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# Analysis of the Efficiency and Effectiveness of Public Service Obligation (PSO) Sea Transportation Routes in Indonesia: A Case Study of PT PELNI (Persero)

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**Abstract:** Maritime transportation under the Public Service Obligation (PSO) scheme plays a strategic role in ensuring interregional connectivity, particularly in Indonesia's disadvantaged, frontier, outermost, and border (3TP) areas. However, variations in the operational efficiency of PT PELNI (Persero)'s passenger ship routes may reduce the effectiveness of government subsidy utilization. This study aims to measure the operational efficiency of PSO passenger shipping routes, identify efficient and inefficient routes, and formulate operational improvement recommendations. A quantitative approach was employed using the Input-Oriented CCR Data Envelopment Analysis (DEA) model on 26 Decision Making Units (DMUs) representing PT PELNI (Persero)'s PSO passenger ship routes. The input variables consisted of fuel consumption, operating costs, and the number of crew members, while the output variables included the number of passengers, cargo volume, and sailing frequency. The study findings indicate that 5 vessel routes are operating efficiently, while the remaining 21 routes are still inefficient. Based on the DEA projection results, there is potential to improve efficiency through a reduction in fuel consumption of 37,599,416 litres (19%), operational cost savings of Rp744.57 billion (18%), and the optimisation of 458 crew members (20%), without reducing passenger volumes, cargo volumes, or sailing frequency. The relatively high fuel consumption, operating costs, and crew requirements are closely related to PT PELNI's role as a Public Service Obligation (PSO) operator serving government-assigned routes. The fleet continues to operate to ensure national connectivity and support regional economic activities through its ship promotes trade function, particularly in remote, frontier, and outermost (3T) regions. Consequently, operational costs tend to be higher than those of purely commercial shipping services.

**Keywords:** Data Envelopment Analysis (DEA), Public Service Obligation (PSO), operational efficiency, shipping routes, PT PELNI (Persero), maritime transportation.

## INTRODUCTION

Indonesia, as a maritime nation and archipelagic country, relies heavily on maritime transportation to support national connectivity, logistics distribution, and population mobility. The strategic role of maritime transportation is reflected in the substantial volume of passengers and goods transported throughout the country. In 2025, domestic maritime transportation served approximately 30.5 million passengers, while the volume of transported goods reached approximately 508.4 million tons, representing an increase of more than 16% compared with the previous year. This substantial volume confirms that maritime transportation serves as a backbone of national logistics distribution, particularly for strategic commodities and essential goods across Indonesia's archipelagic regions. Data from Statistics Indonesia (BPS, 2025) further indicate that, cumulatively from January to February 2025, the number of maritime transportation passengers increased by 19.34% compared with the same period in the previous year, whereas air transportation passengers increased by only 1.36%. The relatively higher growth of maritime passenger transportation demonstrates its continuing importance, particularly for communities in island and remote regions where maritime transportation remains essential for inter-island mobility and connectivity.

To support national connectivity, the Government of Indonesia, through PT PELNI (Persero) as a state-owned enterprise, provides maritime transportation services throughout the archipelago, including remote, outermost, underdeveloped, and border areas, commonly referred to as 3TP regions. PT PELNI (Persero) currently operates a fleet consisting of 26 passenger vessels, 30 pioneer vessels, 9 sea toll vessels, 18 rede vessels, and 1 livestock vessel (PT PELNI Annual Report, 2024). In carrying out its operational activities, PELNI receives government assignments through the Public Service Obligation (PSO) and subsidy schemes. These schemes represent government intervention to ensure the availability and continuity of maritime transportation services, particularly in areas that are commercially less attractive but strategically important for national connectivity. Through these assignments, the Government provides compensation for transportation services on designated routes established by the Ministry of Transportation, thereby supporting service accessibility, continuity, and equitable mobility for communities in 3TP regions (Samosir, 2014; Paramita, 2023).

The PSO and subsidy schemes make a significant contribution to the performance of PT PELNI (Persero). During the 2019–2024 period, PSO-related revenue accounted for approximately 60–65% of the company's total revenue, while customer satisfaction with PSO passenger vessel services consistently remained above 90% (PT PELNI Annual Report, 2024). These conditions demonstrate that PELNI functions not only as a business entity but also as a development agent performing an important social role in supporting national territorial integration. The high level of customer satisfaction indicates that the services provided have generally met public expectations in terms of accessibility and service quality. Nevertheless, from an operational and business perspective, the existing route network continues to face various challenges related to optimization. Several routes still operate over long distances with numerous port calls (multi-port routes), resulting in longer travel times, greater operational complexity, and suboptimal fleet utilization. Furthermore, demand is uneven across route segments, with some legs experiencing relatively low occupancy while others experience higher passenger concentrations. This situation indicates that the current route structure has not yet been fully aligned with actual demand patterns.

From an economic and operational perspective, routes characterized by low demand and long sailing distances tend to generate limited financial returns and may potentially experience operational losses when they are not adequately supported by the PSO scheme. Major operating cost components, including fuel, port charges, maintenance, and other

operational expenditures, may not be proportional to the revenue generated from passengers (Angelopoulos et al., 2013; OECD, 2024). This condition contributes to the company's dependence on government support and limits its flexibility in improving operational and financial performance. Furthermore, the current route network has developed largely from historical arrangements and has not been fully optimized through market-demand analysis, operational efficiency considerations, or integration with logistics systems and other transportation modes. Consequently, several routes experience imbalances between supply and demand, suboptimal occupancy levels, and potential inefficiencies in fleet allocation. Therefore, route restructuring based on data-driven approaches, including route clustering, schedule optimization, and the development of hub-and-spoke networks, is necessary to improve operational efficiency, balance supply and demand, and strengthen the long-term sustainability of PSO services (Farmakis et al., 2023; Zhang et al., 2024).

The increasing mobility of people between islands has contributed to the recovery and growth of passenger demand for PT PELNI services. Historical passenger production data indicate a consistent upward trend before the COVID-19 pandemic. Passenger growth reached 7.72% during 2017–2018 and increased substantially to 33.22% during 2018–2019. However, the COVID-19 pandemic resulted in a dramatic decline of 66.44% during 2019–2020. Recovery subsequently began during 2020–2021, with passenger growth of 12.04%, followed by a significant increase of 92.55% during 2021–2022 and continued growth of 24.14% during 2022–2023 (PT PELNI Annual Report, 2024). In carrying out its public service assignment, PT PELNI applies the ship-promotes-trade concept by operating non-commercial shipping routes that connect small and outermost islands, particularly in Central and Eastern Indonesia. Operationally, PELNI routes can generally be classified into long-distance and short-distance routes. The continued demand for these services demonstrates the importance of maritime transportation in connecting communities across islands, particularly in areas where alternative transportation modes are limited (Van de Velde, 2013).

Despite the strategic role of the PELNI route network, passenger distribution remains uneven across Indonesia. In 2024, the highest passenger-producing routes represented Western, Central, and Eastern Indonesia. In Western Indonesia, the Belawan–Batam route recorded the highest passenger volume, followed by the Makassar–Bau-Bau route in Central Indonesia and the Ambon–Ternate route in Eastern Indonesia. This concentration indicates that passenger demand remains concentrated in particular areas and has not been evenly distributed across 3TP regions. The passenger movement pattern also demonstrates substantial intra-regional concentration. Central Indonesia contributed approximately 34% of intra-regional passenger movements, followed by Eastern Indonesia at approximately 23% and Western Indonesia at approximately 17%. Meanwhile, inter-regional movements remained comparatively limited, including movements between Western–Central, Western–Eastern, Central–Eastern, Eastern–Central, and Eastern–Western regions. This pattern suggests that the existing network primarily supports regional connectivity rather than fully integrating national inter-regional mobility. Such conditions may contribute to uneven passenger distribution and suboptimal utilization of vessel capacity on particular routes.

A similar imbalance can be observed in the distribution of cargo transported by PSO passenger vessels. Empirical data indicate substantial variation in cargo volume between routes, suggesting that logistics utilization is not evenly distributed throughout the network. Some routes transport significantly larger volumes of goods, whereas others carry relatively limited cargo. This disparity may be influenced by differences in regional economic activity, population density, port infrastructure, transportation connectivity, and geographical characteristics. Consequently, the role of PSO passenger vessels as an instrument for supporting national logistics distribution has not yet been fully optimized. Uneven cargo distribution may contribute to disparities in the availability of goods, differences in logistics

costs, and unequal access to essential commodities, particularly in remote, outermost, and underdeveloped areas. Therefore, further analysis of the factors influencing cargo distribution across PSO routes is necessary to formulate strategies for improving service effectiveness and developing a more equitable, efficient, and sustainable national logistics distribution system.

Furthermore, the dominance of intra-regional passenger movements indicates an opportunity to restructure the route network through regional clustering and the development of hub-and-spoke patterns. By strengthening major transportation hubs within each regional cluster and improving connectivity between hubs, PT PELNI can potentially increase operational efficiency, improve load factors on inter-regional routes, and optimize the utilization of vessel capacity. At the same time, PT PELNI faces operational challenges related to fuel consumption and vessel load factors. The company has implemented fuel-saving measures and routine engine maintenance to improve fuel efficiency, considering that fuel consumption constitutes a significant component of vessel operating costs (Yan, Wang, & Psaraftis, 2021). Meanwhile, low load factors may be associated with route design, service frequency, and fare structures that are not sufficiently responsive to demand (Chen & Wang, 2021; Guo, Xu, & Liu, 2023). Marketing and pricing strategies, together with coordination between public transportation policies and operational strategies, are therefore important instruments for increasing demand and improving vessel utilization (Li & Hensher, 2022; Zhang & Wang, 2021).

Maritime transportation is also considered an important option for inter-island mobility because of its accessibility and relatively affordable service characteristics compared with alternative transportation modes. This role becomes increasingly important in remote and archipelagic regions where airport infrastructure and flight frequencies remain limited. Maritime services can therefore provide an essential transportation alternative for passengers traveling between islands, particularly those traveling in groups or carrying goods. In such circumstances, the availability of PSO services enables maritime transportation operators to continue serving routes that may not be commercially attractive but remain socially and geographically important. Government compensation under the PSO scheme allows operators to maintain services while supporting transportation accessibility, population mobility, and logistics distribution across regions. Consequently, the PSO mechanism should not be evaluated solely from a commercial profitability perspective but also from the perspective of public-service effectiveness, connectivity, accessibility, and the equitable distribution of transportation services.

Based on these conditions, this study proposes a novel integrated framework for analyzing the efficiency and effectiveness of PSO routes operated by PT PELNI (Persero), incorporating both operational and logistics distribution dimensions through a Data Envelopment Analysis (DEA) approach. Unlike previous studies that have primarily focused on connectivity, passenger services, financial performance, or overall fleet efficiency, this research evaluates the relative efficiency of individual routes and identifies performance disparities across regional clusters. The study integrates passenger volume, cargo volume, sailing frequency, fuel consumption, operating resources, and route performance as the basis for evaluating route efficiency and formulating optimization strategies. Route clustering and hub-and-spoke network development are considered potential strategies for strengthening regional hubs, improving inter-regional connectivity, increasing load factors, and optimizing fleet utilization. This research is important because PSO maritime services continue to face challenges related to fuel consumption, variations in operating costs among routes, and suboptimal utilization of operational resources. In addition, passenger volumes, cargo volumes, and sailing frequencies on several routes remain relatively low, indicating potential inefficiencies. Although previous studies have examined financial and fleet efficiency, research specifically evaluating route-level efficiency from spatial and temporal perspectives

remains limited (Rinaldi et al., 2022; Budiman & Kurniawan, 2023). Therefore, this study is expected to address the existing research gap by providing an objective quantitative assessment of route efficiency and establishing an evidence-based foundation for optimizing operations and improving the effectiveness of PSO subsidies in Indonesia. The findings are expected to contribute to more efficient and equitable maritime transportation services, improved logistics distribution, optimized resource utilization, and stronger national maritime connectivity.

## METHODS

This study employs a quantitative approach to evaluate the efficiency of Public Service Obligation (PSO) routes operated by PT PELNI (Persero). The research is conducted at PT PELNI (Persero), located at Jl. Gajah Mada No. 14, Central Jakarta, DKI Jakarta, Indonesia, from May to August 2026. The research stages consist of a literature and field study, problem identification, formulation of research problems, objectives and benefits, determination of research variables, collection of secondary data, data processing and validation, data analysis and discussion, and formulation of conclusions and recommendations. The population comprises all passenger vessel routes operated by PT PELNI under the Government's PSO assignment, particularly routes designated through the relevant decisions of the Ministry of Transportation and the Directorate General of Sea Transportation. Because the population is relatively limited and complete data are available, this study applies a census or total sampling approach, in which all PSO routes are treated as Decision Making Units (DMUs). Secondary data are obtained from PT PELNI's internal operational, financial, logistics, and human-resource records through formal requests, as well as from publicly available documents published by Statistics Indonesia (BPS) and the Ministry of Transportation.

The data are analyzed using Data Envelopment Analysis (DEA), a non-parametric method based on linear programming that measures the relative efficiency of homogeneous Decision Making Units by simultaneously considering multiple inputs and outputs. The study applies the input-oriented CCR (Charnes, Cooper, and Rhodes) model under the assumption of Constant Returns to Scale (CRS). The input-oriented approach is selected because the primary objective is to determine the extent to which operational inputs can be minimized while maintaining the existing level of service outputs. The input variables consist of fuel consumption, total operating costs, and the number of crew members, while the output variables consist of the number of passengers transported, cargo volume, and sailing frequency. Each variable represents an important aspect of route operations, where inputs reflect the resources consumed in providing PSO services and outputs represent the operational and public-service results achieved. The DEA model produces a relative efficiency score for each DMU, generally ranging from 0 to 1, where a score of 1 indicates that the route lies on the efficient frontier, while a score below 1 indicates relative inefficiency (Charnes, Cooper, & Rhodes, 1978; Cooper, Seiford, & Tone, 2007; Cooper, Seiford, & Zhu, 2011).

The DEA analysis is conducted through several stages, beginning with the identification of homogeneous DMUs, followed by the collection and validation of input-output data and the construction of the DEA input-output matrix. The data are subsequently processed using appropriate DEA software or linear-programming tools, such as DEAP 2.1, MaxDEA, PIM-DEA, or Excel Solver. The analysis identifies efficient and inefficient routes, as well as potential improvements in input utilization and output achievement. For inefficient DMUs, the analysis considers input reduction targets, output improvement targets, slack values, and efficient reference units (peers) that can serve as benchmarks for improvement (Zhu, 2020). The resulting efficiency scores are then interpreted to evaluate the operational performance of each PSO route and to identify disparities in resource utilization and service

output. The findings provide an empirical basis for formulating recommendations concerning route restructuring, operational optimization, fleet utilization, and more targeted allocation of PSO subsidies. Ultimately, the DEA results are expected to support the development of a more efficient, effective, equitable, and performance-based PSO maritime transportation network in Indonesia.

## RESULTS AND DISCUSSION

### Results

The results of the reference set analysis indicate that vessels achieving an efficiency score of 1.00 not only serve as DMUs on the efficiency frontier, but also serve as benchmarks for less efficient vessels. In the DEA method, benchmarks represent best operational practices that can be used as references by other DMUs in an effort to improve their efficiency levels. Thus, the existence of benchmarks provides information on vessels that have the most optimal combination of input usage and output achievement compared to other vessels in the research sample.

**Table 1. The Ship That Became the Reference Set**

| No. | DMU | Boat | DEA CCR Score | Status |
|---|---|---|---|---|
| 1. | DMU1 | NP-132 | 1 | Efficient |
| 2. | DMU8 | NP-119 | 1 | Efficient |
| 3. | DMU9 | NP-117 | 1 | Efficient |
| 4. | DMU15 | NP-115 | 1 | Efficient |
| 5. | DMU24 | NP-123 | 1 | Efficient |

Based on the DEA processing results, there are six ships that are on the efficiency frontier, namely NP-132, NP-119, NP-117, NP-115 and NP-123. These ships serve as a reference for ships that are not yet efficient because they are able to show relatively better operational performance in managing fuel consumption, operational costs, and the number of crew to produce the optimal number of passengers, volume of goods, and frequency of sailings. The success of these ships in achieving a perfect efficiency score indicates that there are no other DMUs in the research sample that are able to produce higher output with the same or lower input levels.

Benchmark analysis also shows that inefficient vessels do not have to completely emulate a single vessel, but can instead reference a combination of vessels on the efficiency frontier. For example, an inefficient vessel could use NP-132 as a benchmark for optimizing cargo transportation, while simultaneously adopting NP-119 or NP-117 operational practices for managing operational costs and utilizing passenger capacity. Thus, the DEA benchmark serves not only as a comparison tool but also as a source of information regarding more efficient operational patterns.

These findings align with research by Krmac and Mansouri Kaleibar (2023), which explains that one of the main advantages of DEA is its ability to identify units operating at the best practice frontier and serve as a benchmark for less efficient units. According to the study, benchmark analysis enables organizations to identify performance gaps and determine more targeted efficiency improvement strategies based on proven best practices. Similar findings were also found by Nong and Ha (2023), who stated that units at the efficiency frontier can be used as a benchmark in setting operational improvement targets for units with lower efficiency levels.

In the context of PT PELNI (Persero), benchmarking is crucial given the characteristics of the PSO fleet, which differs in service areas, route lengths, number of ports of call, and levels of passenger and cargo demand. Therefore, efficiency improvements cannot be achieved through a uniform approach for all vessels. Instead, each vessel needs to identify the

benchmarks most relevant to its operational characteristics so that the implemented improvement strategies can be more effective and realistic in reaching the efficiency frontier.

Overall, the benchmark analysis results indicate that vessels on the efficiency frontier play a strategic role as models of best operational practices within PT PELNI (Persero)'s PSO fleet. This information serves as the basis for the next analysis stage, which is to determine the magnitude of input and output adjustments required for inefficient vessels through DEA projections or slack analysis.

**Projection Analysis of Inefficient Ship Route Improvements**

The results of the Input-Oriented DEA CCR efficiency measurement show that of the 26 PSO passenger ship routes analyzed, there are still a number of routes that have not achieved efficient conditions. Although the efficiency score is able to indicate the relative performance level of each route, this information cannot explain the magnitude of adjustments required for inefficient routes to reach the efficiency frontier. Therefore, an analysis of improvement projections is needed to identify operational targets that must be achieved by inefficient routes.

DEA projection analysis is performed by comparing actual conditions with the target conditions generated by the DEA model. This approach can determine the magnitude of input reductions and output increases required for a ship's route to achieve an efficiency level equivalent to that of a route on the efficiency frontier. Thus, the projection results not only illustrate the level of inefficiency but also provide more concrete and measurable improvement directions for the operational management of PSO passenger ships.

In this study, a projection analysis was conducted on all inefficient ship routes. The projection results were then used to identify potential optimizations for fuel consumption, operational costs, and crew size, as well as to evaluate opportunities for improving service productivity, as measured by passenger numbers, cargo volume, and shipping frequency. A summary of the aggregate improvement projections is presented in Table 2 below.

**Table 2. Potential Improvement of Input and Output Variables**

| No. | Variables | Current | DEA Target | Gap | % Repair |
|---|---|---|---|---|---|
| 1. | Fuel (liters) | 194,737,001 | 157,137,585 | -37,599,416 | -19% |
| 2. | Operating costs (Rp – Million) | 4,050,818 | 3,306,246 | -744,572 | -18% |
| 3. | Crew (People) | 2,247 | 1,789 | -458 | -20% |
| 4. | Passengers (Pax) | 4,372,407 | 4,372,407 | 0 | 0 |
| 5. | Goods (Kg) | 265,929,856 | 265,929,856 | 0 | 0 |
| 6. | Frequency (Voyage) | 562 | 562 | 0 | 0 |

Based on Table 2 the results of the Input-Oriented DEA CCR projection indicate that the main source of inefficiency in the PSO passenger ship routes of PT PELNI (Persero) lies in the relatively excessive use of input (input excess), not in the low achievement of output. In aggregate, fuel consumption which originally reached 194,737,001 liters can still be optimized to 157,137,585 liters, so there is a potential savings of 37,599,416 liters or approximately 19%. In addition, operational costs which reached Rp 4,050,818 million can still be reduced to Rp 3,306,246 million or potentially reduced by Rp 744,572 million (18%). In the variable number of crew members, there is a potential optimization of 458 people or approximately 20% of the actual condition. In contrast, the output variables consisting of the number of passengers, volume of goods, and frequency of sailings do not indicate any need for improvement to reach the efficiency frontier. Thus, the absence of gaps in passenger, cargo, and frequency variables indicates that these three variables are considered optimal in providing services under current conditions. Efficiency improvements are more focused on

reducing operational resource use, such as fuel consumption, operating costs, and crew size, without reducing the number of passengers served, the volume of goods transported, or the frequency of voyages.

These findings indicate that most PSO ship routes are capable of producing adequate service output, but still face inefficiencies in the utilization of operational resources. In other words, efficiency improvements are more effectively achieved through controlling input usage than through increasing passenger numbers, cargo volume, or shipping frequency. This condition aligns with the characteristics of the Input-Oriented DEA CCR model, which focuses on minimizing input usage to maintain the same level of output.

The results of this study align with those of Bartosiewicz (2024), which analyzed the efficiency of container terminals in the Baltic Sea region using the DEA-SBM approach. The study found that the primary source of inefficiency in the maritime sector generally stems from excess input usage compared to output shortfalls. Therefore, efficiency improvements are more effectively achieved through optimizing operational resource utilization rather than expanding service capacity.

This research finding is also supported by research (Liu and Shih, 2023), which explains that slack analysis in DEA serves to identify input surpluses and output shortages that prevent a unit from moving to the efficiency frontier. According to them, inefficient DMUs can improve their performance by reducing excess inputs and aligning them with predetermined DEA targets.

Furthermore, research (Emrouznejad, 2025) on the development of the Slacks-Based Measure (SBM) model in DEA shows that slack analysis is a crucial tool for identifying specific sources of inefficiency in each input and output variable. Through this approach, organizations can gain a more detailed understanding of which variables require improvement and the extent of adjustment required to achieve efficiency.

In the context of transportation, (Park, 2018) states that improving operational efficiency in transportation does not always have to be achieved through increased service output, but can be achieved through more effective resource management. Reducing the use of unproductive inputs will increase technical efficiency while generating economic benefits through lower operational costs.

Based on research results and various previous findings, it can be concluded that the potential for increasing the operational efficiency of PSO passenger ships of PT PELNI (Persero) comes more from optimizing resource use than increasing service capacity. The results of the Data Envelopment Analysis (DEA) projection indicate the potential for reducing fuel consumption, operational costs, and the number of crew members based on comparisons with units with the best performance (best practices). However, the efficiency targets generated by the DEA are theoretical targets obtained through a mathematical approach and therefore do not necessarily become operational targets that must be directly implemented by the company.

Implementing these potential efficiencies requires considering various operational aspects, such as the characteristics of each vessel and route, weather and shipping conditions, passenger demand, compliance with safety standards, applicable regulations, and the quality of service to the public. Therefore, the results of this study are more appropriately positioned as a decision support tool to identify opportunities for efficiency improvements. This will then require technical studies, operational evaluations, and gradual implementation testing before being used as the basis for formulating company policies.

Thus, the findings of this study indicate that the operational efficiency of the PSO fleet has the potential to be improved through more productive and targeted resource management without compromising service levels. However, the potential efficiency figures generated by the DEA should be understood as relative benchmarks, and their application must be adapted

to the actual operational conditions of PT PELNI (Persero) and should not be interpreted as targets that must be directly achieved.

## Discussion

### Implications for Optimizing PSO Ship Routes

The results of the Data Envelopment Analysis (DEA) demonstrate that the operational efficiency of PT PELNI (Persero)'s Public Service Obligation (PSO) passenger ship routes varies considerably across Decision-Making Units (DMUs). While several routes have reached the efficiency frontier, others continue to operate below the optimal level due to excessive utilization of operational inputs relative to the outputs produced. These findings indicate that significant opportunities remain for improving operational performance without reducing the level of public services provided. Consequently, the DEA results provide an objective basis for identifying efficient and inefficient routes and offer valuable information for evaluating the effectiveness of current operational policies.

From a managerial perspective, the findings imply that optimization strategies should prioritize improving the productivity of operational resources rather than increasing service output. Efficiency improvements can be achieved through more effective management of fuel consumption, operational expenditures, crew utilization, fleet allocation, and route network planning. Therefore, the results of this study provide practical guidance for PT PELNI (Persero) in developing evidence-based operational policies that enhance service sustainability while ensuring that government PSO subsidies are utilized more effectively and accountably.

### Optimizing the Use of Fuel Oil (BBM)

The DEA CCR Input-Oriented analysis identifies fuel consumption as one of the primary sources of operational inefficiency in PT PELNI (Persero)'s PSO passenger ship services. The projection results indicate that total actual fuel consumption reached 194,737,001 liters, whereas only 157,137,585 liters were required for efficient operations. This finding reveals a potential reduction of approximately 37.6 million liters, or about 19% of total fuel consumption, without decreasing passenger numbers, cargo volume, or sailing frequency. Such results demonstrate that substantial efficiency gains can be achieved by optimizing energy utilization while maintaining the quality of public transportation services.

These findings suggest that fuel efficiency should become a strategic priority in fleet management because fuel represents one of the largest operational cost components in passenger shipping. Practical improvement strategies include implementing economic sailing speeds, optimizing voyage schedules, minimizing idle time at ports, strengthening preventive maintenance programs, and utilizing digital fuel monitoring systems. These recommendations are consistent with previous DEA-based maritime studies, which conclude that operational efficiency is more effectively improved through better management of energy resources than by increasing operational outputs. Consequently, improving fuel efficiency will not only reduce operational costs but also strengthen the financial sustainability and environmental performance of PSO maritime transportation services.

### Operational Cost Optimization

The DEA analysis also reveals that operational costs remain one of the most influential input variables affecting the efficiency of PSO passenger ship routes. Based on the efficiency projections, actual operational expenditures amounted to IDR 4,050,818 million, while efficient operations could be achieved with only IDR 3,306,246 million. This indicates a potential cost reduction of IDR 744,572 million, equivalent to approximately 18% of current operational expenditures. The results suggest that many routes continue to utilize financial

resources beyond the level required to produce their existing service outputs, indicating opportunities to improve resource allocation without compromising public service obligations.

From a managerial perspective, operational cost optimization should focus on improving resource utilization rather than reducing service coverage. Cost control strategies may include enhancing fuel efficiency, improving procurement processes, optimizing maintenance scheduling, reducing unnecessary port-related expenditures, and implementing performance-based budgeting systems. Since PSO services are financed through government subsidies, improving operational cost efficiency will increase the effectiveness of public fund utilization while strengthening the long-term sustainability of maritime transportation services. These findings are consistent with previous DEA studies, which emphasize that controlling operational costs is among the most effective approaches for improving both technical and operational efficiency in the maritime transportation sector.

**Optimization of Ship Crew Resources**

The results of the DEA CCR Input-Oriented analysis indicate that ship crew resources remain one of the input variables with considerable potential for efficiency improvement. The DEA projection shows that the total number of crew members currently assigned to all PSO passenger ship routes is 2,247 personnel, whereas only 1,789 personnel are required to achieve the efficiency frontier. This represents an optimization potential of 458 crew members, or approximately 20% of the existing workforce. These findings suggest that several routes still employ more human resources than are operationally required relative to the outputs they produce, thereby creating opportunities to improve workforce productivity while maintaining existing service levels.

However, crew optimization should not be interpreted merely as workforce reduction, since all vessels must continue to comply with the Minimum Safe Manning Certificate and international maritime safety regulations established by the International Maritime Organization (IMO). Instead, the findings emphasize the importance of improving human resource management through more effective crew allocation, competency development, multi-skilled crew implementation, digitalization of administrative processes, and technology-assisted operations. Such strategies will enable PT PELNI (Persero) to increase labor productivity, reduce operational costs, and maintain high standards of safety and passenger service while supporting the long-term sustainability of PSO maritime transportation.

**Optimizing Ship Capacity Utilization**

The DEA results indicate that passenger volume and cargo volume are the most influential output variables in determining the operational efficiency of PT PELNI (Persero)'s PSO passenger ship routes. The efficiency projections reveal that no additional increases in passenger numbers, cargo volume, or sailing frequency are required for the fleet to reach the efficiency frontier. Instead, the variation in efficiency scores among routes reflects differences in the degree to which existing ship capacity is utilized. Some routes are able to maximize available capacity effectively, whereas others continue to experience relatively low utilization levels despite operating under similar service obligations.

These findings imply that improving operational efficiency should focus on maximizing the utilization of available passenger and cargo capacity rather than expanding operational resources. Strategies such as strengthening inter-island logistics integration, improving cargo distribution on underutilized routes, enhancing passenger service quality, and matching vessel capacity with route-specific demand characteristics can significantly improve productivity without compromising public service functions. Greater capacity

utilization will reduce operational costs per unit of output, improve asset productivity, and enhance the overall financial sustainability of PSO passenger ship operations while continuing to support national connectivity.

**Fleet Assignment Optimization**

The DEA analysis demonstrates that the operational efficiency of PT PELNI (Persero)'s PSO passenger ship routes is not evenly distributed across all Decision-Making Units (DMUs). While several routes operate efficiently, others remain below the efficiency frontier due to differences in demand characteristics, cargo potential, voyage distance, number of ports of call, and resource utilization. These findings indicate that fleet assignment decisions play a critical role in determining operational efficiency and that matching vessel characteristics with route requirements is essential for maximizing fleet productivity.

From a managerial perspective, fleet assignment should be based on the principle of **"the right ship for the right route,"** whereby vessel size and operational characteristics correspond closely to passenger demand, cargo potential, and service requirements. Larger vessels should be deployed on high-demand routes to maximize capacity utilization, whereas smaller vessels are more appropriate for routes with relatively limited demand. Furthermore, periodic evaluations of fleet deployment supported by DEA results and route clustering analysis can improve asset utilization, reduce unnecessary operational costs, and strengthen the effectiveness of PSO subsidy utilization. Consequently, fleet assignment optimization represents a strategic approach to enhancing operational efficiency while maintaining equitable maritime transportation services across Indonesia.

**PSO Route Network Optimization**

The DEA CCR Input-Oriented analysis reveals that the efficiency of PT PELNI (Persero)'s PSO passenger ship routes is heterogeneous, indicating that not all routes utilize operational resources with the same level of effectiveness. The findings show that inefficiency primarily originates from excessive input utilization, particularly fuel consumption, operational costs, and crew deployment, rather than insufficient service output. Since no additional increases in passenger volume, cargo volume, or sailing frequency are required to achieve the efficiency frontier, the study suggests that operational improvements should focus on optimizing the existing route network rather than expanding service capacity. This finding highlights the importance of evaluating route characteristics, operational patterns, and resource allocation to improve overall system performance.

From a managerial perspective, PSO route network optimization should be implemented through comprehensive evaluations of passenger demand, cargo potential, voyage distance, number of ports of call, and fleet utilization across different service areas. Route clustering based on similar operational characteristics may facilitate more effective fleet deployment and integrated scheduling while maintaining connectivity for remote and underdeveloped regions. In addition, periodic reviews of service frequencies and route integration can improve operational productivity without compromising the social objectives of the PSO program. Therefore, a data-driven route network planning approach supported by DEA findings will contribute to more efficient resource allocation, improved service sustainability, and stronger national maritime connectivity.

**Implications for Subsidy Policy and Decision Making**

The results of this study demonstrate that the operational efficiency of PT PELNI (Persero)'s PSO passenger ship routes varies considerably across routes, indicating differences in the effectiveness of resource utilization under the same subsidy scheme. DEA projections reveal the potential to reduce fuel consumption by approximately 19%,

operational costs by 18%, and crew utilization by 20% without decreasing service outputs. These findings indicate that efficiency improvements can primarily be achieved through better input management rather than increasing passenger numbers, cargo volume, or sailing frequency. Consequently, the study provides objective evidence that operational efficiency should become an important consideration in evaluating the effectiveness of PSO service delivery.

From a public policy perspective, DEA results provide valuable information for developing a more performance-based subsidy allocation system. Rather than relying solely on operational expenditure requirements, subsidy evaluation can incorporate efficiency indicators to identify routes that utilize government resources effectively and those requiring operational improvements. Furthermore, DEA findings can support managerial decision making in areas such as budgeting, fleet assignment, operational planning, and performance evaluation by identifying best-performing routes and benchmarking inefficient ones against efficient counterparts. Integrating efficiency analysis into subsidy policy and strategic planning will strengthen accountability, improve public resource utilization, and enhance the long-term sustainability of Indonesia's PSO maritime transportation system.

**Managerial Implications**

The findings of this study indicate that significant opportunities remain to improve the operational efficiency of PT PELNI (Persero)'s PSO passenger ship services through better management of operational inputs. The DEA analysis identifies considerable potential for reducing fuel consumption, controlling operational costs, optimizing crew deployment, improving vessel capacity utilization, and enhancing fleet assignment without reducing public service outputs. These results suggest that the principal challenge lies not in expanding transportation services but in increasing the productivity of existing operational resources. Consequently, PT PELNI (Persero) should incorporate efficiency indicators into its operational performance management system to complement traditional service performance measures such as passenger volume and sailing frequency.

The managerial implications extend beyond operational improvements to broader strategic planning and corporate governance. DEA results can serve as an objective decision-support tool for evaluating route performance, preparing operational budgets, determining fleet deployment, planning future investments, and designing long-term efficiency improvement strategies. Furthermore, adopting an efficiency-based management approach will strengthen accountability in the utilization of government PSO subsidies while ensuring that public transportation services remain reliable, accessible, and financially sustainable. Overall, integrating DEA into routine operational evaluation provides PT PELNI (Persero) with a comprehensive framework for achieving more effective, efficient, and sustainable maritime transportation services that support national connectivity and regional economic development.

## CONCLUSION

The efficiency and operational effectiveness of the passenger vessel routes operated under the Public Service Obligation (PSO) scheme by PT PELNI (Persero) still vary across Decision Making Units (DMUs). Of the 26 passenger vessel routes analyzed, 5 routes achieved an efficient condition with a DEA efficiency score of 1.00, while 14 routes were classified as relatively close to efficient ($\geq 0.70$ and $< 1.00$), and 7 routes were categorized as inefficient ($< 0.70$). These results need to be interpreted by considering the characteristics of PSO assignments, which apply an *all-cost* approach in which all cost components arising from the implementation of the assignment are taken into account in the efficiency measurement. Furthermore, PSO routes are not operated solely on the basis of commercial

considerations but constitute part of the Government's efforts to maintain maritime connectivity and transportation accessibility, particularly for communities in archipelagic areas and in underdeveloped, frontier, outermost, and border regions (3TP). Therefore, a DEA score below 1 does not necessarily indicate that a route is inefficient or unfeasible. Rather, its performance needs to be assessed within the broader context of PSO objectives, including service continuity, interregional connectivity, and the fulfillment of community mobility needs. The improvement opportunities identified through DEA can subsequently be used as a basis for optimizing resource utilization while maintaining the public-service function of the respective routes.

The research findings also indicate that operational inefficiency is primarily attributable to relatively excessive input utilization compared with the outputs generated. Based on the DEA projection results, there is potential to reduce fuel consumption by approximately 19%, operating costs by 18%, and the number of route crew members by 20%, without reducing the number of passengers transported, cargo volume, or sailing frequency. The relatively high operating costs are closely related to PT PELNI's role as a Public Service Obligation (PSO) operator serving government-assigned routes. The fleet must continue to operate to maintain connectivity and support trade activities through the *ship-promotes-trade* concept across various regions, including 3TP areas. Consequently, operating costs tend to be higher than those of routes that are operated purely on a commercial basis.

Based on the efficiency measurement results, this study successfully identifies passenger vessel routes that have achieved efficient conditions and can serve as benchmarks for routes that have not yet reached the efficiency frontier. The DEA approach also provides specific directions for improving the performance of inefficient routes. Accordingly, the findings can serve as a basis for PT PELNI (Persero) to optimize fuel consumption, operating costs, and crew allocation, while supporting the evaluation and management of PSO routes in a more effective, efficient, accountable, and sustainable manner. Ultimately, these efforts are expected to contribute to improving the quality and sustainability of national maritime transportation services.

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