DOI: 10.4274/jems.2024.28863

Journal of ETA Maritime Science 2024;12(4):395-403

Strategic Ship Fleet Planning for Crude Palm Oil Marine Transportation: A Case Study in Indonesia

Achmad Riadi, Muhammad Hanif Fajri Ramadhan

Universitas Indonesia Faculty of Engineering, Department of Mechanical Engineering, Depok, Indonesia

Abstract

This paper presents the application of strategic ship fleet planning for the maritime transportation of crude palm oil. This study aims to determine the optimal number of chemical tankers required, their capacity (in deadweight tonnage), and the appropriate timing for chartering, buying, or selling vessels within the fleet. To achieve this, mixed integer linear programing is utilized as the optimization framework for strategic ship fleet planning. To ensure a more authentic approach, the investigation utilized a case study focused on the export of Indonesian crude palm oil. The research findings indicate that several export routes cannot be serviced due to higher transportation costs, which could potentially be anticipated through an increase in freight rates. In addition, decisions regarding the quantity and categories of fleets required for each transportation route were also made. The importance of this study is highlighted by its capacity to offer valuable insights to exporters, shipping companies, and the government regarding tanker fleet deployment, management, and regulatory considerations. Furthermore, these findings provide a clearer understanding of the necessity of a tanker fleet for transporting crude palm oil. This supports the Indonesian government's "beyond cabotage" policy, which mandates the use of vessels operated by national shipping companies for crude palm oil exports, making it a relevant case study for examining the effectiveness of such measures.

Keywords: Strategic ship fleet planning, Crude palm oil, Beyond cabotage policy, Mixed integer linear programing, Optimization, Marine transportation

1. Introduction

The expansion of palm oil plantations in regions like Southeast Asia has significantly contributed to the increase in its global trade volume, although it raises concerns regarding deforestation and biodiversity loss [1]. Additionally, the growing utilization of crude palm oil (CPO) in biofuel production, driven by policies promoting renewable energy sources, has propelled its international trade, highlighting its significance in the context of energy sustainability. As a result, the intricate interplay between economic, environmental, and social factors underscores the complex dynamics influencing the escalating trade of CPO the global stage.

In the context of global CPO trade via marine transportation, the size of ships plays a pivotal role in the strategic decisions of shipping companies operating as ship operators. The choice between purchasing or chartering vessels involves meticulous consideration of cargo volume, transportation efficiency, and operational costs. Optimal ship size selection influences economies of scale, impacting loading capacities and voyage expenses, thereby allowing shipping companies to effectively meet market demands while maximizing profitability in the competitive landscape of CPO transportation.

Meeting fleet requirements requires strategic fleet planning, which involves activities like acquiring new vessels or chartering existing ones. In addition, addressing the specific characteristics of the CPO export shipping markets is crucial given their competitive and highly volatile nature. Therefore, planning should include both the timing for expanding the fleet capacity and the appropriate moments for reducing it, which can be accomplished by selling or scrapping

Address for Correspondence: Achmad Riadi, Universitas Indonesia Faculty of Engineering, Department of Mechanical Engineering, Depok, Indonesia
E-mail: achmadriadi@ui.ac.id
ORCID iD: orcid.org/0000-0002-1697-2299

Received: 08.08.2024
Last Revision Received: 22.10.2024
Accepted: 19.11.2024

To cite this article: A. Riadi, and M. H. F. Ramadhan, "Strategic Ship Fleet Planning for Crude Palm Oil Marine Transportation: A Case Study in Indonesia." *Journal of ETA Maritime Science*, vol. 12(4), pp. 395-403, 2024.

ships. Hence, the optimization of fleet planning is crucial for determining the appropriate timing for the chartering, purchasing, or selling of vessels within the fleet. Ship fleet planning in maritime transportation can be categorized based on its planning level into three main stages: strategic, tactical, and operational fleet planning [2]. Strategic fleet planning primarily focuses on critical decisions related to ship acquisition, sales, chartering, and scrapping [3]. Numerous research papers have explored strategic fleet planning in liner shipping [4-13], and tramp shipping contexts [3,14-17]. One study concentrated on strategic maritime fleet planning, incorporating the potential for retrofitting and uncertainties related to future fuel and carbon prices [18].

Strategic ship fleet planning using Mixed-Integer Linear Programing (MILP) optimization is a critical approach in the shipping industry, addressing various operational challenges, such as fleet deployment, scheduling, and cost management. This method allows for the simultaneous consideration of multiple objectives, including economic efficiency and environmental impact, thereby enhancing decision-making processes in fleet management. MILP models can optimize service schedules, vessel speeds, and cargo allocation while balancing costs and emissions. For instance, a model that integrates CO_2 emissions and operational costs demonstrates the trade-offs between economic and environmental objectives [19]. A previous study developed a MILP formulation for shuttle tankers that incorporates variable travel times to improve scheduling efficiency under logistical constraints [20]. Another study proposed a model that considers multimode investments for fleet capacity expansion to address market fluctuations and operational needs [21].

This section presents the development of a strategic ship fleet planning model tailored specifically for CPO transportation. The MILP optimization model is designed to maximize the overall profit and to offer recommendations regarding the ideal timing for chartering, buying, or selling vessels in the fleet. To be more realistic, the research was carried out using a case study of Indonesian CPO exports.

The present study differs from previous studies on strategic fleet planning of tankers [3]. The previous study primarily focused on contract analysis for tanker shipping, where strategic fleet planning was based on the existence of freight contracts in tramp shipping, such as spot charter, Contract of Affreightment, and time charter [22]. Consequently, the objective function of the optimization model is to maximize profit by determining which transportation contracts to serve. In contrast, the present study focuses on strategic fleet planning to meet the optimal fleet requirements for transporting CPOs, specifically using Indonesia as a case study. The proposed approach provides a comparative analysis between existing and optimal fleet requirements. Unlike previous studies, the present study considers the transportation demand to be fully met without regard to the form of transportation contracts. This study provides novel insights into strategic ship fleet planning by emphasizing the practical implications of MILP for both the government and shipping companies. By providing recommendations based on robust analytical models, this study aims to address specific fleet needs for exporting cargo, particularly Indonesian CPO cargo. Furthermore, the outcomes of this study align with government policies, especially beyond cabotage policy. This policy enhances the competitiveness of national shipping companies by allowing them to operate in international markets. By understanding and optimizing fleet requirements, policymakers can facilitate trade and improve the competitive position of local shipping companies in the global market. The recommendations derived from this study will not only support the implementation of the policy but also enhance the overall economic performance of the maritime sector.

The remainder of this study is organized as follows. Section 2 outlines the materials and methods, Section 3 discusses the results and analysis, and Section 4 provides the conclusions.

2. Materials and Methods

2.1. Study Area

The CPO is a key export commodity for Indonesia. It is exported to various countries, including India and several European Union nations, while the remainder is sold domestically. Hence, it was selected as our study case. Statistics on Indonesia's CPO exports reveal a consistent upward trend from 2016 to 2019, with annual growth rates ranging from 12.03% to 19.44% [23]. Given the growing global demand for CPO, Indonesia's CPO export volume is expected to continue to rise [24].

With the increasing volume of CPO exports, the Indonesian government took steps to establish a national maritime transportation policy. This policy was introduced through a series of Minister of Trade Regulations, including Number 82 of 2017, Number 80 of 2018, Number 40 of 2020, and Number 65 of 2020 [25-28]. Among these regulations, one significant policy stipulates that exporters are obligated to utilize vessels under the control of national shipping companies when exporting certain commodities, including CPOs. The rationale behind implementing this policy is rooted in various factors, such as challenging global economic conditions and Indonesia's trade deficit in the services sector [29]. This policy is commonly called the "beyond cabotage policy", and it has been in effect since July 2020 [30].

Currently, the fleet of chemical tankers registered under the Indonesian flag and operated by national shipping companies primarily serves the transportation of CPO between domestic ports for domestic transportation needs. In contrast, foreign shipping companies appointed by CPO importers largely handle the transportation of CPO for export purposes. The trade of CPO exports from Indonesia generally uses International Commercial Terms (INCOTERMS) of the Free on Board (FOB) terms, with the Cost Insurance and Freight (CIF) terms being very rarely used [31].

The Beyond Cabotage policy implemented by the Indonesian government aligns with the government's desire to propose a shift in international shipping INCOTERMS, specifically for CPO, from FOB to CIF. Implementing the beyond cabotage policy for CPO exports presents considerable challenges if not supported by an adequate fleet of chemical tankers. According to the Indonesian Ministry of Transportation, only 65 Indonesian-flagged chemical tankers suitable for transporting CPO is only 65 units, representing a mere 3.4% of the total tanker fleet [32]. Figure 1 shows the descriptive statistics (box-plot) of the fleet of chemical tankers transporting CPO. It can be seen that the average gross tonnage (GT) was 3,600 GT, and the average Length Overall (LOA) of the fleet was 94 meters. Only a few chemical tankers have a capacity above 10,000 GT and a length above 120 meters.

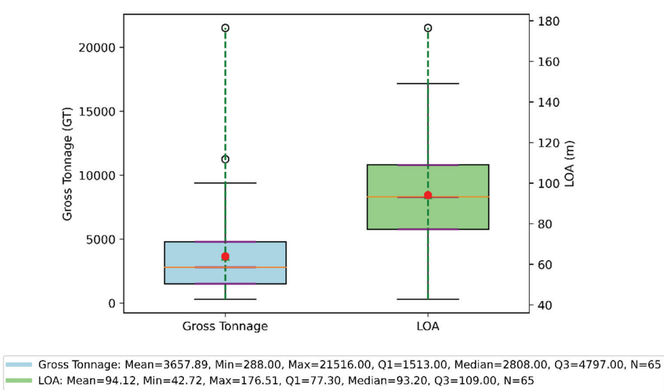

Figure 1. *Descriptive statistics (box-plot) of the fleet of chemical tankers transporting CPO*

CPO: Crude Palm Oil, LOA: Length Overall

2.2. Research Framework

In this study, a strategic ship fleet planning model was developed to determine the optimal number of chemical tankers required, their capacities, and the suitable timing for chartering, purchasing, and selling the fleet for transporting Indonesian CPO exports. Figure 2 depicts a schematic representation of the research framework.

This study began with data collection, including demand data for Indonesia's CPO export, chemical tanker fleet, and shipping cost data. Each dataset was then used for statistical analysis and clustering models to determine alternative chemical tankers to be considered in fleet planning. Subsequently, an optimization process was conducted using MILP to generate objectives in the form of the optimal number of chemical tankers required, their capacities, and the suitable timing for chartering, purchasing, and selling the fleet. In the optimization process conducted using MILP, there are several optimization conditions grouped as objective functions, decision variables, and constraints, as can be seen in Table 1.

2.3. Model Assumptions

The developed strategic ship fleet planning model considers CPO export demands from Indonesia to various export destinations over multiple years. This approach addresses challenges in determining the number of ships to operate, when acquiring or chartering vessels, and optimizing ship capacity.

To address this challenge, optimization-based fleet planning aims to maximize profits by considering the revenue generated from freight costs charged to shippers and shipping costs based on the export destination and the used fleet.

Several model assumptions are made, including those pertaining to CPO export destination routes. Specifically, the model considers the five largest CPO export destinations: India, China, Pakistan, the Netherlands, and the United States. Data on CPO export demand in these countries were obtained from the microdata service of the Indonesian Central Bureau of Statistics [33]. Using the obtained data, CPO export demand forecasting was conducted for the 10-year fleet planning period (2023 to 2032). The forecasting model used is exponential smoothing forecasting based on the Additive Error, Additive Trend, and Additive Seasonality for Exponential Triple Smoothing algorithm. This algorithm mitigates minor fluctuations in historical data trends by identifying seasonal patterns and establishing confidence intervals [34].

To determine the optimal vessel capacity, a vessel alternative approach is employed, which is obtained by applying the K-Means clustering algorithm. Over 100 Indonesian and foreign-flagged chemical tankers are used for both domestic and international CPO shipments [32]. Ship data, including GT, LOA, and service speed (Vs), are used as attributes in the clustering method. The clustering results yield 6 clusters, each represented by the vessel closest to the cluster centroid. The clustering results are visualized in Figure 3, and vessel alternatives are derived from the vessels representing each cluster, as shown in Table 2. The table also presents several variables, such as dead weight tonnage (DWT), Draft, Main Engine (M/E) capacity, and Auxiliary Engine (A/E) capacity. These variables are used to calculate the cost of operating each vessel.

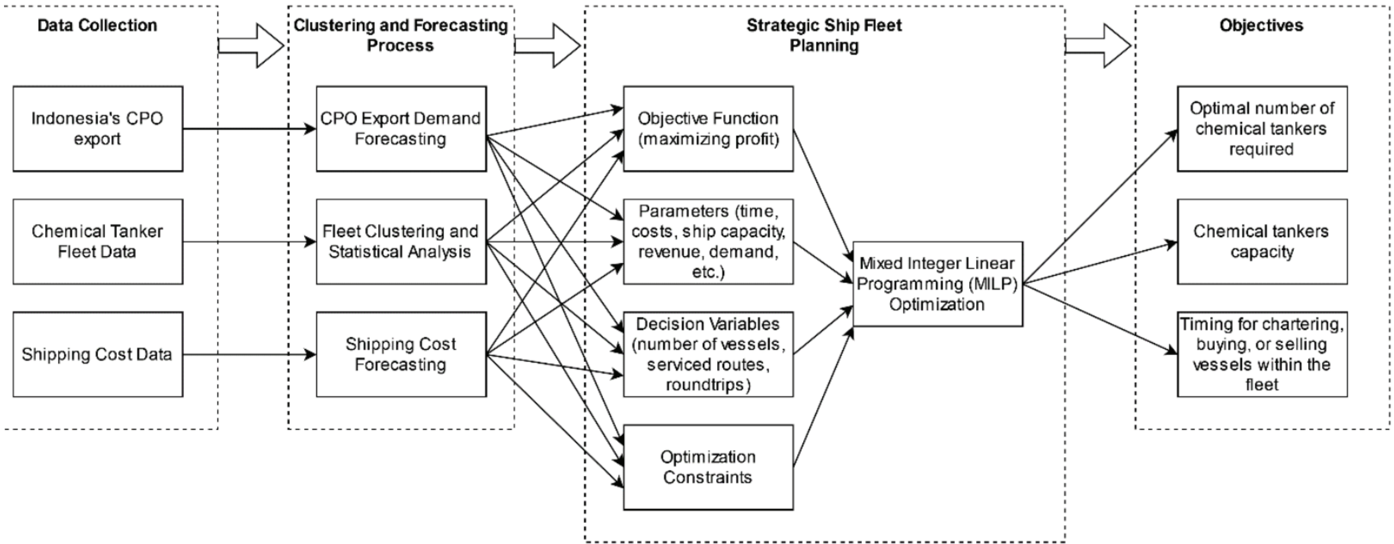

Figure 2. *Research framework*

CPO: Crude Palm Oil

Table 1. *Optimization conditions*

Objective Function	Decision Variables	Constraints
Maximizing profit to serve the export transportation of CPOs from Indonesia to several export destination countries.	• The number and capacity of vessels chartered. • Number and capacity of owned vessels, including newly built and secondary acquired vessels. • Number of round trips. • Serviced and non-serviced routes.	• Vessels must have sufficient capacity to meet the CPO requirements for serviced routes. • The total time spent on all round trips for each vessel type does not exceed the available time.
CPO: Crude Palm Oil		

Table 2. *Alternative chemical tankers to be considered in fleet planning*

Cluster	Vessel alternatives	DWT (ton)	Gross tonnage (GT)	LOA (m)	Vs (knots)	Draft (m)	M/E (kW)	A/E (kW)
0	*v*1	9,045	5,256	110	10	7.5	2,720	1,341
1	*v*2	49,539	29,965	183	12	12.5	12,750	3,600
2	*v*3	12,975	8,448	127	12	8.7	4,440	1,680
3	*v*4	25,086	16,202	160	14	10.5	5,200	1,800
4	*v*5	19,992	11,925	146	12	9.5	6,150	1,649
5	*v*6	3,974	2,432	85	5	4.1	462	240

Before presenting the optimization model's formulation, the notations are defined in Tables 3-5.

2.4. Model Formulations

Equation 1 defines the objective function, which maximizes profit. The initial component assesses the revenue generated from servicing existing CPO export routes from Indonesia to various destinations or evaluates the feasibility of servicing these routes. The second component calculates the revenue obtained from chartering and selling vessels, considering the number of vessels and transaction values. The third component determines the costs associated with chartering and acquiring new vessels. The fourth component estimates the expenses related to new vessel purchases. The fifth component addresses the costs incurred during voyages. The sixth component includes both the operational and capital expenses associated with owned vessels.

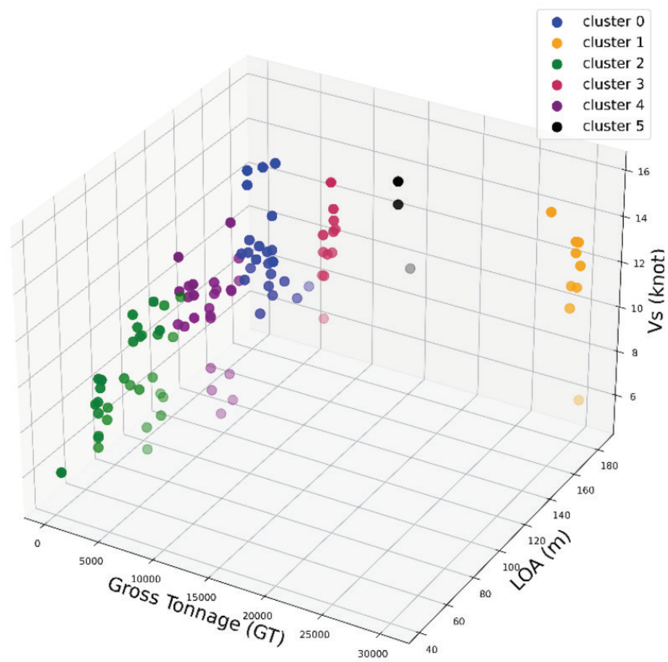

Figure 3. *Visualization of chemical tanker clustering results*

$$max \sum_{r\in R} R_r^{SV}\, \alpha_r + \sum_{v\in V}\sum_{t\in T} R_{vt}^{TC}\, N_{vt}^{TCout} + \sum_{v\in V}\sum_{t\in T} R_{vt}^{SL}\, N_{vt}^{SL} - \sum_{v\in V}\sum_{t\in T} C_{vt}^{TC}\, N_{vt}^{TCin} - \sum_{v\in V}\sum_{t\in T} C_{vt}^{BY}\, N_{vt}^{BY}$$
$$- \sum_{v\in V}\sum_{t\in T} C_{vt}^{NW}\, N_{vt}^{NW} - \sum_{v\in V}\sum_{r\in R}\sum_{t\in T} C_{vr}^{VY}\, y_{vrt} - \sum_{v\in V}\sum_{t\in T} (C_{vt}^{OP} + C_{vt}^{CP})\, N_{vt}^{OWN} \quad (1)$$

Equation 2 maintains the total count of owned vessels, and Equation 3 guarantees the total count of controlled and operated vessels. Equation 4 specifies that only owned vessels can be chartered. Equations 5 and 6 define the initial fleet, and Equation 7 restricts the acquisition of newly built vessels in the early stages due to delivery time requirements.

$$N_{vt}^{OWN} = N_{v,t-1}^{OWN} + N_{vt}^{BY} - N_{vt}^{SL} + N_{vt}^{NW} \quad \forall\ v \in V, t \in T \quad (2)$$

$$N_{vt}^{TOT} = N_{vt}^{OWN} + N_{vt}^{TCin} - N_{vt}^{TCout} \quad \forall\ v \in V, t \in T \quad (3)$$

$$N_{vt}^{OWN} \geq N_{vt}^{TCout} \quad \forall\ v \in V, t \in T \quad (4)$$

$$N_{v,0}^{OWN} = F_v^0 \quad \forall\ v \in V \quad (5)$$

$$N_{v,0}^{TOT} = N_{v,0}^{OWN} + N_{v,0}^{TCin} - N_{v,0}^{TCout} \quad \forall\ v \in V \quad (6)$$

$$N_{v,1}^{NW} = 0 \quad \forall\ v \in V \quad (7)$$

Equations 8 and 9 represent CPO demand and fleet capacity constraints. Equation 8 guarantees that the fleet has sufficient capacity to meet the CPO demands for the serviced routes, while Equation 9 ensures that the total time spent on all round trips for each vessel type on a route does not exceed the available time.

$$\sum_{v\in V} P_v A_{vr} y_{vrt} \geq D_{rt} \alpha_r \quad \forall\ t \in T, r \in R \quad (8)$$

$$T_{vt}^{TOT} N_{vt}^{TOT} \geq \sum_{r\in R} T_{vr} y_{vrt} \quad \forall\ v \in V, t \in T \quad (9)$$

Equations 10-12 define the characteristics of variables such as Boolean and integer.

$$\alpha_r \in \{0,1\} \quad \forall\ r \in R \quad (10)$$

$$N_{vt}^{TOT}, N_{vt}^{OWN}, N_{vt}^{TCin}, N_{vt}^{TCout}, N_{vt}^{BY}, N_{vt}^{NW}, N_{vt}^{SL} \geq 0 \text{ and integer } \forall\ v \in V, t \in T \quad (11)$$

$$y_{vrt} \geq 0 \text{ and integer } \quad \forall\ v \in V, r \in R, t \in T \quad (12)$$

3. Results

The MILP optimization model was solved using the MILP solver available in Matrix Laboratory (MATLAB) software [38]. Table 6 presents the results of the decision variable α_r, where 1 indicates that route r is serviced, and 0 indicates otherwise. It is noteworthy that CPO export routes to India and Pakistan are not currently serviced. Optimization models aim to maximize profits by finding optimal solutions. Thus, these two routes have higher shipping costs than the revenue generated by them.

Table 3. *Sets and indices*

Set	Index	Description
T	*t*	The time periods are denoted as $T = \{0,1,2,3,\cdots,T_{max}\}$, where period 0 represents the initial planning phase, and T_{max} indicates the maximum time period considered.
R	*r*	Available CPO export routes from Indonesia to other countries
V	*v*	Available vessel types

Table 4. *Parameters*

Parameter	Description	Unit	Data collection
T_{vr}	The total duration of a roundtrip of vessel type *v* on route *r*, encompassing both the time spent at sea and the time spent in port.	Days	[35]
T_{vt}^{TOT}	Total time available for vessel type *v* during the period *t*	Days	Depends on the vessel docking time (14 to 30 days)
D_{rt}	Demand for CPO on route *r* during the period *t*	Ton	[33]
P_v	The cargo capacity (Payload) of the vessel *v*	Ton	90% of the DWT
A_{vr}	This binary parameter is set to 1 if assigning vessel type *v* on route *r* is feasible. Draft-related constraints typically define this parameter.	-	Port bathymetry along each route
F_v^0	Quantity of vessels of type *v* that are owned during the planning period	Ship	set to 0, implying that no vessel was owned during the planning period.
R_r^{SV}	Revenue from the servicing route *r*	USD	Based on forecasted CPO export demand and calculated freight rate for each route
R_{vt}^{SL}	Revenue generated from sale of vessel type *v* during the period *t*	USD	Based on depreciation calculation (5% per year)
R_{vt}^{TC}	The revenue generated from time chartering vessel type *v* during the period *t*	USD	Based on the time charter rate [36]
C_{vr}^{VY}	The cost of a round trip for sailing route *r* with vessel type *v*	USD	Based on port and fuel consumption cost
C_{vt}^{BY}	The expenditure for acquiring vessel type *v* during the period *t*	USD	Based on depreciation calculation (5% per year)
C_{vt}^{NW}	The expense associated with acquiring a new vessel of type *v* during the period *t*	USD	Tanker new building price (BIMCO)
C_{vt}^{TC}	The expenses associated with chartering a vessel of type *v* during the period *t*	USD	Based on the time charter rate [36]
C_{vt}^{OP}	Operational costs of vessel type *v* during the period *t*	USD	Based on vessel operating expenses per DWT [37]
C_{vt}^{CP}	Capital expenditures for vessel type *v* during the period *t*	USD	80% of the acquisition price with an interest rate of 4% per year [3]

Table 5. *Decision variables*

Decision variable	Description	Unit
N_{vt}^{TOT}	Total number of vessels type *v* utilized during the period *t*	Ship
N_{vt}^{OWN}	Number of vessels of type *v* owned during the period *t*	Ship
N_{vt}^{TCin}	Number of vessels of type *v* that are on time charter (charter in) during the period *t*	Ship
N_{vt}^{TCout}	Number of vessels of type *v* that are under time charter (charter out) during the period *t*	Ship
N_{vt}^{BY}	Number of vessels of type *v* obtained during the period *t*	Ship
N_{vt}^{NW}	Number of newly ordered buildings of type *v* vessels during the period *t*	Ship
N_{vt}^{SL}	Number of vessels of type *v* sold during the period *t*	Ship
α_r	A binary variable that takes the value of 1 if route *r* is serviced and 0 if it is not	-
y_{vrt}	Total number of roundtrip completed by vessel type *v* on route *r* during the period *t*	Roundtrip

In cases where an unserved export route exists, a specific increase in the freight rate on that route is required to boost revenue. This is done, of course, to ensure that the route can still be serviced while generating income for the shipping business. The question is, to what extent should the freight rate increase be applied to that route? This requires further analysis, including the use of methods such as sensitivity analysis.

As mentioned before, the Indonesian government, through the Ministry of Trade, is proposing a shift in international shipping incomers, specifically for CPOs, from FOB to

CIF [31]. This policy change also drives the emergence of a beyond cabotage policy as a subsequent measure. The policy does not restrict CPO exports to specific countries; rather, it creates opportunities for shipping and transportation companies to actively participate in the CPO export business. Thus, although this research indicates the existence of underserved CPO export routes, it does not imply that these routes cannot be served. Shipping companies can cater to these routes, albeit with the requirement for a minimum increase in freight costs to achieve a balance between revenue and operational expenses.

The results generated from this research are displayed in Table 7. The table displays the fleet planning results during the planned period. This includes the total number of operated vessels, the number of owned, acquired, newly built, and chartered-in/out vessels, and the number of sold vessels. In the early stages of the planning period, the fleet is prepared by chartering-in, followed by acquisition of the fleet without any new builds until the end of the planning period. Some of the acquired vessels were chartered out during this period. This demonstrates that, in addition to the CPO freight market, the charter market also offers promising revenue opportunities. Furthermore, there were several sales of owned vessels during the planning period.

Table 6. *Decision variable α_r*

*r*1 India	*r*2 China	*r*3 Pakistan	*r*4 Dutch	*r*5 US
0	1	0	1	1

Table 8 presents the number of vessels operated for each vessel alternative (fleet size and mix). Alternative vessel number 4 (*v*4), with a capacity of approximately 16,000 GT, emerges as the preferred option. Although the principle of economies of scale indicates that larger vessels offer better benefits, it does not imply that vessels with large capacities can be used indiscriminately. Draft limitations for vessels entering certain ports are significant factors in this decision. Vessel number 4 did not have the largest capacity but was the second-largest among the alternatives considered in

Table 7. *Result of fleet planning (number of vessels)*

Planning period	Operated	Owned	Acquired	New built	Charter in	Charter out	Sold
1	33	0	0	0	33	0	0
2	34	59	59	0	0	25	0
3	39	64	5	0	0	25	0
4	38	68	6	0	0	30	2
5	56	86	18	0	0	30	0
6	55	85	0	0	0	30	1
7	51	81	1	0	0	30	5
8	52	82	6	0	0	30	5
9	45	75	0	0	0	30	7
10	53	45	0	0	8	0	30

Table 8. *Number of vessels operated for each vessel alternative*

Number of operated vessels						
Period	*v*1	*v*2	*v*3	*v*4	*v*5	*v*6
1	0	0	0	33	0	0
2	0	0	0	34	0	0
3	0	0	0	39	0	0
4	0	0	0	37	0	1
5	0	0	0	41	0	15
6	0	0	0	40	0	15
7	0	0	0	41	0	10
8	0	0	0	47	0	5
9	0	0	0	45	0	0
10	0	0	0	51	0	2

Table 2. This indicates that the maximum draft limitation, represented by the A_{vr} parameter in the optimization model, is appropriate. Therefore, the obtained results can be deemed feasible.

Based on the data presented in Figure 1, the existing chemical tanker fleet has an average capacity of approximately 3,600 GT, comprising 65 vessels. Meanwhile, the optimization results (Table 8) indicate a trend toward an increasing fleet size of type $v4$ vessels, with the overall fleet size steadily growing. The vessel type, $v4$, has a capacity of approximately 16,000 GT, as indicated in Table 2. This indicates a potential gap between the fleet requirements based on the optimization results and the actual conditions of the existing fleet. The composition of this fleet provides insights for shipping companies in executing CPO transportation, particularly for exports. Moreover, it serves as a focal point for the government to assess and evaluate the fleet support provided by national shipping companies in implementing beyond cabotage policy.

This research, at the very least, can provide a solution to the tendency of mutual waiting between shipping companies and the government. Shipping companies await the development of the CPO shipping industry, while the government continues to wait for shipping companies to increase their fleet size to support the export of Indonesian CPO. Therefore, this research provides an overview of solutions for shipping companies to decide on acquiring fleets to support the implementation of the beyond cabotage policy advocated by the government.

4. Conclusion

This study developed a strategic ship fleet planning model tailored for Indonesian CPO exports to determine the optimal number of chemical tankers required, their capacities, and the appropriate timing for chartering, purchasing, or selling vessels. The model, which is structured as MILP optimization, was designed to maximize profits while ensuring the fleet's capacity meets the CPO export demands.

The analysis revealed a significant gap between the current capabilities of the existing tanker fleet and the requirements identified by the optimization results. The existing fleet had a relatively low average capacity, which was insufficient to meet the optimal fleet needs for CPO transportation. In contrast, the optimization results indicate a clear trend toward increasing the fleet size, particularly for a specific vessel type with a much larger capacity. This disparity highlights the necessity for fleet expansion to align with the growing demand for CPO exports, emphasizing the potential for enhanced operational efficiency and profitability through strategic investments in larger, more capable vessels.

Upon careful examination of the fleet planning results outlined earlier, it is possible to derive significant conclusions pertaining to the indispensable fleet requisites essential for bolstering Indonesian CPO export endeavors and effectively addressing the intricacies posed by "the beyond cabotage policy". The essence of this research lies in its comprehensive exploration of strategic fleet planning concerns, encompassing not only the intricacies of ascertaining the precise number of vessels for operation but also the intricacies of determining the opportune moments for vessel acquisition or charter. Additionally, a crucial facet of this investigation involves the meticulous determination of the optimal ship capacity to ensure optimal operational efficiency. However, it is imperative to underscore the necessity for further in-depth analysis, with a particular focus on scrutinizing the dynamics of shifts in CPO demand, fluctuations in shipping costs, and the nuanced considerations surrounding ship charter expenses.

Footnotes

Authorship Contributions

Concept design: A. Riadi, Data Collection or Processing: A. Riadi, Analysis or Interpretation: A. Riadi, Literature Review: M. H. F. Ramadhan, Writing, Reviewing and Editing: A. Riadi, and M. H. F. Ramadhan.

Funding: This work is supported by "Hibah Publikasi Terindeks Internasional (PUTI) Q3 2020" funded by DRPM Universitas Indonesia no.: NKB-4577/UN2.RST/HKP.05.00/2020.

References

[1] L. P. Koh, and D. S. Wilcove, "Is oil palm agriculture really destroying tropical biodiversity?". *Conservation Letters*, vol. 1, pp. 60-64, Jun 2008.

[2] M. Christiansen, K. Fagerholt, B. Nygreen, and D. Ronen, "Chapter 4 maritime transportation". *Handbooks in Operations Research and Management Science,* vol. 14, pp. 189-284, 2007.

[3] J. Laake, and A. Zhang, "Joint optimization of strategic fleet planning and contract analysis in tramp shipping". *Applied Economics*, vol. 48, pp. 203-211, Jan 2016.

[4] A. N. Perakis, and D. I. Jaramillo, "Fleet deployment optimization for liner shipping Part 1. Background, problem formulation and solution approaches". *Maritime Policy & Management*, vol. 18, pp. 183-200, Jan 1991.

[5] D. I. Jaramillo, and A. N. Perakis, "Fleet deployment optimization for liner shipping Part 2. Implementation and results". *Maritime Policy & Management*, vol. 18, pp. 235-262, Jan 1991.

[6] S.-C. Cho, and A. N. Perakis, "Optimal liner fleet routing strategies". *Maritime Policy & Management*, vol. 23, pp. 249-259, Jan 1996.

[7] B. J. Powell, and A. N. Perkins, "Fleet deployment optimization for liner shipping: an integer programming model". *Maritime Policy & Management*, vol. 24, pp. 183-192, Jan 1997.

[8] A. Imai, and F. Rivera, "Strategic fleet size planning for maritime refrigerated containers". *Maritime Policy & Management*, vol. 28, pp. 361-374, Oct 2001.

[9] K. Fagerholt, T. A. V. Johnsen, and H. Lindstad, "Fleet deployment in liner shipping: a case study". *Maritime Policy & Management*, vol. 36, pp. 397-409, Oct 2009.

[10] Q. Meng, and T. Wang, "A chance constrained programming model for short-term liner ship fleet planning problems". *Maritime Policy & Management*, vol. 37, pp. 329-346, Jul 2010.

[11] Q. Meng, and T. Wang, "A scenario-based dynamic programming model for multi-period liner ship fleet planning". *Transportation Research Part E: Logistics and Transportation Review,* vol. 47, pp. 401-413, Jul 2011.

[12] D. F. Koza, S. Ropke, and A. Boleda Molas, "The liquefied natural gas infrastructure and tanker fleet sizing problem". *Transportation Research Part E: Logistics and Transportation Review,* vol. 99, pp. 96-114, Mar 2017.

[13] J. Xia, K. X. Li, H. Ma, and Z. Xu, "Joint planning of fleet deployment, speed optimization, and cargo allocation for liner shipping". *Transportation Science*, vol. 49, pp. 922-938, Nov 2015.

[14] K. Fagerholt, "Optimal policies for maintaining a supply service in the Norwegian Sea". *Omega (Westport)*, vol. 28, pp. 269-275, Jun 2000.

[15] X. Xinlian, W. Tengfei, and C. Daisong, "A dynamic model and algorithm for fleet planning" *Maritime Policy & Management*, vol. 27, pp. 53-63, Jan 2000.

[16] K. Fagerholt, M. Christiansen, L. Magnus Hvattum, T. A. V. Johnsen, and T. J. Vabø, "A decision support methodology for strategic planning in maritime transportation". *Omega (Westport)*, vol. 38, pp. 465-474, Dec 2010.

[17] J. F. Alvarez, P. Tsilingiris, E. S. Engebrethsen, and N. M. P. Kakalis, "Robust fleet sizing and deployment for industrial and independent bulk ocean shipping companies". *INFOR: Information Systems and Operational Research*, vol. 49, pp. 93-107, May 2011.

[18] O. Loennechen, K. Fagerholt, B. Lagemann, and M. Stålhane, "Maritime fleet composition under future greenhouse gas emission restrictions and uncertain fuel prices". *Maritime Transport Research*, vol. 6, 100103, Jun 2024.

[19] J. Mandal, A. Goswami, L. Thakur, and M. K. Tiwari, "*Simultaneous planning of liner ship speed optimization, fleet deployment, scheduling and cargo allocation with container transshipment*". Jul 2023.

[20] L. S. de Assis, and E. Camponogara, "A MILP model for planning the trips of dynamic positioned tankers with variable travel time". *Transportation Research Part E: Logistics and Transportation Review,* vol. 93, pp. 372-388, Sep 2016.

[21] Q. Yang, X. Xie, and W. Huo, "Modeling fleet planning strategy based on multimode investment". *Published in: 2009 Second International Symposium on Computational Intelligence and Design,* pp. 493-496, 2009.

[22] M. Stopford, *Maritime Economics 3e.* 3rd edition, Routledge, London. 2008.

[23] Subdirektorat Statistik Tanaman Perkebunan, *Indonesian Oil Palm Statistics 2019*. Badan Pusat Statistik, 2020.

[24] R. Y. Priyati, "Determinants of global palm oil demand: A gravity approach". *Economic Journal of Emerging Markets*, vol. 10, pp. 148-164, Oct 2018.

[25] Kementerian Perdagangan, *Peraturan Menteri Perdagangan No.* 82. 2017. [Online]. Available: https://peraturan.bpk.go.id/Home/Download/119670/Permendag No. 82 Tahun 2017.pdf

[26] Kementerian Perdagangan, *Peraturan Menteri Perdagangan No. 80*. [Online]. Available: https://peraturan.bpk.go.id/Home/Download/119404/Permendag No. 80 Tahun 2018.pdf

[27] Kementerian Perdagangan, *Peraturan Menteri Perdagangan No. 40*. 2020. [Online]. Available: https://peraturan.bpk.go.id/Home/Download/152850/Permendag Nomor 40 Tahun 2020.pdf

[28] Kementerian Perdagangan, *Peraturan Menteri Perdagangan No. 65*. 2020. Accessed: May 24, 2022. [Online]. Available: https://peraturan.bpk.go.id/Home/Download/152883/Permendag Nomor 65 Tahun 2020.pdf

[29] M. Reily, "*Indonesia Ministry of trade answered the criticism of the obligatory insurance and sea transportation policy*". Accessed: Aug 03, 2021. [Online]. Available: https://katadata.co.id/berita/2019/01/21/kemendag-jawab-kritik-soal-kebijakan-wajib-asuransi-dan-angkutan-laut

[30] Staf Ahli Menteri PPN Bidang Hubungan Kelembagaan, "Kajian Tantangan dan Hambatan Pelaksanaan Beyond Cabotage di Indonesia" 2020.

[31] World Bank, *Evaluating the Shift in Incoterms for Indonesian Export Products*. World Bank, 2016.

[32] Departemen Perhubungan, "Indonesian flag ship database". 2021. [Online]. Available: https://kapal.dephub.go.id/index.php/monitoring/

[33] Badan Pusat Statistik, "Indonesian central statistics agency". https://www.bps.go.id/.

[34] R. J. Hyndman, and G. Athanasopoulos, "Forecasting: Principles and Practice (2nd ed)." Accessed: May 30, 2024. [Online]. Available: https://otexts.com/fpp2/

[35] Ports.com, "*Sea route & distance - ports.com*". Accessed: May 30, 2023. [Online]. Available: http://ports.com/sea-route/

[36] E. Plomaritou, and A. Papadopoulos, *Shipbroking and Chartering Practice*. Eighth edition. | Milton Park, Abingdon, Oxon; New York, NY : Informa Law from Routledge, 2018. | Series: Lloyd's practical shipping guides: Informa Law from Routledge, 2017.

[37] Market Realist, "Comparing Tanker Companies' Operating Expenses per DWT". Accessed: May 30, 2023. [Online]. Available: https://marketrealist.com/2015/07/comparing-tanker-companies-operating-expenses-per-dwt/

[38] Mathworks, "MILP Solver MATLAB". https://www.mathworks.com.