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Optimization of Fleet Size and Mix Problems in Indonesian Sea Tollway

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This article deals with the Fleet Size and Mix Problem (FSMP). The main focus is to find the optimal fleet size and the type of ships used for the Indonesian Sea Tollway. A mathematical model for anticipating fleet demand under various circumstances has been built. The model primarily focuses on the strategic level, where the task is to minimize the total renting and operating/fuel costs for the vessels during the planning horizon. A deployment model was also generated to test the Fleet Size and Mix Model's accuracy, which comes under tactical planning. Fleet composition is given in tactical planning, and the goal is to find the precise utilization of the available ship to fulfil the transportation demand. Both FSM and FDM Models for our given problem are solved by integer programming on Python using Pandas, Numpy, and Pulp libraries. This article can be used as a guide to assist the Indonesian government in finding the exact fleet composition and routing.

[Keywords: Fleet size and mix problems, Indonesian Sea Tollways, Fleet deployment Problems, Integer programming, routing and scheduling problems]

1 INTRODUCTION

Maritime transport (or ocean transport) is the transport of people (travellers) or items (cargo) through conduits. Cargo transport by waterways has been broadly utilized all through recorded history. While aviation has reduced the importance of sea travel for passengers, it remains popular for short trips and delightful cruises. Water transit is less expensive than air transport [Sto09]. The ask for marine transportation is faultlessly related to around the world budgetary headway and effectiveness.

Since 1980, there has been an expansion in the maritime fleet by 25% approximately. Yet, simultaneously, the world productivity has become more remarkable with only half of that [HCA10]. This caused an impenetrable rivalry between shipping companies, compelling them to function with reducing edges, which can be referred a questionable market. Furthermore, there has been a shift within the political climate (e.g., common points).

Afloat towards fundamental rationalization can be found; horizontal and vertical incorporation of shipping into terminal operations and hinterland transportation is possible [VV09]. However, the maritime industry is traditionalist and conservative, with low-risk family companies still inside the show's run. As a result, when surveying their long-term wander plans, most companies continue to place a high value on knowledge and subjective analysis performed by experienced examiners, as they have in the past. Therefore, finding the ideal task force to evaluate and mix ships (strategic planning) for potential needs is the most dominant and challenging settlement for any shipping company.

It is a general practice in the shipping industry to categorize planning decisions according to their time. Strategic preparation is done for years, tactical planning is done for months, and operational planning is done daily. The dilemma of fleet size and the combination is commonly referred to as a strategic planning decision. However, one must consider both tactical and operational aspects, as the available vessels dictate possible routing options and overall profits [FCH10].

Fleet Size and Mix Model (FSM) comes under strategic planning, and Fleet Deployment Model (FDM) comes under tactical problem. Indonesia has been selected for our case study because Indonesia is a maritime country, strategically located between the Indian and Pacific oceans, with seas covering more than 50% of its land. In addition to that, almost 90% of the international trade is transported by sea. Out of which, 40% of these global trade passes through Indonesia. However, despite these enormous numbers, the primary mode of transport in Indonesia is roadways. Indonesia, thus, utilizes 90% of land routes. Mode of transportation by sea is limited to only 9%, and the remaining 1% is by trains [PN19].

Indonesian ports are still lagging behind the ports of Singapore, Thailand, and Malaysia in terms of quality, performance, operability, and functionality. The fundamental reason for this is that the western region generates more than 80% of the GDP, while the eastern region contributes less than 20% of GDP. As a result, there are more shipping trade activities in the region around Java since this region is more developed. At the same time, eastern Indonesia is less developed due to the significant distance and low demand/supply from these regions. As a result, cargo distribution is problematic, and cargo transport prices in the eastern region are much higher than in the western region [PN19]. Thus shipping companies do not prefer to sail in the eastern region because of low demand, higher transport prices, and lower profits.

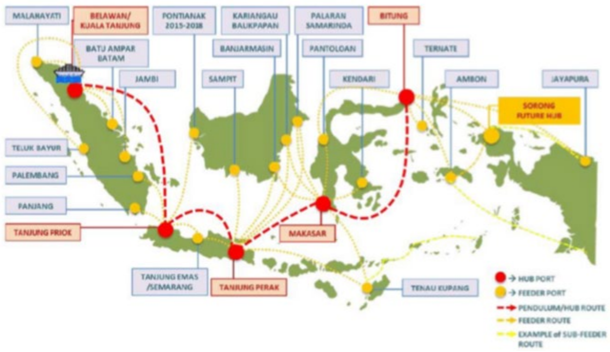

Figure 1. Indonesian Sea Tollway Ports (Source: Ministry of National Development Planning-BAPPENAS, 2015)

Therefore, President Jokowi launched this program in 2014 involving 24 strategic ports and 18 routes connecting the west to east of Indonesia. This program's objective is to ease connectivity, improve the cost efficiency of goods, capitalize on a strategic maritime position and solve serious backhaul problems. Indonesian Sea Tollway is organizing marine transportation regularly connecting ports from western to eastern Indonesia [PN19].

Figure 2. Route-3 and 8 in Indonesian Sea Tollway 2017

In addition to the connectivity, the Indonesian Sea Tollway also facilitates trading from Pacific countries to Eastern Asian countries. The main goal here is to enhance the connectivity not only locally but also internationally. In this program, there are two international ports, i.e. Kuala Tanjug and the port of Bitung, for serving service to large commercial vessels. Indonesian Sea Tollway is a liner shipping with hub and spoke network, having five hub ports (Two international and Three national hubs) and 19 feeder ports, as shown in figure 1 [PN19].

We have worked on T-3 (Tanjug Perak - Calabai/Dompu - Maumere - Larantuka - Lewoleba - Rote - Sabu - Waingapu - Sabu - Rote - Lewoleba - Larantaku - Maumere - Calabai/Dompu - Tanjung Perak) and T-8 (Tanjung Perak - Belang Belang - Sangatta - Sebatik - Sangatta - Belang Belang - Tanjung Perak) routes, which is given in Indonesia Sea Tollway 2017. The article aims to build a suitable FSM and FDM Model for these two routes, shown in figure 2.

2 Theoretical Background

The shipping industry can be divided into divisions and groups in various ways, one of which is to differentiate between the ship's modes of service. Lawson introduced this division in 1972. Lawson splits up shipping into three categories: industrial, tramp, and liner activities. Industrial shipping is defined as when the same person owns both the ships and the cargo. The objective of shipping is to transport cargo for the least amount of money. Tramp shipping is similar to a taxi service in which it follows available cargo on the market. Although it may have a specific load of contractual goods to ship, additionally, it trades on the commodities market to expand the gains. Contrarily, companies with liner shipping, like a bus line, follow fixed itineraries and schedules between predetermined ports. The different operating modes are not inconsistent; a ship can operate in several modes simultaneously and efficiently. A freight company's fleet can be used in various ways at the same time [CFR04].

Over the past couple of years, the shipping segment has boomed a lot. Fleet size and mix problems (FSMP), which comes under strategic planning, play a vital role in assigning diverse ships to already predefined routes. However, the model is affected by fluctuating demands, shipping capacities, operation, serviceability, and various other uncertainties. As a result, the shipping industry is always left with an open question: How the Fleet has been developed most effectively to suit the given market and future demands?

Long before the recent slowdown following the UNCTAD in 2010, maritime economics has always been defined by a periodic recurrence of peaks and troughs in demand and freight rates. Although demand for maritime transportation responds instantly to changes in freight rates, supply responds more slowly, owing to the long lead time associated with the procurement of new ships. As a result, supply and demand imbalances are regular. The global fleet was increased by 7% in 2009 over the previous year, a trend that persisted into the first quarter of 2010, despite lower trade volumes. Orders for new ships placed before the downturn resulted in a tonnage oversupply. Tonnage is

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usually renewed in a trough, whereas disposal of older ships is frequently postponed at a peak. Demolitions of old tonnes increased by 300 per cent in 2009, indicating this tendency [ABF10].

According to Stopford, these elements are among the leading causes for the wave-motions in cargo prices, which can be portrayed in different cycles [Sto09]:

1. Long-term cycles, ordinarily caused by significant changes within the businesses of seaborne commodities.
2. Short-term cycles, which primarily take after the advancement of the world economy
3. Seasonal cycles, which are common in many seaborne product exchanges (e.g., rural ones).

Designing an optimum ship fleet is a critical strategic decision for shipping companies operating in such an unpredictable and changing climate. The maritime fleet size and mix issue (MFSMP) is essentially a decision about how many vessels and what type to use to satisfy demand. The goal is to optimize the overall cost of establishing and maintaining the ships, and the problem generally entails ship routing or deployment decisions to help tonnage estimation [GFH14].

As stated in the introduction, uncertainty in maritime transportation affects all planning stages. No other mode of transportation, to our knowledge, is affected by such a high level of demand, ship costs, and freight rates. For example, from 2008 to 2009, the average daily charter rate for 1600-1999 TEU container ships dropped by 67.6%, and by 2010 it was less than 50% of what it was in 2008 [ABF11]. Furthermore, the long lifespan of ships, usually about 30 years, adds to the ambiguity, which is much long-lasting than the lifespan of trucks and automobiles. However, it is equivalent to the lifespan of planes and trains. As a result, investing in ships necessitates is one of the company's long term prospects. Stopford, in 2009 argues that, rather than economics, the course of transition for the political geography system should be the jumping-off point for any possible study [GFH14].

Finding the best optimal fleet composition could be defined as determining resource utilization to increase a company's value. FSMPs are differentiated from their land-based counterparts by the amount of capital needed to buy new (or used) ships, similar to purchasing new airplanes, as Stopford 2009 points out. New ships can cost hundreds of millions of dollars, making financing even more critical. Generally, many financing options are available, and the one selected would impact the ship's capital cost (i.e., the sum of debt repayment and interest or dividend). Even for a ten-year-old ship, these costs will account for more than 40% of overall operating costs [Sto09]. Undoubtedly, a shipping company can make the best use of its resources in multiple ways at the same time and be beneficial in all respect.

3 Methodology

The article's primary goal is to create FSM and FDM models for the Indonesian Sea Tollway. To implement strategic decisions, one typically requires some tactical and even operational data. As a result, strategic and tactical/operational decisions often overlap with each other. Ship routing strategies are often evaluated in models used for fleet size and mix decisions and network design decisions. The arc flow model and path flow formulation are the two essential methods for integrating routing into a mathematical model. The arc flow model differs from the other, as it uses binary variables to indicate when a ship moves from i to j, building routes. Routes are predefined in a path flow model, with binary variables indicating whether or not the ship traded on that route [CFB07]. We have used path flow models in both the FSM and the deployment model presented here. The approach utilized in this study is depicted in Figure 3 as a complete flow chart.

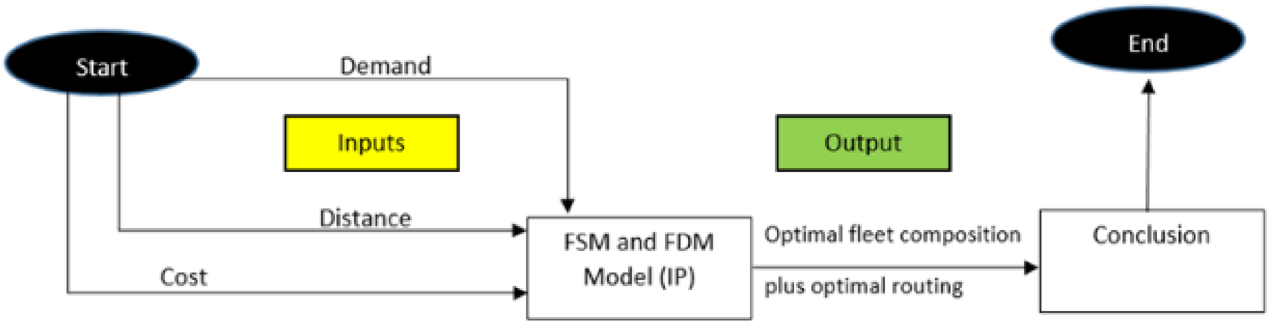

Figure 3. Methodology flow diagram

3.1 The Fleet Size and Mix Model

According to Fagerholt et al. [FCH10], there are two ways to solve maritime fleet size and mix problems.

1. The IP and MIP methods have traditionally been used to solve strategic problems. This can make it difficult to formulate the problem in a way that is complex enough to resemble reality.

Many of the routing and scheduling aspects that make an event realistic are usually omitted.

2. Another approach is to find an appropriate Optimization-based iteration method for routing and scheduling.

To obtain a finite answer, the conventional approach, the method which was first presented, has been used in this study. The objective function for FSM Model is given by the equation below [GFH14].

$$min \sum_{v \in V} C_v^F \; y_v + \sum_{v \in V} \sum_{r \in R_v} C_{vr}^V \, x_{vr} \qquad (1)$$

The objective is to optimize the total chartering costs and operating costs during a planning horizon of 52 weeks. Here, V denotes the available ship types, and R_v denotes the set of routes r that a ship of type v can sail. C_v^F represents the chartering/renting costs for a vessel type-v during the planning horizon and C_{vr}^V represents the operating costs for a single voyage by ship type v on route r. In the objective function, we have two decision variables, i.e. y_v, which will give the number of ships of type v to include and x_{vr}, which will give the number of times. The ship type-v has operated the route r during the planning horizon.

To ensure the feasibility of the fleet operations, various constraints to the objective function (1) can be applied. There are usually four constraints, i.e., time, operation, capacity and non-negativity constraints.

TIME CONSTRAINT

$$\sum_{r \in \mathbf{Rv}} \boldsymbol{Z_{vr}\, x_{vr} - Z y_v \leq 0} \;, \qquad \boldsymbol{v \in V} \qquad (2)$$

Here, Z_{vr} represents the sailing time by ship type v ship on the route r and Z represents the total planning horizon for 52 weeks. This constraint (equation 2) states that all ships finish their sailing routes within the planning horizon.

OPERATION CONSTRAINT

$$\sum_{v \in V} \sum_{r \in R_v} \boldsymbol{A_{ir}\, x_{vr} \geq d_i} \;, \boldsymbol{i \in N} \qquad (3)$$

Here A_{ir} is the binary parameter and equals to 1 if route r calls port i and is equal to 0 otherwise. The parameter d_i represents the minimum number of times that a port i has to be serviced during the planning horizon, i ∈N (number of ports). This constraint (equation 3) states that each port should service at least the required number of times and has been given for our problem.

CAPACITY CONSTRAINT

$$\sum_{v \in V} \sum_{r \in R_v} \boldsymbol{A_{ir}\, x_{vr}\, Q_v \geq D_i} \;, \boldsymbol{i \in N} \qquad (4)$$

Here Q_v represents the capacity of a ship type-v, and D_i represents the demand in TEU of the respective port. Demand is usually defined as the number of containers received by the port. This constraint (equation 4) states that the supply by ships should be greater than the actual demands of ports for better capacity utilization of ships.

NON-NEGATIVITY CONSTRAINT

$$\sum \boldsymbol{x_{vr} \geq 0}\text{, \textbf{and integer}} \qquad (5)$$

$$\sum \boldsymbol{y_v \geq 0}\text{, \textbf{and integer}} \qquad (6)$$

These Constraints (equation 5) and (equation 6) ensure that we get only valid results. This particular model is Fleet Size and Mix (FSM) and gives the optimal number of ships and mix for the predefined routes, keeping the total costs minimum and satisfying all the given demands.

3.2 THE FLEET DEPLOYMENT MODEL

After getting the optimal fleet size and mix from the FSM model, the next step is to allocate the available ships (results from the FSM model) to the predefined routes. Thus, the Fleet deployment model is used to check the accuracy of the FSM Model and provide the best ships to the best routes. Our FDM model is based on lay-up days and costs. The most general way to adjust the fleet is to lay up. It consists of removing ships from service for a limited time by stopping them at a port. The ship's operating costs are reduced as a result. As evidenced by the data, demand is not constant and continues to fluctuate. So, when there is low demand, we can lay some ships at the ports instead of sending the entire fleet at once, allowing lower demands to be met while also lowering total operating costs.

The first thing is to define the objective function in terms of decision variables. FSM model gives the fixed number of ships and mix. So, chartering cost for the available fleet will be fixed now. The main focus will be to optimize the total operating costs and lay-up costs of ship type-v on the route r during the planning horizon [CFR04].

$$\min \sum_{v \in V} \sum_{r \in R_v} TC_{vr}^V \, N_{vr} + \sum_{v \in V} C_{ev} d_v \qquad (7)$$

Here TC_{vr}^V represent the total operating/fuel cost of ship type v along with route r, and C_{ev} represents the

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total lay-up costs of ship type-v in USD/day during the planning horizon. N_{vr} and d_v represent the number of ships of type-v operating on route r and whole lay-up days for ship type-v within the planning horizon.

As an assumption, all the ships in Indonesia sail throughout the year. So, we have assumed a shipping season (S_v) for 50 weeks for all the ships during a planning horizon of 52 weeks. This means that each ship will be layed only for 2 weeks in a year for maintenance or because of low demand. We can lay up some ships at the ports when there is low demand instead of sending empty cargo. This will save operational or running costs for the ships. For our convenience, we have assumed lay-up costs (C_{ev}) for the ship at every port to be 800 USD/day.

To ensure the feasibility of the fleet operations, various constraints to the objective function (equation 7) can be applied. There are only four constraints, i.e., ship availability, operation, Lay-up time and non-negativity constraints.

Ship availability constraint

$$\sum_{r\in Rv} \boldsymbol{N_{vr}} \le \boldsymbol{y_v^{max}},\ \boldsymbol{v \in V} \quad (8)$$

These constraints (equation 8) ensure that the number of ships operating on the route cannot be greater than the maximum number of ships available. We get y_v from FSM Model results.

Operation constraint

$$\sum_{v\in V} n_{vr} N_{vr} \ \ge \ N_r \quad ,r \in R_v \quad (9)$$

Here N_r represents the minimum number of voyages required on a route r during a year, and n_{vr} represents the number of voyages in a shipping season (S_v). This constraint (equation 9) represents that each port should service at least the required number of times. Liner shipping is driven mainly by service frequency. Here for our problem, the minimum required number of voyages (N_r) for the predefined routes are given. For route-3, we have been given a minimum of 6 voyages, and for route-8, we have been given a minimum of 14 voyages. Also, the number of voyages in a shipping season (n_{vr}) can be calculated with the help of the following formula [PP97]:

$$n_{vr} = \frac{S_v\,(shipping\ season : time\ for\ which\ ship\ is\ being\ operated)}{Z_{vr}(\ Sailing\ time\ of\ ship\ v\ on\ route\ r)} \quad (9)$$

Here shipping season is assumed to be 50 weeks during a planning horizon of 52 weeks.

Lay-up days constraint

$$\mathbf{d_v = Zy_v - S_v \sum_{r\in R_v} N_{vr}} \quad (10)$$

This constraint (10) represents that the entire lay-up days for each type of ship should equal the difference between planning horizon and the shipping season.

Non-negativity constraint

$$\sum \boldsymbol{N_{vr}} \ \ge \mathbf{0}\,\textbf{, and integer} \quad (11)$$

These Constraints (11) makes sure that we will get only valid results.

Model Comparison

The two models shown in the research have two distinct purposes, the FSM model is used to find the exact ship's number and type, the deployment model is used to find the optimal routing of this fleet. Despite the similarities, both of the models are entirely very discrete from each other. The main distinction between the models presented can be summed up in one word, i.e. time. Knowing when things happen and need to happen is critical when planning for tactical situations, but less so in strategic planning. Because the timing of events is critical, the variables are made time-dependent, and the fleet deployment model requires additional limitations. Individual vessels are the focus of the deployment model. When assigning which routes are to be operated by which type of vessel, the FSM model does not discriminate between the different vessels. This assumption is that there are currently no vessels. The fleet is determined based on operation demand.

3.3 Cost Calculation for FSM and FDM Model

For our problem, we have been given two types of ships, KM Caraka Jaya (CJ) NIII-22 (KM CJ) with capacity 135 TEU and KM EL03 (KM EL) with a capacity of 400 TEU. Total chartering costs can be easily calculated for both types of ships by multiplying chartering costs per day with the planning horizon time. However, we have to first calculate the daily fuel consumption (in tonne/day) for calculating operating costs.

Table 1. Available fleet for the route

Vessel Name	Ship type	Capacity (TEU)	Charter Cost (USD/day)	Draft (m)	Design Speed (knots)	Max Speed (knots)	Displacement (ton)	Fuel Coefficient
KM CJ	1	135	1900	8	10.71	11.9	5703	120000
KM EL	2	400	4969	9.5	9.9	11	1714	120000

Ministry of Transportation Republic of Indonesia, 2017

DAILY FUEL CONSUMPTION

The daily fuel consumption was calculated using Barrass [Bar04] formula in 2004.

$$F_S = \frac{\Delta^{\frac{2}{3}} \times V^3}{Fuel\,Coefficient} \qquad (12)$$

Here f_s is the daily fuel consumption (ton/day), Δ is the given displacement of the ships, and V is the vessel's service speed. There exists a directly proportional relationship between fuel consumption and the speed of the vessel. For more incredible speed, the fuel consumption will always be more. If the shipping company wants to deliver the goods in a shorter amount of time, the ship has to sail faster, resulting in more fuel consumption and more operating costs. Similarly, low operating costs are incurred due to the slow streaming of ships.

For our problem, we have assumed that the ships are streaming at a constant speed, which will give a constant fuel consumption. Also, the fuel costs will be minimized by a constant sailing speed.

ACTUAL VESSEL SPEED

The most important question comes, i.e. what should be the speed of vessels on the routes or at what speed we should steam our vessels?

To calculate the vessels' actual speed on the routes, we have first to consider the time taken by the vessel in a single voyage. As we have assumed that both types of ships can sail freely on both routes. So, sailing time for both types of ships on both routes must be calculated using the following formula [MD16].

$$Z_{vr} = \frac{\frac{d}{v_{s*}} + 24\,p}{24 \times 7} \qquad (13)$$

Here d, v_{s*} and p represent the total tour length (nautical miles), ship's design speed (knots), and the number of ports in the route. Here we have assumed that the vessel will stay for 24 hours for loading and unloading purposes at each port. We have rounded off this sailing frequency to the next integer. For example, sailing time for 3.4 weeks has been rounded off to 4 weeks to obtain a weekly frequency. Now for this sailing time, we have calculated the actual speed of the vessel of type v on route r using the same formula [MD16].

$$V_{vr} = \frac{d}{168 \times Z_{vr} - 24 \times p} \qquad (14)$$

OPERATING COSTS FOR VESSELS

In the calculations, a simplified version of the fuel cost function as provided in Brouer et al. [Bro14] has been used, and the fuel costs based on the actual speed of ship type v on routes r has been calculated.

$$F_v(v) = 600 \times \left(\frac{v_{vr}}{v_{s*}}\right)^3 \times f_s \qquad (15)$$

Here, $F_v(v)$ and v_{vr} represent the fuel cost (in USD/day) for a ship of type v sailing at the actual speed (in knots) and actual speed (in knots) of ship type v on route r, respectively. The bunker cost continuously varies over time, but it is assumed to be constant and equal 600 USD per ton in this research. Then the operating cost for the vessel type v on route r for one voyage can be given by the formula:

$$C_{vr} = \frac{F_v(v) \times d}{24 \times v_{vr}} \qquad (16)$$

This way, the operating cost for both the vessels on both routes for one voyage has been calculated. Multiplying it with the total number of voyages during the planning horizon will give the total operating costs for the vessels during a planning horizon of a year. This will describe the objective function for our FSM Model, to find the number of voyages in a year and the number of ships of different types to include in the fleet, keeping total chartering and operating costs in a year optimal.

When FSM Model is solved completely, and we know the exact fleet composition, then the task would be to optimize the running/operating costs of the vessel during a year, as chartering costs will be fixed, and we need now to allocate the vessels into the predefined routes. For FDM Model, the objective function can be redefined by total operating costs and lay-up costs.

Here, the objective is to find the number of vessels on route r. As mentioned earlier, we have assumed the lay costs to be 800 USD/day. The total operating costs during the planning horizon can be calculated by multiplying the total number of voyages in a year (results from FSM Model) with the cost of a single voyage and the number of ships of type v assigned to the route r.

4 RESULT AND ANALYSIS

4.1 FLEET SIZE AND MIX

After solving the model on Python, we have got the following fleet composition:

Table 2. Fleet composition

Vessel Name	Ship type	Capacity (TEU)	Number of ships
KM CJ	1	135	4
KM EL	2	400	0

FSM Model also gives the following number of voyages during the planning horizon of a year:

Table 3. Number of voyages during the planning horizon

Routes	Types of the ship available	
	KM CJ	KM EL
Route-3	24	0
Route-8	52	0

COST ANALYSIS IN FSM

The objective is to minimize the total chartering cost and operating costs during a year. The following table gives the cost distribution during a year.

The total costs produced by the fleet during a planning horizon of 52 weeks from FSM Model comes to be **3,186,316 USD.**

Table 2: Total cost structure for a planning horizon of 52 weeks

Types of Costs	Types of ships	
	KM CJ	KM EL
Chartering costs (USD)	2,774,000	0
Operating costs (USD)	412,316	0
Total Costs (USD)	3,186,316	0

4.2 FLEET DEPLOYMENT MODEL

Now the main objective of the model is to tell the number of ships sailing towards a particular route, keeping the total running costs throughout the shipping season constant. In this model, we have assumed the lay-up costs at any port and shipping season to be 800 USD/day and 50 weeks, respectively.

Each ship is assumed to be laid up for two weeks during a planning horizon of 52 weeks. Total lay-up days for all the type-1 ships will be 56 days. With these assumptions, we got the following deployment results.

Table 3. Fleet deployment

Routes	Types of ships	
	KM CJ	KM EL
Route-3	3	0
Route-8	1	0

For route-3, we have to deploy three ships of type-1 (capacity-135 TEU), and for route-8, we have to deploy only one ship of type-1 (Capacity-135 TEU). Since we did not get any ships of type-2 from the FSM Model, the fleet deployment model will automatically consider the routing of ships of only type-1.

COST ANALYSIS IN FDM

The goal is to keep the vessels' overall running and lay-up costs as low as possible on the predetermined routes.

Table 4: Total cost for a planning horizon of 52 weeks

Type	Name of the ships	Total operating costs on routes (USD)		Total lay-up costs (USD)	Total costs (USD)
		Route-3	Route-8		
1	KM CJ	578,088	219,544	44,800	842,342
2	KM EL	0	0	0	

Since we do not have a type-2 vessel in our fleet, so, the cost incurred due to it will be zero. The total operating costs and lay-up costs for a planning horizon of 52 weeks come to be **842,342 USD.**

5 CONCLUSION

This study has shown how the fleet is generated from fleet size and mix problems in the Indonesian sea tollway. Indonesia has a bright future because of its strategic position between the Indian and Pacific oceans. The Indonesian government launched the Indonesian Sea Tollway program in 2014, connecting the western region with the eastern region to reduce disparity. There were 13 routes in Indonesia sea tollway 2017. This article has calculated the fleet composition by building an FSM Model for two routes from this program. In addition to that, this article has also presented the routing of the vessels on the routes.

From the results, we can see that we need only four ships of KM Caraka Jaya (CJ) NIII-22 has a capacity of 135 TEU, and none of the other types has 400 TEU for our given market conditions. The main reason could be the lower demands of ports on both routes, which can easily be satisfied with a smaller available vessel.

Secondly, the chartering cost during the planning horizon has been reduced significantly by taking the smaller vessel. These could be the main reasons for the FSM Model giving the mentioned outputs for our problem.

Since we got no ships of KM EL03 having a capacity of 400 TEU in our fleet from FSM Model. So, FDM Model will not consider this type of ships for routing. It is evident from the results that three ships of KM Caraka Jaya (CJ) NIII-22 are assigned to route-3 and only one ship to route-8. We believe that the vessel takes four weeks on route three and only two weeks on route-8 for a single voyage. Also, the demands for the ports on route-3 are more than the ports on route-8, this is why model has allocated more ships on route-3.

We have assumed a constant demand and streaming speed of the ships on the routes. However, in reality, demands are constantly fluctuating according to the seasons, and the vessel can stream slow or fast according to various other parameters, such as environmental conditions, demand, time etc. As a result, the FSM and FDM model used in the study cannot be counted as the sole manner of determining the optimal fleet and routing. However, one can use it as a guide to assist the Indonesian government in finding the exact fleet composition and routing.

6 RECOMMENDATION

This study focuses on the liner shipping system, which can be considered static and not characterized by erratic. Because of the stochastic behaviour of maritime industries, it is necessary to investigate better ways to develop a dynamic FSM and FDM Model, which is more likely in real-time situations. Additional constraints, such as including the maximum number of voyages allowed during a year or the loading and unloading time at the ports, etc., can be added to the model to improve the effectiveness. The impact of the change in environment on the operating costs can also be incorporated into the model.

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