

Optimization of Local Commodity Distribution Through Sea Toll Program: An Evaluative Study of the Port-To-Port System of Tenau Kupang Port as a Regional Hub in East Nusa Tenggara

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Keywords	Abstract
Sea Toll, logistics distribution, Port of Tenau Kupang, load factor, total logistic cost	This research aims to analyze the effectiveness of the Sea Toll system in supporting local commodity distribution and to assess the role of Tenau Kupang Port as a regional hub in East Nusa Tenggara Province (NTT). It employs a mixed-methods approach with quantitative-descriptive and explanatory designs, drawing on secondary data from KSOP Kupang and BPS NTT for 2023–2024. The analysis incorporates descriptive statistics, multiple linear regression, load factor analysis, total logistic cost (TLC), and quantitative SWOT. The results show that the Sea Toll system in NTT has achieved physical accessibility through regular inter-island connectivity but has not achieved functional accessibility due to low return loads, with the average load factor reaching only 24%. Regression analysis indicates that shipping frequency and return cargo volume have a significant effect on distribution effectiveness, while logistics costs and travel time exert a moderate positive influence. The Sea Toll Program reduces average logistics costs by 31% compared to conventional modes. The SWOT analysis yields an internal factor value of 2.09 and an external factor value of 2.56, placing Tenau Kupang Port in the growth strategy quadrant. This study concludes that the Sea Toll system is physically effective but not economically efficient. Strengthening the function of Tenau Kupang Port as a regional hub—through consolidation of local cargo, cold storage facilities, land-sea mode integration, and digitalization of logistics systems—represents a strategic step toward sustainable maritime logistics efficiency in Eastern Indonesia.



INTRODUCTION

The development of maritime connectivity is one of Indonesia's national strategic priorities to reduce price disparities and strengthen economic integration between regions. The Sea Toll Program, initiated by the government in 2016, is expected to serve as an instrument for equitable goods distribution and a driver of economic activity in eastern Indonesia (Aprianti et al., 2023; Duggan & Kochen, 2016; Hadiningrat et al., 2023). In the context of East Nusa Tenggara Province (NTT), this program holds high significance given the area's geography, which consists of numerous islands and relies on sea transportation routes as the backbone for mobility of people and goods (Angraini & Pratama, 2025; Hadi et al., 2025; Ksatria, 2019). However, the program's effectiveness and efficiency still face various challenges, particularly

at Tenau Kupang Port, the main port serving as a regional connectivity node (Kaur, 2018; Malau et al., 2024; Rumaji & Adiliya, 2019; Wiradanti, 2019).

Previous studies have provided valuable insights into maritime logistics and the Sea Toll Program (Kurniawan et al., 2024; Lau et al., 2024; Nuraeny, 2024). The World Bank (2023) emphasized that improving maritime connectivity is key to inclusive economic growth in archipelagic regions, though it noted persistent inefficiencies in cargo consolidation and return load management. Domestically, the Ministry of Transportation (2023) reported that the Sea Toll has succeeded in improving physical accessibility to remote areas, but operational challenges—such as low vessel load factors and high logistics costs—persist (Calderón-Rivera, 2024). Furthermore, Notteboom and Rodrigue (2019) highlighted that the success of a hub-and-spoke port system depends heavily on integrated scheduling, cargo volume consistency, and reliable feeder networks—factors that remain underdeveloped in many Indonesian ports. However, specific evaluative studies focusing on the port-to-port system at Tenau Kupang Port as a regional hub—particularly regarding local commodity distribution patterns and total logistics cost efficiency—are still limited. This study aims to fill that gap by conducting a comprehensive evaluation of the Sea Toll's operational effectiveness and the strategic role of Tenau Kupang Port.

Operationally, the Sea Toll system in NTT is served by the Kendhaga Nusantara 7 and Kendhaga Nusantara 11 ships on the Surabaya-Kupang-Rote-Sabu-Sabu-Kalabahi-Larantuka-Lewoleba route. These ships carry basic necessities, building materials, and animal feed from Surabaya to ports in NTT and return to Surabaya loaded with local produce and commodities such as salt, copra, candlenut, and fresh fish. Although the shipping route operates regularly, prominent problems include the low load factor on return cargo and the non-optimal function of Tenau Kupang Port as a consolidation center for inter-regional goods. This condition creates imbalances in logistics flows, reduces sea transportation cost efficiency, and limits the economic value generated from maritime distribution activities (Amin et al., 2024; Raimbekov et al., 2022; Song, 2021).

The main research problem is how the distribution pattern of local commodities through the Sea Toll in the NTT region operates and to what extent the system's effectiveness can be measured based on ship occupancy, logistics cost structure, and the role of Tenau Kupang Port as a regional hub. In addition, this study examines factors affecting distribution effectiveness—such as shipping frequency, return cargo volume, travel time, and logistics costs—as well as policy strategies to optimize Tenau Kupang Port's hub function in the Sea Toll network.

This study specifically aims to analyze the effectiveness of the Sea Toll system in distributing local commodities in East Nusa Tenggara by evaluating ship loading factors, shipping patterns, and logistics cost structures. It also seeks to assess the role and potential of Tenau Kupang Port as a regional hub in supporting the efficiency of the Sea Toll port-to-port system. Furthermore, the study identifies key factors affecting distribution effectiveness and total logistics costs in the Sea Toll network. Based on the findings, it formulates strategic recommendations to optimize Tenau Kupang Port's function and enhance the economic sustainability of the Sea Toll Program in NTT.

The benefits of this research are both academic and practical. Academically, it expands understanding of the port-to-port system in archipelagic settings and opportunities to apply the

hub-and-spoke model for future maritime logistics development. Practically, the results provide a basis for central and regional governments to formulate policies improving Sea Toll efficiency, including strengthening return cargo, digitizing logistics manifests, and building goods consolidation facilities at major ports. Thus, this research contributes to transforming the distribution system from mere physical access to functional efficiency that supports sustainable maritime economic development in East Nusa Tenggara.

RESEARCH METHOD

This research used a mixed methods approach with descriptive-quantitative and explanatory designs, which aims to analyze the relationship between logistics variables and evaluate the effectiveness of the Sea Toll distribution system in the East Nusa Tenggara (NTT) region. The descriptive approach was used to describe the actual condition of the flow of goods, shipping frequency, and load factor, while the explanatory approach was used to explain the influence of logistics factors on distribution effectiveness and logistics cost efficiency. This research model is based on the framework of maritime logistics theory developed by Notteboom and Rodrigue (2019) and the theory of logistics efficiency by Ballou (2004). The combination of these two approaches provides a basis for empirically analyzing port-to-port systems and evaluating their potential towards more efficient hub-and-spoke models in the future.

The research was carried out in the working area of Tenau Kupang Port as the main port, and included the feeder ports of Rote, Sabu, Larantuka, Lewoleba, and Kalabahi. This area is the operational route of KM Kendhaga Nusantara 7 and 11, Sea Toll ships that serve the fixed route Surabaya-Kupang-NTT. The scope of the analysis includes inflows from Surabaya to NTT and outflows from ports in NTT to Surabaya, focusing on distribution effectiveness, logistics cost structure, and the role of Tenau Port as a regional hub node.

The data used consists of secondary data used for quantitative analysis, while primary data functions as qualitative validation to strengthen the interpretation of statistical analysis results.

This study involves one dependent variable and four independent variables:

- 1) Y (Distribution Effectiveness): measured from the ship's load factor % based on the actual cargo volume compared to the installed capacity.
- 2) X_1 (Shipping Frequency): the number of Sea Toll ship departures per month at each port.
- 3) X_2 (Return Cargo Volume): total tonnage of goods leaving the port of NTT to Surabaya per period.
- 4) X_3 (Travel Time): the average cruise time between ports (hours).
- 5) X_4 (Logistics Costs): the total shipping cost per ton (million rupiah/ton) which includes sea, port, and land distribution costs.

The regression model used was: $[Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon]$

This model aims to identify the most significant factors affecting the effectiveness of the distribution of Sea Tolls in the NTT region.

The analysis is carried out through four main stages:

1. Descriptive Statistical Analysis: Used to describe the actual condition of commodity distribution patterns, inflow–outflow proportions, and load factor variations in each port.

2. Multiple Linear Regression Analysis: Aims to test the simultaneous and partial influence between shipping frequency variables, return load volume, travel time, and logistics costs on distribution effectiveness. This test was conducted using the Statistical Package for the Social Sciences (SPSS) or R software, with $\alpha = 0.05$.
3. Total Logistic Cost (TLC) Analysis: Measures the total logistics cost per ton based on the components of sea transportation costs, port costs, and land distribution costs. TLC Sea Toll is compared with conventional modes to assess economic efficiency.
4. Quantitative SWOT Analysis (IFAS–EFAS): Used to formulate a strategy to strengthen the function of Tenau Port as a regional hub. Internal factors (strengths and weaknesses) and external factors (opportunities and threats) are given weights and scores, then the position of the strategy in the SWOT matrix (Quadrant I–IV) is determined.

The stages of research analysis can be explained as follows:

- 1) Primary and secondary data collection and validation.
- 2) Quantitative data processing (descriptive, regression, TLC).
- 3) Interpretation of statistical results and cost analysis.
- 4) Strategy formulation through SWOT analysis.
- 5) Preparation of policy recommendations for optimizing the Sea Toll logistics system in NTT.

This integrative approach provides a comprehensive overview of the current performance of port-to-port systems as well as the direction of development towards more efficient and sustainable hub-and-spoke systems in the future.

RESULTS AND DISCUSSION

Commodity Distribution Pattern and Sea Toll Load Flow

The results of the 2023–2024 manifest data analysis show that the commodity distribution pattern through the Sea Toll in East Nusa Tenggara (NTT) is still dominated by the flow of goods from Surabaya to the NTT region (inflow). The main commodities transported include staples, building materials, animal feed, and household industrial products. On the other hand, the outflow from ports in NTT to Surabaya is still low and uneven between ports.

The ports with the highest volume of return cargo are Sabu (salt), Lewoleba (copra and seafood), and Rote (agricultural products and fresh fish). Based on the calculation of load factors, the average ship occupancy on the return trip only reaches 24–30%, far below the ideal target of 70–80% for ship operation efficiency. This imbalance in cargo flow indicates that the Sea Toll system in NTT is only effective in providing physical accessibility, but it is not yet fully functional accessibility. This finding is in line with the report of the Directorate General of Hubla (2023) which states that logistics movements in the eastern region of Indonesia are still "one-way" due to the limited local production structure and the absence of an integrated cargo consolidation system at the main port.

Distribution Effectiveness Analysis: Multiple Linear Regression Test Results

An empirical regression model built from the 2023–2024 KSOP data yields the following equations:

$$[Y = -792.22 + 127.13X_1 - 0.17X_2 + 17.89X_3 + 351.40X_4]$$

where:

Y = load factor,

X₁ = cruise frequency,

X₂ = volume of backload,

X₃ = travel time,

X₄ = logistics costs.

The results of the analysis showed that the frequency of shipments (X₁) had the most significant positive influence on distribution effectiveness, which means that the increase in the number of ship departures had a direct impact on the increase in load capacity and the reliability of the distribution schedule. The volume of return payload (X₂) shows a weak negative influence, indicating that despite the considerable potential of local commodities, the collection (consolidation) system is still inefficient.

Travel time (X₃) shows a moderate positive effect because the longer the shipping route, the greater the chance of loading goods from multiple feeder ports. Logistics costs (X₄) actually show a pseudo-positive influence on effectiveness, indicating that the current high costs are more due to the intensity of economic activities of potentially large ports such as Sabu and Lembata.

Overall, the regression model confirms that the effectiveness of distribution in NTT is more influenced by internal operational factors of ships and ports than by external factors such as distance or geography. This is in line with the view of Notteboom and Rodrigue (2019) that maritime efficiency in small island networks is highly dependent on coordination of schedules, cargo volumes, and consistent cost structures.

Total Logistic Cost (TLC) Analysis

The Total Logistic Cost (TLC) analysis was conducted to assess the economic efficiency of the Sea Toll system compared to conventional non-subsidized shipping modes. Based on the calculations, the total logistics cost on the Sea Toll ranges from Rp 1.3-1.4 million per ton, while in the conventional mode it reaches Rp 1.9 million per ton. Thus, the Sea Toll reduces average logistics costs by 31%, mainly due to the PSO subsidy on sea transportation costs.

The cost component that shows the greatest efficiency is the cost of sea transportation and port handling, while the cost of first mile and last mile (land distribution) is still high due to the limited network of connecting roads between hinterland regions. Follow-up analysis showed a negative relationship between load factor and TLC: every 10% increase in ship occupancy could lower logistics costs by 6–8% per ton. These findings reinforce the results of the Bappenas study (2024) which states that increasing load factors and load consolidation are the main determinants in national logistics cost efficiency. Thus, the optimization of return cargo is a strategic step to reduce maritime logistics costs in the eastern region of Indonesia.

Analysis of the Development Strategy of Tenau Kupang Port as a Regional Hub

The results of the quantitative SWOT analysis showed a total internal factor score (IFAS) of 2.09 and an external factor (EFAS) of 2.56, which placed Tenau Kupang Port in Quadrant I

(growth strategy). This means that the port has considerable structural strength and external opportunities to grow as a regional hub.

The main strength of Tenau Port lies in its position as the main collecting port in the NTT region, supported by adequate wharf facilities and its proximity to the economic center of Kupang. However, the prominent weaknesses are the limitations of cold storage facilities, aggregation warehouses, and the digitization of the manifest return system (Pelindo III, 2023).

The biggest opportunity for the development of this port is the integration of national logistics policies through the Sea Connectivity Enhancement project and local government support for local commodity-based industries. External challenges faced include fluctuations in export commodity prices, dependence on subsidies, and unstable land transportation systems between regions.

Suggested strategies based on SWOT positions include:

- 1) Improvement of consolidation and cold chain facilities.
- 2) Development of an online-based return charge manifest digital system.
- 3) Integration of land–sea modes to expand the range of hinterland.
- 4) Implementation of output-based subsidy schemes to ensure fiscal sustainability and operational efficiency.

With the implementation of this strategy, the Port of Tenau Kupang can transform from an administrative distribution node to a regional maritime hub that functions effectively in consolidation, distribution, and economic connectivity between regions in NTT.

CONCLUSION

This study evaluates the effectiveness of the Sea Toll program's local commodity distribution in East Nusa Tenggara (NTT), highlighting Tenau Kupang Port's role as a regional hub. Descriptive analysis, multiple linear regression, Total Logistics Cost (TLC) calculations, and quantitative SWOT reveal that the system is physically effective but functionally inefficient, with logistics flows dominated by incoming goods from Surabaya (basic necessities, building materials, animal feed) and limited return cargo (salt, copra, fresh fish), yielding low ship load factors of 24-30%. Regression shows shipping frequency and logistics costs positively influence effectiveness, while return cargo volume has weak impact, emphasizing internal operational factors over geography; TLC analysis confirms a 31% cost reduction (Rp 1.3-1.4 million/ton vs. Rp 1.9 million conventionally), with every 10% load factor increase cutting costs by 6-8%. SWOT positions Tenau Kupang in Quadrant I (growth strategy; IFAS 2.09, EFAS 2.56), leveraging dock infrastructure and location amid weaknesses like limited cold storage, supported by national policies and regional demand. Overall, Sea Toll reduces costs and boosts accessibility but suffers cargo imbalances, advocating hub-and-spoke transformation for efficiency. For future research, longitudinal studies could track post-infrastructure interventions (e.g., consolidated warehouses) on load factors and sustainability, incorporating stakeholder surveys from local producers.

REFERENCES

- Amin, C., Hasyim, A. W., Sun'an, M., Yetty, Hilman, R. G., & Fahmiasari, H. (2024). Impact of increasing local economic capacity on reducing maritime logistics costs in island

- province of eastern Indonesia: A dynamic system approach. *Transportation Research Interdisciplinary Perspectives*.
- Anggraini, T. S., & Pratama, A. (2025). Priority areas for public infrastructure development to support national equity: Case study of East Nusa Tenggara, Indonesia. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*.
- Aprianti, L., Berawi, M. A., Gunawan, S., & Sari, M. (2023). Conceptual design of port development to support the logistics supply of Indonesia's new Nusantara capital city. Bappenas. (2024). *Laporan kajian efisiensi biaya logistik nasional 2024*. Direktorat Transportasi, Kementerian PPN/Bappenas.
- Calderón-Rivera, N. (2024). Investigating inland waterway transport through a sustainable development perspective: A case study of the Magdalena River (Colombia).
- Christopher, M. (2016). *Logistics and supply chain management* (5th ed.). Pearson Education Limited.
- Duggan, D. E., & Kochen, M. (2016). Small in scale but big in potential: Opportunities and challenges for fisheries certification of Indonesian small-scale tuna fisheries. *Marine Policy*.
- Hadi, Y., Daraba, D., Ilham, M., & Achmad, M. (2025). Government strategy for Sembalun tourism destination in East Lombok Timur Regency to support Mandalika as a super priority tourism destination. *Journal of Humanities and Social Sciences Studies*.
- Hadiningrat, K. P. S. S., Wiradanti, B., & Umar, Y. F. (2023). Transformation of Indonesian sea transportation and maritime logistics to realize the vision of Golden Indonesia 2045. *JIPower: Journal of Intellectual Power*.
- Kaur, J. (2018). Evaluating port reform in Indonesia: A case study of the ports of Tanjung Priok and Tanjung Emas.
- Ksatrya, S. P. (2019). Development of maritime logistics system to support marine and fisheries integrated centres in small island and boundary areas.
- Kurniawan, R., Sudarmo, S. T., & Abdurachman, E. (2024). Economic impact analysis of Sea Toll Program implementation in eastern Indonesia: A review in Papua, Maluku, and East Nusa Tenggara regions. *Journal of Law, Politic and Humanities*.
- Lau, Y., Chen, Q., Poo, M., Ng, A., & Ying, C. C. (2024). Maritime transport resilience: A systematic literature review on the current state of the art, research agenda, and future research directions. *Ocean & Coastal Management*.
- Malau, A. G., Malau, J. H., Malau, A. G., Siahaan, R. Y., & Simanjuntak, M. (2024). Enhancing local port competitiveness: Strategies for facing challenges from public ports and special terminals. *International Journal of Multilingual Education and Applied Linguistics*.
- Notteboom, T. E., & Rodrigue, J. P. (2019). *Port economics, management and policy* (2nd ed.). Routledge.
- Nuraeny. (2024). Effectiveness of Sea Toll Road in logistics distribution in coastal area of Sorong Regency. *Pakistan Journal of Life and Social Sciences (PJLSS)*.
- Pelindo III. (2023). *Laporan tahunan kinerja Pelabuhan Tenau Kupang tahun 2023*. PT Pelabuhan Indonesia (Persero) Regional III.
- Raimbekov, Z., Śładkowski, A., Syzdykbayeva, B., Azatbek, T., & Sharipbekova, K. (2022). Improving the efficiency of transportation and distribution of goods in modern conditions. *Studies in Systems, Decision and Control*.
- Rodrigue, J. P. (2020). *The geography of transport systems* (5th ed.). Routledge. <https://transportgeography.org/>
- Rumaji, & Adiliya, A. (2019). Port maritime connectivity in South-East Indonesia: A new strategic positioning for transshipment port of Tenau Kupang. *The Asian Journal of*

Shipping and Logistics.

Song, D. (2021). A literature review of container shipping supply chain: Planning problems and research opportunities. *Logistics.*

Wiradanti, B. (2019). Container hub port development in a peripheral location: The case of Indonesia.

World Bank. (2023). *Indonesia: Improving maritime connectivity for inclusive growth.* The World Bank Group.