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ANALYSIS OF SHIP OPERATION PATTERN BASIS ON THE BIRA-PAMATATA FERRY ROUTE

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Abstract

The Bira-Pamatata ferry route route is an essential South Sulawesi transport service operated by KMP Bontoharu, KMP Kormomolin, and KMP Balibo. Each ship has different technical specifications. Howefer, the same tariff applies to these three ships. Therefore, this study aims to determine the basis of the operation pattern to ensure that the three ships can be feasible and also serve as the basis for determining the operation pattern at the Bira-Pamatata ferry route. This difference in the ships' specifications results in different production costs of transportation services with a load factor of 60%, which is the basis for setting the rates. The frequency base is also necessary to allow the three vessels to meet the operational requirements at the established rates. The results of the base frequency required by each ship are the following: KMP Balibo, 770 trips/year; KMP Kormomolin, 464 trips/year; and KMP Bontoharu, 439 trips/year. The amount of load available on the Bira-Pamatata route cannot be known as it depends on demand. Therefore, an equation model of the operating pattern basis is required to ensure these ships can be feasible under existing service demand conditions. This model is determined using a nonlinear regression method. This equation model produced a high correlation (R2) and a deficient mean absolute percentage error (MAPE) of less than 1%. Therefore, this model can be used to determine the optimal management pattern and increase the efficiency and profitability of the Bira-Pamatata ferry route.

Keywords: Cost, Frequency, Load Factor, Basis, Operation Pattern

1. INTRODUCTION

Ferry in Indonesia is vital in supporting equitable development across the country [1]. This service is provided by strategically placing several vessels at ferry routes that meet specific requirements for vessel seaworthiness, minimum service standards, ferry route specifications, and port facilities [2]. One of the ferry routes available in South Sulawesi that serve inter-regency is the Bira-Pamata.

Since 1980, the Bira-Pamata ferry route has been the primary link between the Selayar Islands and mainland South Sulawesi. Despite the introduction of flights between Makassar and the Selayar Islands in 2019 and 2021, the Bira-Pamata ferry route remains the preferred choice due to its daily operations and its crucial role in facilitating the smooth movement of passengers, vehicles, and goods. This vital connection supports economic growth and fosters economic activity in the Selayar Islands.

The Bira-Pamata ferry route is serviced by KMP Bontoharu, KMP Kormomolin, and KMP Balibo and operates according to an established operating pattern set by the port manager. This operational ferry route pattern includes the number of ferries, frequency of ferry routes, adjusted load capacity, demand, and route distance [3]. Determining the operational pattern influences the production costs of ship operations. As the three ships have different technical specifications, The production cost of the transportation service of each ship differs (IDR/Sup. trips). [4]. The production cost of the transportation service determines the tariff basis at a 60% load factor [5]. It is based on ship operation costs and activities in the services provided according to the ship's operating pattern [6].

A frequency-basis analysis is required to ensure the feasibility of operating the three ships (KMP Bontoharu, KMP Kormomolin, and KMP Balibo) based on the current IDR 33,900 per SUP tariff. The feasibility criterion used was revenue equal to ship operation cost (break-even point); thus, the determination of the base frequency is based on the ship operating costs, which consist of fixed and variable costs [5] and revenue at a load factor of 60%.

In the Bira - Pamatata ferry route, the amount of available load cannot be determined because it is determined by the existing demand [7]. Therefore, a ship operating pattern-based model equation is required to ensure the feasibility of ship operations, which can be adjusted to the available demand conditions. The model equation of the ship operation pattern basis was determined based on the load factor required for each frequency plan using nonlinear regression. These studies provide valuable insights into determining the basis of operating patterns of ships to set operating patterns and optimize the efficiency and profitability of the Bira-Pamatata ferry route.

2. METHODS

2.1. Object of Research

This research aims to determine the basis of the operating patterns of ships operating on the Bira-Pamata ferry route. The Ships used in this study were KMP Balibo 540 GT, KMP Kormomolin 884 GT, and KMP Bontoharu 1053 GT. Table 1 lists the technical specifications for each ship.

Table 1. Ship Technical Specification

No	Description	Unit	KMP Balibo	KMP Kormomolin	KMP Bontoharu
1	Ship Tonnage	GT	540	884	1053
2	Main Dimension				
	A. Length (Loa)	Meter	45.35	46.6	54
	B. Length (Lbp)	Meter	38.50	40.6	47.45
	C. Width (B)	Meter	12.00	12	14
	D. Height (H)	Meter	3.00	3.1	3.5
	E. Laden (T)	Meter	2.00	2.15	2.5
3	Operating Speed	Knot	8	9	9
4	Main Engine				
	A. Engine Power	HP	650	670	1000
	B. Number of Engines	Unit	2	2	2
5	Auxiliary Engine				
	A. Engine Power	HP	102	130	122
	B. Number of Engines	Unit	2	2	2

2.2. Determination of Load Capacity

The load capacity of the ferry includes passenger and vehicle load capacities. The passenger load capacity is determined based on the passenger deck area and the number of seats available on the ship. In contrast, the vehicle load capacity is determined by the vehicle deck area and arrangement of vehicles, considering the spacing between them on the vehicle deck of the ship. The vehicle load capacity was determined by considering the car layout based on the average vehicle load production per trip in 2022. The passenger and vehicle loading capacities converted into production units (SUP). The conversion process involves applying a ratio between the tariff assigned to each load type, class, or category (T1) and the economy class passenger load (TPE) [8]. The reason for using this ratio is because the passenger load is assigned a value of one SUP. Table 2. provides the conversion index for each class of cargo vehicles on the Bira-Pamata ferry route.

Table 2. SUP Conversion Index

No.	Load	Tarif (IDR)	SUP Conversion Index
1	Passenger	33,900	1
2	Vehicles		
2.a	Class I	48,300	1.42
2.b	Class II	82,600	2.44
2.c	Class III	105,500	3.11
2.d	Class IV A	595,900	17.58

No.	Load	Tarif (IDR)	SUP Conversion Index
2.e	Class IV B	444,600	13.12
2.f	Class V A	1,075,900	31.74
2.g	Class V B	643,100	18.97
2.h	Class VI A	1,710,700	50.46
2.i	Class VI B	905,000	26.70
2.j	Class VII	1,351,700	39.87
2.k	Class VIII	1,627,000	47.99
2.l	Class IX	3,415,100	100.74

2.3. Determination of Potential Frequency

The potential frequency of a ferry route refers to the number of trips a ship can make in a given period. The available service time and the ship operation time ratio determine the daily potential frequency. The ship operation time in one cycle consists of maneuvering time, berthing time, and sailing time [9], so the daily frequency is based on Equation 1, and the potential frequency in one year is determined based on Equation 2 is follow as:

$$Fpd = \frac{Ast}{(tm + tb + ts)} \quad (1)$$

$$Fpy = D \times fpd \quad (2)$$

Where Fps is the daily potential frequency in trip/day, Ast is available to service time in hours/day, tm is maneuvering time in hours, tb is berthing time in port in hours, and ts is sailing time in hours. Sailing time was determined based on the ratio of ferry route distance in 18 miles and the speed ship based on the specification technic of each ship in Table 1. Fpy is the potential frequency in one year (trip/year), and D is the total number of days in a year during which a ship is in operation and was determined to be 330 days/year.
The available service time is 12 hours based on the Bira–Pamatata port class. However, at peak conditions, the service time can be extended up to 24 hours to serve ship operations. Fulfil the demand and potentially available load; the possible frequency is determined using the unit plan of service time (open time) for 6 hours, 12 hours, 15 hours, 20 hours, and 24 hours. The time maneuvering was determined to be 0,5 hours, and berthing time was determined to be 2 hours by the service time at Bira - Pamatata ferry route.

2.4. Ship Operating Cost Calculation

The operating costs for each ship were calculated based on the unit price obtained from the PT ASDP Indonesia Ship Selayar Branch. The operating cost component of the ship consists of fixed and variable costs and determination based on PM N0 66 Tahun 2019.

2.4.1. Fixed Cost

The fixed cost component consists of the following:
1. The Ship Depreciation Cost is based on Ministerial Regulation No. 66/2019 (Appendix II, page 2) and was determined using Equation 3 as follows:

$$DC = \frac{Sp - Rv}{Dp} \quad (3)$$

Where DC is the depreciation cost in IDR/year, Sp is the price of the ship IDR, RV is the residual value in IDR, and DP is the depreciation period in the year.
The investment price of each ship is as follows: KMP Balibo for the IDR. 4,162,793,880, KMP Kormomolin of IDR. 4,378,787,633, and KMP Bontoharu of IDR. 7,067,546,117. The depreciation period for the three ships was determined based on their remaining economic life. The economic life used is 30 years, so the depreciation period of each ship is four years for KMP Balibo and KMP Kormomolin and seven years for KMP Bontoharu.

2. Insurance costs are annual premiums paid to insurance institutions to protect against the risk of damage or destruction of ships and other hazards. The amount of insurance premium cost (IC) used to calculate ship operating costs is 1.5% of the shipping price based on Ministerial Regulation No. 66/2019 (Appendix II, Page 2).
3. The cost of the crew determines based on PM 66/2019 (Appendix II Page 2 -3) and consists of the salary, allowance, and crew freshwater consumption cost.

- Wage salary

$$\text{wage salary} = \text{As} \times Nc \times 12\, month \tag{4}$$

- Allowance consists of:

a. Meal allowance

$$Meal\ allowance = Ma \times Nc \times 365\ days \tag{5}$$

b. Sail premium

$$Sail\ Premium = Sp \times Nc \times 365\ days \tag{6}$$

c. Health care

$$Health\ care = Hc \times Nc \times 12\ months \tag{7}$$

d. Official Clothing

$$Official\ Clothing = POC \times NC \tag{8}$$

e. BPJS Employment

$$Be = 5\% \times wage\ sallary \tag{9}$$

f. Holiday Allowance

$$Ha = 1\ month\ wage\ salary \tag{10}$$

- Crew freshwater needs are a component of freshwater costs determined based on PM 66 of 2019 (Appendix II Page 4).

$$Fc = Nc\ x\ Fwc\ x\ 365\ days\ x\ Fwp \tag{11}$$

Where Nc is the number of crew members and was determined to be for each vessel KMP Balibo 19 people, KMP Kormomolin 19 people, and KMP Bontoharu 23 people, As the average salary in IDR/month/person and was determined to be for each ship KMP Balibo IDR 4,382,018; KMP Kormomolin IDR4,110,347; KMP Bontoharu IDR4,273,625, ma is meal allowance and was determined to be IDR75.000/day/person, sp is sail premium in IDR/day/person was determined to be for each ship KMP Balibo IDR16,667; KMP Kormomolin IDR15,450; KMP Bontoharu IDR 16,263; Hc is health care allowance in IDR/month/person and was determined to be for each ship KMP Balibo IDR223,868; KMP Kormomolin IDR198,758 KMP Bontoharu IDR217,376, Poc is Price of official clothing for two steals in IDR/person/year was determined to be IDR. 450,000, Fc is freshwater consumption and was determined to be 220 liter/person/day, and FWP is fresh water price and was determined to be IDR 30/ liter.

4. The repair, Maintenance, and Supply (RMS) cost data determines based on the RMS cost of each ship in 2022
5. Ship washing costs (Swc) using equation 12 based on PM 66/2019 (Appendix II Page 4)

$$Swc = Ts \times Twu \times D \times fwp \tag{12}$$

Where Ts is the ship's tonnage in GT, Twu is total water usage in 5 liter/GT/day, and is ship operation day/year.

6. Indirect Costs based on PM 66/2019 (Appendix II, Page 10-12) consist of the following cost components:
1. Ground Staff Costs (Branch and Representative Offices) consist of the following:
a. Salary Wages are calculated based on the average salary of onshore employees, that is, that of Branch Managers and staff.
b. Allowances include food & transport, health, official clothing, jamsostek, and holiday allowance.
2. The management fee was 7% of the previous period's revenue. The revenue for each ship in the previous period was KMP Balibo IDR728,113,057; KMP Kormomolin IDR826,006,647; KMP Bontoharu IDR1,130,841,092.
3. Cost of branch offices, representative offices, and official residence
4. Maintenance fee
5. Office stationery and printing costs
6. Telephone, telegram, postal, electricity, and freshwater charges
7. Ticket administration fee
8. Office inventory Supervision and official travel expenses cost.

The total cost of fixed cost determines by using equation 13 as follows:

$$TFC = DC + IC + CC + RMS + Swc + Tic \tag{13}$$

Where TFC is the total fixed cost in IDR/year, DC is the depreciation cost in IDR/year, IC is the insurance cost in IDR/year, CC is the crewing cost in IDR/year, RMS in IDR/year, Swc is the ship washing cost in IDR/year, and tic is the total indirect cost in IDR/year.

2.4.2 Variable Cost

The variable cost component consists of the following:
1. The Ship engine operating costs include fuel, lubricating, and cooling water. The engine operating costs consist of main and auxiliary engine costs and determines by using Equations 14 and 15 [10].

$$CME = nme \times Pme \times \left((Cfo \times Pfo) + (Clo \times Plo) + (Ccw \times Pfw)\right) \times tme \tag{14}$$

$$CAE = nae \times Pae \times \left((Cfo \times Pfo) + (Clo \times Plo) + (Ccw \times Pfw)\right) \times tae \tag{15}$$

Where CME is the cost of the main engine in Rp/trip, nme is the number of main engines in a unit and was determined to be for each ship 2 units, Pme is the main power engine and was determined to be for each ship KMP Balibo 659,1 PS; KMP Kormomolin 679,38 PS; KMP Bontoharu 1014 PS; Cfo is fuel consumption rate and was determined to be 0.13 Liter/PS/Hour, Pfo is fuel oil price and was determined to be IDR6.800/Liter, clo is lubricant oil consumption rate and was determined to be 0.0003 Liter/PS/Hour, Plo is price lubricant oil and was determined to be 33.550 Rp/Liter, Ccw is cooling water consumption rate and was determined to be 0.192 liter/PS/Hour, tme is main engine operation time and was determined to be for each ship KMP Balibo 2.92 Hour; KMP Kormomolin 2.5 Hour; KMP Bontoharu 2,5 Hour.
Where CAE is the cost of the auxiliary engine in Rp/trip, nae is the number of auxiliary engines in a unit and was determined to be for each ship two units; Pae is the power of the auxiliary engine and was determined to be for each ship KMP Balibo 103.42 PS; KMP Kormomolin 95.316 PS, KMP Bontoharu 123.70 PS, and tae is auxiliary engine operation time in Hour.
The time operating off the main engine (tme) determined byequation 16, and the time operating the auxiliary engine (tae) determined by equation 17

$$tme = tp + tm + ts \tag{16}$$

$$tae = OHNO + OHND + tm + \left(0.5\,(ts + tb + At)\right) \tag{17}$$

Where tme is the main engine operation time in hours, tp is preheating time and was determined to be 0.25 Hours, tm is the maneuvering time and was determined to be 0.25 Hours, and ts is the sailing time, and was determined to be for each ship KMP Balibo 2.42 Hour; KMP Kormomolin 2 hour; and KMP Bontoharu 2 hour. tae is the auxiliary engine operation time in hours, OHNO is the one-hour nautical origin and was determined to be 1 hour, OHND is one-hour nautical destination and was determined to be 1 hour, tb is berthing time and is determined to be 2 hours and At is anchoring time and was determined to be 12 hours.

The engine operation cost is determined using Equation 18, based on the main and auxiliary engine costs.

$$EOC = (CME + CAE) \quad (18)$$

Where EOC is the engine operation cost in the IDR/trip, CME is the main engine operation cost in the IDR/trip, and CAE is the auxiliary engine operation cost in the IDR/trip.

2. The grease cost is determined using Equation 19 based on PM 66/2019 (Appendix II, Page 4).

$$\mathrm{GC} = \frac{Agu \times gp}{Nso} \quad (19)$$

Where GC is the grease cost in IDR/trip, Agu is the grease used kg/month and was determined to be for each ship KMP Balibo 50 kg/month; KMP Kormomolin 50 kg/month; and KMP Bontoharu 60 kg/month, gp is the grease price and was determined to be IDR 65.000/Kg, and Nso is the number of ferry operations trips/month.

3. The cost of passenger freshwater consumption using Equation 20 based on PM 66 of 2019 (Appendix II Page 4) is as follows:

$$Pfc = Plc \times twup \times s \quad (20)$$

Where Pfc is the cost of passenger freshwater consumption in IDR/trip, Plc is Passenger load capacity in person, Twup is Total water usage per passenger and was determined to be 0.5 Liter/mile/trip/person, and s is a distance of a route and was determined to be 18 miles.

4. Port service costs based on PP 15/2016 port service cost are as follows:

- Anchoring Costs determine when ships carry out transport activities and visit the port. This cost depends on the GRT of the ferry and the length of time the ferry arrives until it leaves the port. The anchoring cost was determined using Equation 21

$$AC = Ts\, x\, BT \times Ar \quad (21)$$

Where AC is the anchoring cost in IDR/trip, Ts is the ship's tonnage, BT is the berthing time (1 h), and Ar is the anchoring rate and was determined to be IDR 90/GT/hour.

- Mooring costs are those incurred when a ship is moored on the dock. The cost depends on the tonnage of the ship. The mooring cost determines by using equation 22.

$$Mc = TS \times Mr \quad (22)$$

Where Mc is the mooring cost in IDR/trip, TS is the ship's tonnage, and Mr is the mooring rate and was determined to be IDR 40 GT/Call

The total Variable cost is determined using Equation 23 as follows:

$$VC = (EOC + GC + Pfc + AC + MC) \quad (23)$$

Where VC is the variable cost of the IDR/trip, EOC is the total engine operation cost in the IDR/trip, GC is the grease cost in the IDR/trip, Pfc is the passenger freshwater consumption cost in the IDR/trip, AC is the anchoring cost in the IDR/trip, and MC is the mooring c ost in the IDR/trip.

The total ship operating costs calculated using Equation 24 are as follows:

$$TOC = TFC + (VC \times frequency\ plan) \quad (24)$$

Where TOC is the total operating cost in IDR/year, TFC is the total fixed cost in IDR/year, and VC is the total variable cost in IDR/trip.

2.5 Revenue

The revenue from the ferry business comes from the rental of passenger transportation and vehicles. The amount of revenue using the total loading capacity of a ship was converted into units using Equation 25.

$$R = ST \times LF \times TM \tag{25}$$

Where R is the ship operating revenue in IDR/Trip, ST is the standard tariff in IDR/SUP (IDR 33,900), LF is the load factor of 60%, and TM is the total load capacity of the Ship in SUP.

2.6 Basis Frequency Analysis

The basis frequency is determined using Equation 26, as follows:

$$Fb = \frac{TFC}{R - VC} \tag{26}$$

Where FB is the basis frequency in trip/ywear, TFC is the total fixed cost in IDR/year, R is the ship operating revenue in Rp/trip at 60% load factor, and VC is the total variable cost in IDR/trip.

2.7 Ship Operating Pattern Basis Analysis

In determining the ship operating pattern basis there is a relationship between the base load factor and the minimum transportation frequency that meets the break-even point (BEP) feasibility criteria, where revenue equals vessel operating costs. To determine the load factor of the base vessel, we must know the number of loads required. The required loads are calculated based on the fixed and variable cost ratios to revenue. The revenue is determined based on the prevailing tariff with the planned frequency. Knowing the planned frequency of service, we can calculate the required number of loads based on Equation 27 and the base load factor based on Equation 28.

$$RNOL = \frac{TFC + VC}{AT \times fp} \tag{27}$$

$$LFB = \frac{RNOL}{TLC} \tag{28}$$

RNOL is the Required number of loads in Sup/trip, TFC is the total fixed cost in IDR/year, VC is the variable cost in IDR/trip, AT is the applicable tariff in IDR/Sup, Fp is the frequency plan Trip/Year, LFB is the load factor basis (%/trip). LFB is load factor basis in %/trip, and TLC is the total load capacity of the ship in SUP.

3. RESULTS AND DISCUSSION

3.1. Ferry Load Capacity Conversion

Based on the specifications of the ship and the arrangement of vehicles on the vehicle deck according to the average load production per trip in 2022, the number of passengers and vehicles can determine. The results of converting the total ship loading capacity in production units find in Table 3

Table 3. Total Ship Loading Capacity (SUP)

No	Ship capacity	Index Konversi (SUP)	KMP Balibo		KMP Kormomolin		KMP Bontoharu	
			Person/Unit	SUP	Person/Unit	SUP	Person/Unit	SUP
1	Passengers	1	250	250	356	356	400	400
2	Vehicle							
2.a	Class IV A	17.58	9	158.20	9	158.20	12	210.94
2.b	Class IV B	13.12	4	52.46	5	65.58	6	78.69
2.c	Class V a	31.74	-	-	-	-	1	31.74

No	Ship capacity	Index Konversi (SUP)	KMP Balibo		KMP Kormomolin		KMP Bontoharu	
			Person/Unit	SUP	Person/Unit	SUP	Person/Unit	SUP
2.d	Class V B	18.97	1	18.97	2	37.94	3	56.91
2.e	Class VI A	50.46	1	50.46	1	50.46	1	50.46
2.f	Class VI B	26.70	1	26.70	1	26.70	1	26.70
Total Conversion Result Load Capacity (SUP)				556.79		694.88		855.44

Based on Table 7, the total loading capacity of the largest ship is KMP Bontoharu because it has the most significant main dimension compared with the other ships.

3.2. Potential Frequency

The potential frequency depends on the ship's operation and available service time. Based on the port class, the time to serve the Bira-Pamataata ferry route was 12 h. However, under peak conditions, the time available is up to 24 h to meet the existing demand. The frequency potential is determined based on the available time of 6 h, 12 h, 15 h, 20 h, and 24 and Equations 1 and 2. The result of frequencies potential are shown in Table 4.

Table 4. Potential Frequency based on Available Service Time Plan

No.	Available time (day hours)	KMP Balibo		KMP Kormomolin		KMP Bontoharu	
		FPH (Trip /day)	FPT (Trip /year)	FPH (Trip /day)	FPT (Trip /year)	FPH (Trip /day)	FPT (Trip /year)
1	6	1	330	1	330	1	330
2	12	2	660	2	660	2	660
3	15	3	990	3	990	3	990
4	20	4	1320	4	1320	4	1320
5	24	5	1650	5	1650	5	1650

Based on Table 8, the number of known potentials for a 24-hour service is 1650 trips/year, and the frequency plan are from 330, 495, 660, 825, 990, 1155, 1320, 1485, and 1650 trip/year.

3.3. Ship Operating Costs

Ship operating costs are costs incurred in connection with the ship's operation in a voyage, which are grouped into cost components while the ship is at the port and ship costs during the ship's shipping activities consisting of fixed and variable costs. The recapitulation of operating costs for ferry route Bira - Pamatata is shown in Table 5.

Table 5. Recapitulation of Ship Operating Costs

No	Ship Operation Cost	Unit	KMP Balibo	KMP Kormomolin	KMP Bontoharu
	A. Fixed cost	IDR/ Year			
1	Ship depreciation cost	IDR/ Year	988,663,546.50	1,039,962,062.84	671,416,881.12
2	Cost of ship insurance	IDR/ Year	62,441,908.20	65,681,814.50	106,013,191.76
3	Cost of crew	IDR/ Year			
	1) Wage Salary	IDR/ Year	999,100,104.00	937,159,116.00	1,179,520,500.00
	2) Allowance	IDR/ Year	721,971,848.00	708,878,227.00	867,763,149.00
	3) Crew freshwater consumption	IDR/ Year	45,771,000.00	45,771,000.00	55,407,000.00
4	RMS Fee	IDR/ Year	1,298,830,000.00	923,900,000.00	1,129,150,000.00
5	Ship washing fee	IDR/ Year	26,730,000.00	43,758,000.00	52,123,500.00
6	Indirect Costs	IDR/ Year			
	1) Ground Staff Costs	IDR/ Year	234,806,429.79	234,806,429.79	234,806,429.79
	2) Management fee	IDR/ Year	50,967,913.99	57,820,465.29	79,158,876.44
	1) Rental fee per year	IDR/ Year	153,811,920.00	153,811,920.00	153,811,920.00
	2)Maintenance fee	IDR/ Year	15,381,192.00	15,381,192.00	15,381,192.00
	3) Cost of office stationery and printed matter	IDR/ Year	8,892,666.67	8,892,666.67	8,892,666.67
	4) Telephone, telegram, postal, electricity, and freshwater charges	IDR/ Year	21,765,968.00	21,765,968.00	21,765,968.00

No	Ship Operation Cost	Unit	KMP Balibo	KMP Kormomolin	KMP Bontoharu
	5) Ticket administration fee	IDR/ Year	-	-	-
	6) Office inventory Supervision and official travel expenses cost.	IDR/ Year	127,737,228.67	127,737,228.67	127,737,228.67
	7) Cost of branch offices, representative offices, and official residence	IDR/ Year	4,125,000.00	4,125,000.00	4,125,000.00
	8) Maintenance fee	IDR/ Year	617,488,319.12	624,340,870.42	645,679,281.57
Total fixed cost		IDR/ Year	4,760,996,725.82	4,389,451,090.75	4,707,073,503.44
	B. Variable cost	IDR/Trip			
1	Total engine operation cost	IDR/Trip	4,904,927.00	4,331,680.97	6,276,845.23
2	Grease Cost	IDR/Trip	54,166.67	54,166.67	5,602,798.19
3	Passenger freshwater charge	IDR/Trip	67,500.00	96,120.00	637,920.40
4	Port service fee	IDR/Trip	118,800.00	194,480.00	36,126.64
Total variable cost		IDR/Trip	5,145,393.67	4,676,447.64	6,681,505.23

The results of the total variable costs based on Table 5 were multiplied by the variation in the number of frequencies each year to obtain the total cost of ferry operations. The results of calculating the total cost of the ferry operations according to the frequency plan in Table 10 are shown in Figure 1.

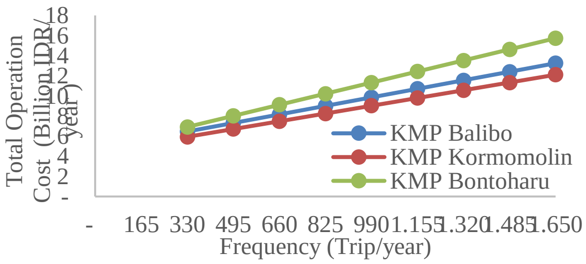

Figure 1. Total Operation Cost

Figure 1. shows that KMP Bontoharu had the highest total ship operating costs, followed by KMP Balibo, and KMP Kormolin had the lowest operating costs. The tonnage and engine power influence the ship's operating costs. The KMP Bontoharu has the highest operating costs because it has the most significant tonnage and engine power. The operating costs were determined to determine the ship operating patterns basis.

3.4. Basis Frequency

The frequency basis analysis was used to determine the minimum frequency required at a load factor level of 60% to ensure the feasibility of operations by the applicable tariff on the Bira-Pamatata ferry route. The operating feasibility criteria are the break-even points between operating costs and ferry revenues. The Base Frequency obtained using Equation 26, and the results for each ship are shown in Table 6.

Table 6. The Frequency basis

No	Description	Unit	KMP Balibo	KMP Kormomolin	KMP Bontoharu
1	Total Fix Cost	IDR/year	4,760,996,725.817	4,389,451,090.750	4,707,073,503.437
2	Total Variable Cost	IDR/trip	5,145,393.671	4,676,447.638	6,681,505.232
3	Tariff	IDR/Sup	33,900.00	33,900.00	33,900.00
4	Total Ship Capacity	SUP	556.83	694.92	855.49
5	Ship capacity Load factor 60	SUP	334.098	416.952	513.294
6	Revenue load factor 60	IDR/trip	11,325,922.20	14,134,672.80	17,400,666.60
7	Base frequency	Trip/Year	770	464	439

Based on Table 11, the frequency basis required by each ferry to fulfill the feasibility of operation according to the applicable tariff is as follows KMP Balibo 770 trip/year, KMP Kormomolin 464 trip/year and KMP Bontoharu 439 trip year.

3.5. Analysis of Ship Operation Pattern Basis

An analysis of the ship operation pattern base shows the base load factor and minimum service frequency required to meet the feasibility of ship operations, where the revenue is equal to the operational costs of the ship by the applicable tariff. The base load factor is determined based on the amount of load required to fulfill the feasibility of operations by the frequency plan that has been determined based on Equation 26, and the results of the amount of load for the three ferries are shown in Figure 2 (b)–4 (b).

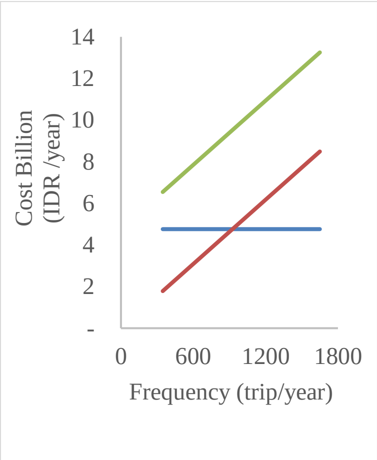

Figure 2.a Component cost of KMP Balibo

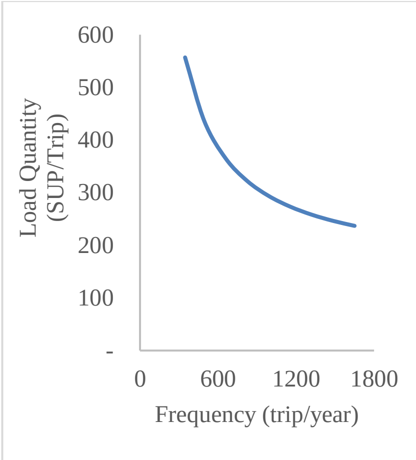

Figure 2.b Required Load Quantity of KMP Balibo

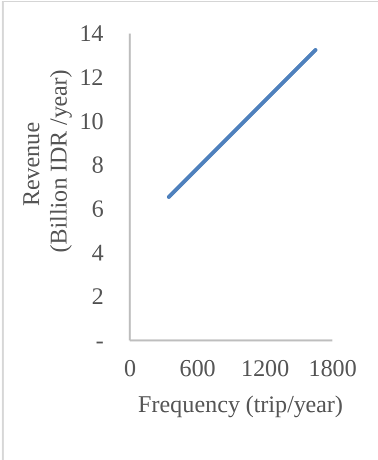

Figure 2.c Revenue of KMP Balibo

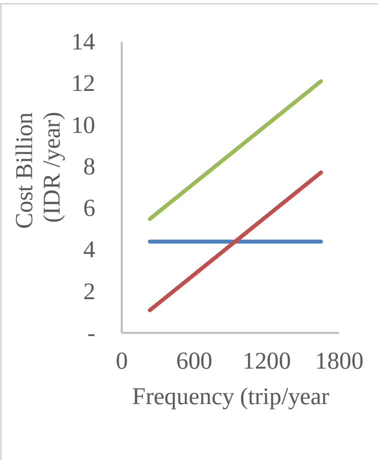

Figure 3.a Component cost of KMP Kormomolin

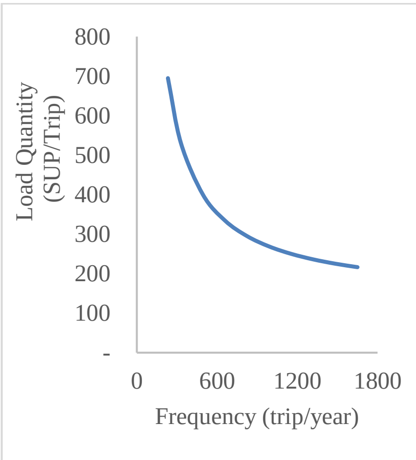

Figure 3.b Required Load Quantity of KMP Kormomolin

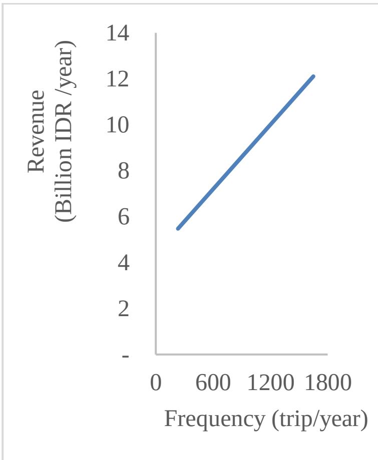

Figure 3.c Revenue of KMP Kormomolin

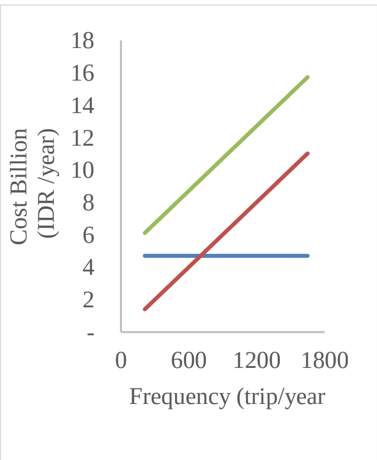

Figure 4.a Component cost of KMP Bontoharu

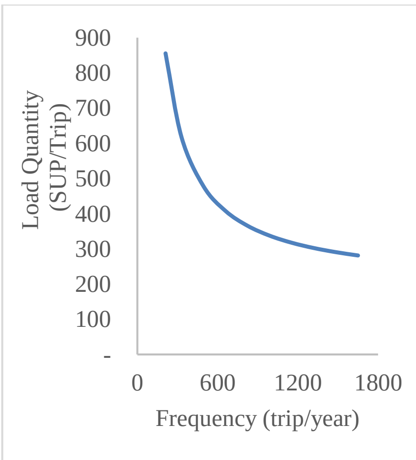

Figure 4.b Required Load Quantity of KMP Bontoharu

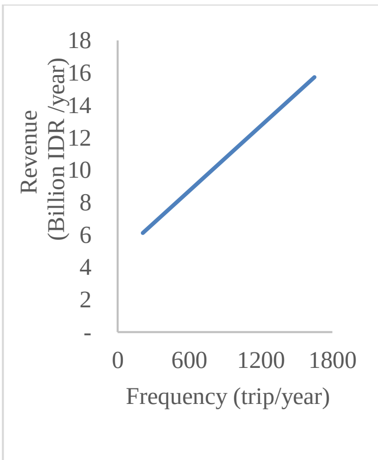

Figure 4.c Revenue of KMP Bontoharu

Based on Figures 2 (b) - 4 (b), determining the number of load requirements with the frequency plan has a negative inverse relationship with different levels of decline. The load factor requirements for each frequency plan were used to determine the base load factor based on Equation 28. The base load factor results based on the frequency plan of each vessel are shown in Figures 5.

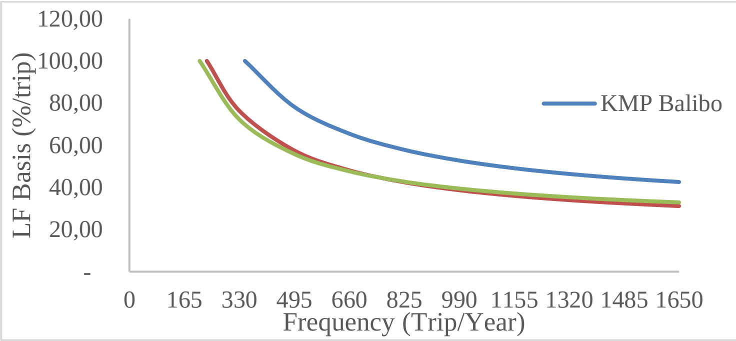

Figure 5. Load Factor Basis based on Frequency plan

Based on Figures 5 an approach to modeling the functional pattern base equation that describes the relationship between the frequency and load factor that meets the operating feasibility criteria was developed using the nonlinear regression method. The equation model considers the trend line of the minimum service frequency (x) and the load factor basis (y), which have different gradients. Therefore, the equation was examined by considering the interception of frequency validity to produce the best model. The results of this equation are shown in Table 7.

Table 7. Equation Model of Ship Operation Pattern Basis

Name of ship	Applicability of Equation				Equation Model	R^2	MAPE (%)
	Base Frequency (X)		Base Load Factor (y)				
	F min	Fmax	LF min	LF Max			
KMP Balibo	347	660	100.00	42.55	y is $4579x^{-0.655}$	0.9992	0.35
	660	990	42.55	52.74	yis $2067x^{-0.532}$	0.9994	0.22
	990	1320	52.74	46.37	yis $1146.9x^{-0.447}$	0.9996	0.20
	1320	1650	46.37	42.55	y is $736.74x^{-0.385}$	0.9997	0.98
KMP Kormomolin	233	330	100	76.32	yis $6667.9x^{-0.771}$	0.9999	0.10
	330	660	76.32	48.09	yis $3542.3x^{-0.663}$	0.9991	0.47
	660	990	48.09	38.67	yis $1553.4x^{-0.536}$	0.9994	0.13
	990	1320	38.67	35.99	yis $861.8x^{-0.45}$	0.9996	0.17
	1320	1650	33.97	31.15	y is $553.03x^{-0.388}$	0.9997	0.59
KMP Bontoharu	211	330	100	72.23	yis $4844.5x^{-0.726}$	0.9997	0.14
	330	660	72.23	47.63	yis $2279.6x^{-0.597}$	0.9987	0.38
	660	990	47.63	39.44	yis $967.56x^{-0.464}$	0.9992	0.27
	990	1320	39.44	35.34	yis $544.19x^{-0.381}$	0.9995	0.17
	1320	1650	35.34	32.88	y is $359.17x^{-0.323}$	0.9996	0.11

Based on Table 7, it can be seen that the equation model of the given operating pattern base has produced a high level of correlation (R2) and a very low Mean Absolute Percentage Error (MAPE), which is below 1%. The equation model can explain the relationship between the independent variable (frequency) and the dependent variable (load factor basis), so it is feasible to analyze the ship operation pattern basis on the Bira–Pamatata ferry route.

The equation model in Table 7 shows that an increased service frequency impacts revenue and variable costs. As frequency increases, revenue and variable costs increase due to the rise, whereas prices remain the same with each increase in frequency. Therefore, any frequency increase will decrease the number of loads required for revenue to equal the value of the costs, resulting in a reduction in the load factor. The model can be seen from the decrease in coefficients a and b with increasing frequency, indicating a lower load factor decline. The equation model in Table 7 shows increased service frequency will impact revenue and variable costs. As frequency increases, revenue and variable costs increase due to the rise, while prices remain the same with each increase in frequency. Therefore, any frequency increase will decrease the number of loads required for revenue to equal the value of costs, resulting in a reduction in the load factor. It can be observed from the decrease in coefficients a and b with an increase in frequency, indicating a lower load factor decline.

4. CONCLUSIONS

The frequency basis required by each vessel at a 60% load factor level to fulfill the feasibility of operation according to the applicable tariff is 770 trips/year for KMP Balibo, 464 trips/year for KMP Kormomolin, and 439 trips/year for KMP Bontoharu. Based on the results of the load factor required for each frequency plan, the operational pattern basis equation model approach describing the relationship between the frequency and load factor that meets the operating feasibility criteria was determined using the nonlinear regression method. The operating pattern base equation model in Table 7 for the three ships is feasible because of the high correlation (R2) level and the deficient mean absolute percentage error (MAPE) below 1%; therefore, the model can be used to set operating patterns and optimize the efficiency and profitability of the Bira-Pamatata ferry route.

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