Terminal) applies to deep-sea routes with heavy wave conditions, served by Motor Tankers 2–5. Route cluster assignment uses the following thresholds: river location if width ≤ 500 m, current ≤ 2 m/s, wave ≤ 5 m; berth classified as short (<50 m), medium (50–100 m), or wide (>100 m); draft as shallow (<3 m), medium (3–7 m), or deep (>7 m).

Worksheet Framework and Mechanism

The framework is implemented as a structured Microsoft Excel worksheet comprising several interconnected sheets: (i) Rekap Rute Moda Air (Route Summary), providing port characteristics and water conditions; (ii) Rekap Informasi Kapal (Vessel Information), containing vessel specifications and fixed cost data; (iii) Data Isian (Input Sheet), where users enter analysis year, region, distributor, route, packaging, cargo composition, vessel parameters, maneuvering data, fuel prices, and multiplication factors; (iv) individual cost calculation sheets for vessel, packaging, HR, administration, security coordination, and overhead; and (v) KK Moda Air and OE (Owner Estimate), showing the final tariff breakdown in IDR/Litre.

A load factor mechanism allocates fixed costs across multi-customer routes, conceptually similar to vehicle-routing-based optimization models that consolidate multiple delivery points to improve fleet utilization and reduce per-unit distribution cost (Hidayat & Mulyono, 2025). When a vessel serves multiple distributors (LPs) in one voyage, the fixed cost share for each LP is proportional to: %LP_i = Cumulative Travel Duration to LP_i / Sum of All Cumulative Durations × 100%. This ensures equitable cost allocation and prevents over- or under-recovery for any single route. A load factor of 100% indicates a single-customer (dedicated) route, while values below 100% reflect multi-customer operations. Key input components requiring user input include: analysis year, region and distributor number, route type and distances, packaging type and cargo composition, vessel type and specifications, maneuvering port class, fuel price, lubricant price, fresh water price, and multiplication factor parameters.

Tariff Simulation Results

Tariff simulations were conducted for seven regions using the proposed worksheet framework. Results were compared against existing contract tariffs. The primary sources of discrepancy between proposed and existing tariffs include: (a) existing tariffs often result from bilateral negotiation rather than cost-based calculation; (b) incomplete cost breakdowns in existing contracts; (c) differences in vessel engine specifications and GT assumptions; (d) differences in load factor methodology (volume-based vs. productivity-based); and (e) vessel multi-tasking (serving multiple principals). This pattern echoes findings on Indonesia's Sea Toll (Tol Laut) program, where logistics cost reductions have been most attributable to standardized, capacity-based freight arrangements rather than ad hoc negotiated rates (Febriansyah & Sahara, 2023). Tables 19 through 22 present simulation results for Kalimantan, Sulawesi, North Sumatera, and combined South Sumatera, Papua Maluku, and Jatimbalinus regions.

Overall, the Sulawesi region shows the highest agreement between proposed and existing tariffs, with six out of seven simulated routes within ±10% of existing rates. The Kalimantan region also shows reasonable agreement for most routes, with outliers attributable to negotiated contracts. The highest discrepancies appear in South Sumatra and Papua Maluku, primarily due to vessel specification differences and the application of multi-destination load factors. The North Sumatra simulation demonstrates that PSA incentive inclusion adds an identifiable and quantifiable cost component absent from most existing contracts. Jatimbalinus simulations reveal that vessel speed assumptions (6 vs. 10 knots) significantly affect tariff outcomes (±6.6%), confirming the sensitivity of the framework to operational parameters.

The proposed worksheet framework offers several advantages over existing tariff structures: (1) comprehensive automated calculation covering all 6 cost components; (2) vessel classification with recommendation logic; (3) credit-based vessel rental model reflecting real market practices; (4) dual packaging cost options (transferred vs. non-transferred containers); (5) regulatory-compliant crew standard determination; (6) PSA incentive module with detailed cost-component basis; (7) security coordination costs grounded in national police norms and provincial crime statistics; (8) overhead costs covering 7 sub-categories; and (9) route-based multiplication factors ensuring higher-difficulty routes receive appropriate compensation.

CONCLUSION

This study successfully developed a standardized cost calculation framework for fuel transportation tariffs using multi-vessel waterway operations in remote and underdeveloped areas of Indonesia. The proposed framework decomposed transportation tariffs into six clearly defined cost components—vessel costs, own-use fuel consumption, packaging, human resources, administrative and certification costs, and overhead expenses. Each component was supported by regulatory references and calculation formulas, categorized as either fixed or variable costs, and integrated into a flexible load factor mechanism to ensure equitable allocation of fixed costs across single-customer and multi-customer distribution routes. A composite adjustment factor incorporating seven weighted parameters—river current speed, berth facility accessibility, seasonal and water-level conditions, number of destinations, regional security index, wind speed, and wave height—was incorporated to adjust tariffs according to the operational complexity and risk level of each route. In addition, the Pertamina

Safety Approval (PSA) incentive module provided quantified financial incentives for vessel operators that maintained proper certification, thereby promoting higher safety standards throughout the distribution network.

Simulation results across seven major regions demonstrated that the proposed framework generated tariffs that were generally consistent with existing contract rates on well-documented routes. Differences observed in other routes were primarily attributed to negotiation-based pricing, incomplete cost breakdowns, variations in vessel specifications, and differences in load factor calculations. These variations did not undermine the validity of the proposed cost-based approach. To further strengthen the framework, four improvements were recommended: (1) enriching route parameters with field-based bathymetric and geographic data to improve vessel recommendation accuracy; (2) expanding safety incentive components to cover high-risk packaging and maritime routes; (3) assigning dedicated multi-modal transportation staff in each regional office to ensure consistent implementation and real-time data updates; and (4) conducting periodic evaluations to update cost assumptions in accordance with changes in energy prices, logistics costs, port service tariffs, and regional infrastructure conditions. These improvements would ensure that the framework remains accurate, transparent, and equitable for all stakeholders over time.

REFERENCES

Anas, R., Surbakti, M. S., & Hastuty, I. P. (2022). An overview of inland freight transportation in Indonesia based on vehicle operating cost. IOP Conference Series: Earth and Environmental Science, 1000, 012004. https://doi.org/10.1088/1755-1315/1000/1/012004

Cao, Y., Wang, X., Yang, Z., Wang, J., Wang, H., & Liu, Z. (2023). Research in marine accidents: A bibliometric analysis, systematic review and future directions. Ocean Engineering, 284, 115048. https://doi.org/10.1016/j.oceaneng.2023.115048

Dominguez-Péry, C., Vuddaraju, L. N. R., Corbett-Etchevers, I., & Tassabehji, R. (2021). Reducing maritime accidents in ships by tackling human error: A bibliometric review and research agenda. Journal of Shipping and Trade, 6, 20. https://doi.org/10.1186/s41072-021-00098-y

Eckert, C., & Gatzert, N. (2017). Modeling operational risk incorporating reputation risk: An integrated analysis for financial firms. Insurance: Mathematics and Economics, 72, 122–137. https://doi.org/10.1016/j.insmatheco.2016.11.005

Eliopoulou, E., Alissafaki, A., & Papanikolaou, A. (2023). Statistical analysis of accidents and review of safety level of passenger ships. Journal of Marine Science and Engineering, 11(2), 410. https://doi.org/10.3390/jmse11020410

Febriansyah, A., & Sahara, S. (2023). Analisis pengaruh program Tol Laut terhadap efisiensi logistik di Indonesia. EKONOMIKA45: Jurnal Ilmiah Manajemen, Ekonomi Bisnis, Kewirausahaan, 10(2), 515–522. https://doi.org/10.30640/ekonomika45.v10i2.1956

Gobel, R. K., Laksmono, B. S., Huseini, M., & Siscawati, M. (2024). Equity and efficiency: An examination of Indonesia's energy subsidy policy and pathways to inclusive reform. Sustainability, 16(1), 407. https://doi.org/10.3390/su16010407

Hanafiah, H., Intansari, W. R. O., & Luthfi, M. (2025). Analysis of fuel tank truck productivity in supply chain oil and gas (case study: State-owned enterprise of oil and gas

Indonesia). Journal of Economics, Finance and Management Studies, 8(1), 522–534. https://doi.org/10.47191/jefms/v8-i1-48

Hidayat, D. W., & Mulyono, N. B. (2025). Optimizing fuel distribution costs through vehicle routing problem modeling in Jakarta-Tanjung Gerem terminals. Jurnal Ilmiah Manajemen Kesatuan, 13(5), 3873–3884. https://doi.org/10.37641/jimkes.v13i5.3547

Ke, L., Liu, Q., Ng, A. K. Y., & Shi, W. (2024). Quantitative modelling of shipping freight rates: Developments in the past 20 years. Maritime Policy & Management, 51(3), 442–460. https://doi.org/10.1080/03088839.2022.2138595

Marijan, D., Mohammed, H. H., & Zaman, B. (2025). Estimation and optimization of ship fuel consumption in maritime: Review, challenges, and future directions. Journal of Marine Science and Technology. Advance online publication. https://doi.org/10.1007/s00773-025-01104-9

Prasongko, M. D., & Pambudi, M. A. L. (2023). Optimization of Berth Electrical Facilities and Vessel Auxiliary Engine Reliability for Cost Efficiency at Tanjung Emas Port. Jurnal Ilmiah Ilmu-Ilmu Maritim, 1–6.

Purwanto, B. R., Lazuardi, R., & Pranowo, W. S. (2019). Analysis of Wave Effects on Patrol Vessel Operations for Maritime Security in North Natuna Sea. Majalah Ilmiah Globe, 121–128.

Simatupang, T. P. (2024). Dampak jangka pendek program Bahan Bakar Minyak Satu Harga terhadap biaya transportasi di daerah tertinggal Indonesia. Jurnal Kebijakan Ekonomi, 18(2), Article 3. https://doi.org/10.21002/jke.2023.08

Simion, D., Postolache, F., Fleacă, B., & Fleacă, E. (2024). AI-driven predictive maintenance in modern maritime transport—Enhancing operational efficiency and reliability. Applied Sciences, 14(20), 9439. https://doi.org/10.3390/app14209439

Sirait, M., Charnsethikul, P., & Paoprasert, N. (2025). A multi-type ship allocation and routing model for multi-product oil distribution in Indonesia with inventory and cost minimization considerations: A mixed-integer linear programming approach. Logistics, 9(1), 35. https://doi.org/10.3390/logistics9010035

Siswanti, T., & Fitrina, R. (2025). Heuristic route optimization using saving matrix and nearest neighbor: Case study at PT Harapan Jaya Multi Bisnis, Makassar. Logistica: Journal of Logistic and Transportation, 3(1), 38–46. https://doi.org/10.61978/logistica.v3i1.691

Suswaini, E., Wibowo, M. A., & Jie, F. (2026). Systematic literature mapping: Integrated system of logistic distribution for island. Journal of Industrial Engineering and Management, 19(1), 215–227. https://doi.org/10.3926/jiem.9038

Yildirim, U., Toygar, A., & Çolakoğlu, C. (2022). Compensation effect of wages on decent work: A study on seafarers attitudes. Marine Policy, 143, 105155. https://doi.org/10.1016/j.marpol.2022.105155

Zega, A., Telaumbanua, B. V., Laoli, D., & Zebua, R. D. (2023). Physical Water Quality Parameters in Boyo River, Onowaembo Village, Gunungsitoli, North Nias. Jurnal Perikanan Tropis, 43–49.