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Efficiency Analysis 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 vessels. The input variables consist of fuel consumption, operating costs, and the number of crew members, while the output variables include the number of passengers, cargo volume, and sailing frequency. The results indicate that six vessels achieved full efficiency with a DEA score of 1.00, while the remaining twenty vessels were found to be relatively inefficient. The DEA analysis reveals that inefficiency primarily results from suboptimal utilization of operational inputs relative to the outputs produced. Based on the DEA projections, the study identified potential efficiency improvements, including a reduction of 37,599,416 liters (19%) in fuel consumption, operating cost savings of IDR 744.57 billion (18%), and optimization of 458 crew members (20%), without reducing the number of passengers, cargo volume, or sailing frequency. These findings demonstrate that DEA is an effective evaluation tool for identifying sources of operational inefficiency and achieving improvement targets to support route optimization, enhance operational performance, and provide evidence-based recommendations for a more effective, efficient, and performance-oriented PSO policy.

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

INTRODUCTION

As a maritime nation, Indonesia's maritime transportation plays a key role in supporting connectivity, logistics distribution, and population mobility. This strategic role is reflected in the high volume of maritime transportation, with data showing that throughout 2025, the number of domestic maritime passengers reached approximately 30.5 million people, while the volume of goods transported reached 508.4 million tons, a growth of more than 16% compared to the previous year. This large volume confirms that maritime transportation is the backbone of national logistics distribution, particularly for strategic commodities and basic necessities in archipelagic regions, particularly for large-scale and inter-island movement of goods.

BPS data (2025) shows that in February 2025, cumulatively from January to February 2025, the number of sea transportation passengers increased by 19.34% compared to the same period the previous year, while air transportation only increased by 1.36%. This indicates that over a certain period, sea transportation experienced relatively higher growth than air transportation. With the relatively higher growth of sea transportation passengers compared to air transportation, it illustrates that the presence of sea transportation is needed by the community, especially in island regions. In supporting this, the Government through PT PELNI (Persero) as a State-Owned Enterprise (BUMN) is present to provide sea transportation services in island regions and 3 TP regions (Remote, Outermost, Underdeveloped and Border).

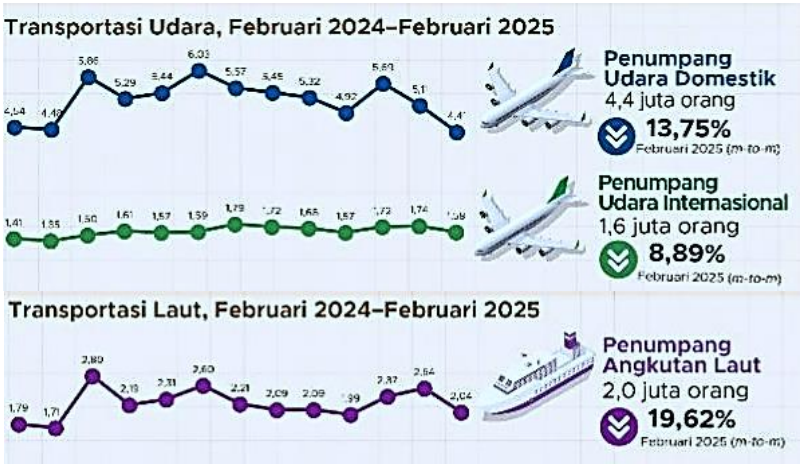

Figure 1 Domestic Air and Sea Transportation Graph for 2024-2025

PT PELNI (Persero) currently operates a fleet consisting of 26 passenger ships, 30 pioneer ships, 9 sea toll ships, 18 rede ships, and 1 livestock ship (PT PELNI (Persero) Annual Report, 2024). In carrying out its operational activities, PELNI receives assignments from the Government through a Public Service Obligation (PSO) and subsidy scheme. This scheme is a form of Government intervention to ensure the availability of sea transportation services, especially in areas that are commercially less attractive but have a strategic role in supporting national connectivity. Through this assignment, the Government provides compensation for the provision of sea transportation services on certain routes determined by the Ministry of Transportation, so as to maintain affordable fares, service sustainability, and equal access to community mobility to the 3TP areas (Samosir, 2014; Paramita, 2023).

PSO and subsidies contribute significantly to the company's performance, with the portion of PSO revenue in the 2019 – 2024 period being in the range of 60 – 65% of total revenue, and the level of customer satisfaction of PSO passenger ship services consistently above 90% (PT PELNI (Persero) Annual Report, 2024). This demonstrates that PELNI's role is not only as a business entity, but also as a development agent that carries out social

functions in supporting national territorial integration. The high level of customer satisfaction also reflects that the services provided have met community expectations, both in terms of accessibility and service quality.

However, based on PT PELNI (Persero)'s 2024 Annual Report, from an operational and business perspective, the current route network structure still faces various optimization challenges. Several routes still employ long journey patterns with numerous ports of call (multi-port routes), resulting in long travel times, increased operational complexity, and suboptimal fleet utilization. Furthermore, there is an imbalance in demand between route segments, with some legs experiencing relatively low occupancy rates, while others are experiencing congestion. This indicates that the route network design is not fully aligned with actual demand patterns.

PT PELNI (Persero) in carrying out its assignment applies the ship promote the trade system, namely PT PELNI opens non-commercial shipping routes connecting small and outermost island regions, especially in Central and Eastern Indonesia. In its operational practice, the routes served by PT PELNI can be classified into two main categories, namely long-distance routes and short-distance routes. Therefore, the number of PT PELNI passengers is increasing every year due to the public's need for sea transportation modes that connect between islands. This is in accordance with the public service instrument mandated to state-owned shipping operators to provide services in corridors that are less commercially viable in order to improve regional connectivity (Van de Velde, 2013).

Based on the passenger production of PT PELNI's busiest routes in 2023, it can be seen that several regions are represented in Western, Central, and Eastern Indonesia. The busiest route in western Indonesia is dominated by the Belawan - Batam Island route with a total of 111,138 passengers. Furthermore, the busiest route in Central Indonesia is Makassar - Bau-bau with a total of 71,200 passengers and the busiest route in Eastern Indonesia is Ambon - Ternate with a total of 33,031 passengers. Therefore, it can be seen that the busiest routes are concentrated in Western Indonesia and are not evenly distributed across the 3TP region. The following is PT PELNI passenger production data based on the busiest routes in 2023.

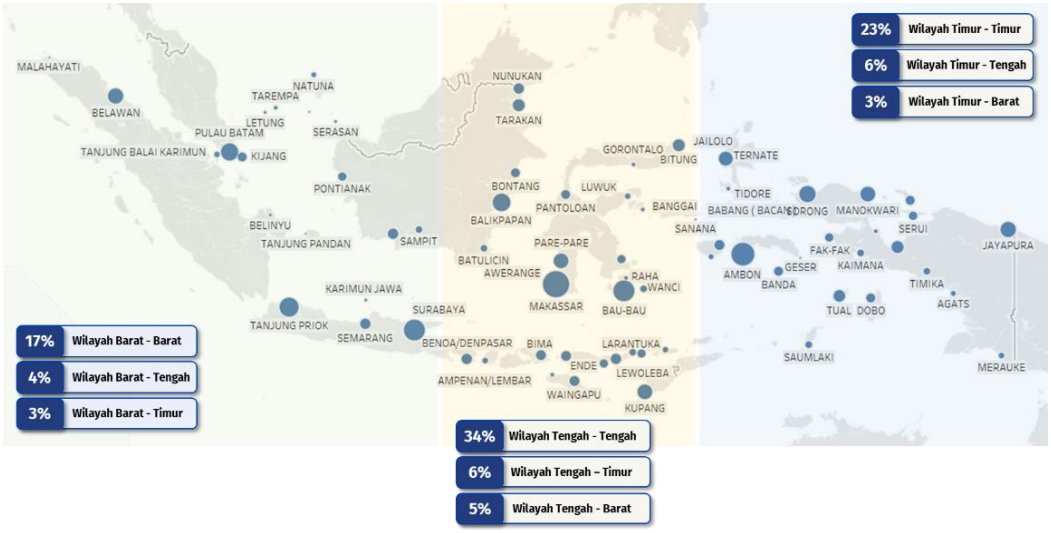

Figure 2. PT PELNI Passenger Production on Busiest Routes by Cluster in 2023

The distribution map of PT PELNI (Persero)'s sea passenger movement shows uneven demand concentration across regions in Indonesia. The Central Region is the largest contributor, accounting for approximately 34% of intra-regional (Central-Central) movement, followed by the Eastern Region at 23% for East-East movement, and the Western Region at

17% for West-West movement. This indicates that passenger mobility tends to be more dominant within each regional cluster than between regions.

On the other hand, inter-regional connectivity remains relatively limited, as reflected in the low percentage of cross-regional travel, such as between West–Central (4%), West–East (3%), Central–East (6%), and East–Central (6%), and East–West (3%). This pattern indicates that the current route network does not fully promote optimal national mobility integration, but rather focuses on regional connectivity patterns. This situation has the potential to lead to an imbalance in passenger distribution and suboptimal fleet capacity utilization on certain routes.

Furthermore, the dominance of intra-regional traffic also indicates an opportunity to reorganize the route network through a regional clustering approach and the development of a hub-and-spoke pattern. By strengthening key nodes in each region and improving connectivity between hubs, PELNI can boost operational efficiency, increase load factors on inter-regional routes, and optimize the role of the route network in supporting more integrated national connectivity.

Furthermore, not all shipping routes operated by PT PELNI (Persero) optimally contribute to service efficiency and fleet utilization. Some routes exhibit low occupancy rates or high cost burdens, raising questions about the effectiveness of route allocation for PSO subsidies (Handayani et al., 2020). Therefore, it is necessary to evaluate route operational efficiency using a quantitative, data-driven approach to ensure optimal use of subsidies and a direct impact on improving national maritime connectivity (Siregar & Putra, 2021).

Furthermore, PT PELNI (Persero) faces operational challenges, namely inefficient fuel costs and ship load factor achievement. PT PELNI (Persero) has taken several steps to address fuel cost inefficiencies, including consistently reducing fuel consumption on board and conducting routine engine maintenance to improve fuel efficiency. Most literature indicates that fuel consumption contributes significantly to ship operational costs, necessitating effective fuel forecasting and management strategies to improve operational efficiency (Yan, Wang & Psaraftis, 2021).

The challenge of increasing ship load factors, where routes and fares are still determined by the government, is that PT PELNI (Persero) has taken several strategic steps to address this problem, namely by optimizing marketing and sales. Although PT PELNI (Persero)'s fares are cheaper than air transportation, they are hampered by its operating patterns, which may be less than optimal. The following illustrates a comparison of ticket fares between PT PELNI (Persero)'s sea transportation and air transportation based on the shortest and longest routes. The transportation fare structure is one of the determining factors in consumer mode choice; although ship fares are cheaper than air transportation, consumers often choose faster and more comfortable modes, resulting in suboptimal ship load factors (Chen & Wang, 2021). In the context of passenger ship services, low load factors are influenced by route design, service frequency, and fare structures that are less adaptive to market demand (Guo, Xu & Liu, 2023). To address this, marketing and pricing strategies are crucial tools for operators to increase demand and optimize ship occupancy rates (load factors), especially amidst competition with other modes (Li & Hensher, 2022). Tariff policies set by public authorities also significantly impact service demand dynamics, necessitating coordination between public policy and company operational strategies to improve load factors and operational performance (Zhang & Wang, 2021).

Figure 3. Comparison of tariffs between PELNI and air transportation modes

Based on the image above, for inter-island routes, using ships is the most cost-efficient transportation for passengers, with a fare of Rp270/km. Although the travel time is quite long, using ships, especially ships operated by PT PELNI (Persero), can connect regional connectivity and open up opportunities for people to save on transportation costs. This is because ships are considered more affordable than planes, especially for passengers from the eastern and central regions. Ships are also a more considered means of transportation, especially for those traveling with large numbers of people. Furthermore, the limited number of airports in remote areas makes ship transportation the only option for long-distance travel to other islands.

In this regard, to increase operational efficiency, route optimization is required on PT PELNI (Persero) ships. The author is interested in conducting research on Route Clustering as a PSO Operational Optimization Strategy at PT PELNI (Persero) using the Data Envelopment Analysis (DEA) method, which is a non-parametric approach widely used to measure the relative efficiency of decision-making units (DMUs), such as ship routes, ports, or other public services. DEA allows the identification of routes that are operationally efficient or inefficient based on a combination of certain inputs and outputs. With this approach, it is hoped that recommendations can be obtained for routes that need to be restructured, improved, or even terminated (Charnes et al. (1978); Tone (2001); Duygun et al. (2020)).

Research on the efficiency of shipping subsidies in Indonesia is still limited, particularly in the context of DEA-based analysis of state-owned enterprise (SOE) PSO routes. Most previous studies have focused on the company's financial aspects or fleet efficiency, but few have examined the spatial and temporal efficiency of each route (Rinaldi et al. (2022); Budiman & Kurniawan (2023)). Therefore, this research is expected to fill the gap in the literature and contribute to evidence-based maritime subsidy policymaking.

METHOD

This research is motivated by the need to conduct a quantitative and objective evaluation of the operational efficiency of Public Service Obligation (PSO) passenger ship routes operated by PT PELNI (Persero). The study employs the Data Envelopment Analysis (DEA) approach, a non-parametric method based on linear programming that measures the relative efficiency of Decision-Making Units (DMUs) by comparing the relationship between multiple inputs and outputs. In this research, each PSO route is treated as a DMU and evaluated according to its utilization of operational resources and the public service outcomes it generates. The efficiency scores obtained from the DEA model are used to classify routes into efficient and inefficient groups, providing an objective basis for assessing operational performance and identifying opportunities for improvement.

The research was conducted at PT PELNI (Persero), located at Jl. Gajah Mada No. 14, Central Jakarta 10130, Indonesia. The study commenced in May 2026 and is scheduled for completion in August 2026, covering the stages of proposal preparation, data collection, data

processing, data analysis, and thesis writing. The population consists of all passenger ship routes operated by PT PELNI (Persero) under the government's Public Service Obligation (PSO) program, based on the Agreement between the Directorate General of Sea Transportation and PT PELNI (Persero) for the 2023 fiscal year (Number: HK.201/I/3/DJPL/2023 and TH.01.02-02/KNP/2023) and the Decree of the Minister of Transportation of the Republic of Indonesia Number KM 154 of 2023 concerning the implementation of PSO services for the 2024 fiscal year. These assignments cover the operations of 26 passenger ships serving PSO routes throughout Indonesia.

Because the population is relatively small and complete operational data are available for all PSO routes, this study adopts a census (total sampling) approach, whereby all routes are included as Decision-Making Units (DMUs) in the DEA model. The analysis evaluates the relative efficiency of each route by comparing input variables, including operational costs and resource utilization, with output variables representing public service performance, namely the number of passengers transported, cargo carried, and sailing frequency. The findings are expected to provide evidence-based recommendations for improving operational performance, optimizing route structures, and supporting a more effective and performance-oriented allocation of PSO subsidies.

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 4.6 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

Based on the analysis results using the Data Envelopment Analysis (DEA) method of the Input-Oriented CCR model, it can be concluded that the operational efficiency level of Public Service Obligation (PSO) passenger ships of PT PELNI (Persero) still shows variations between Decision Making Units (DMU). Of the 26 passenger ships analyzed, there are 5 ships that have achieved efficient conditions with a DEA score of 1.00, while the other 21 ships are still in an inefficient condition with a DEA score below 1. These results indicate that most ships still have opportunities to increase efficiency through more optimal management of operational resources.

The research also shows that operational inefficiencies are primarily caused by the relatively excessive use of input variables compared to the resulting output. Based on the DEA projections, there is potential to reduce fuel consumption by approximately 19%, operational costs by 18%, and the number of crew members by 20%, without reducing the number of passengers, cargo volume, or frequency of sailings. These findings indicate that efficiency improvements are more effective through optimizing input usage than increasing service output.

Based on the results of the efficiency measurement, this study successfully identified ships that have achieved efficient conditions as a benchmark for ships that are not yet efficient and provided directions for improvement through the DEA approach. Thus, the results of the study can be a basis for PT PELNI (Persero) in optimizing fuel use, operational costs, and the number of crew members, as well as supporting the evaluation of PSO route management that is more effective, efficient, accountable, and sustainable in order to improve the quality of national sea transportation services.

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