Volume 4 Number 2 (2026)
July-December 2026
Page:3940-3949

Journal of Creative Power and Ambition (JCPA)
https://edujavare.com/index.php/jcpa
E-ISSN: 3031-4054
DOI: 10.70610/jcpa.2209

Speed-Based Fuel Consumption and Efficiency Potential of the Pioneer Passenger Ship KM. Bung Tomo on Route R-16: An Analysis of Engine-Room Log-Book Data

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Article history Submitted: 2026/10/26; Revised: 2026/10/28; Accepted: 2026/10/29

Abstract

Indonesia's pioneer ships burn subsidised fuel, yet their requests are often based on nominal daily figures from ship specifications rather than measured consumption. This study estimates the fuel demand and speed-related saving potential of KM. Bung Tomo, a 1,257 GT passenger ship serving pioneer route R-16 (836 nautical miles, 10-day round voyage) from Kalianget, Indonesia. Engine-room log-book data for one sailing day were combined with engine particulars and a propeller-law power–speed model calibrated to the logged main-engine consumption. The ship used 3,312 L per sailing day: 2,880 L in the main engines (120 L/h, about 31% of combined MCR) and 432 L in the generators (18 L/h, about 19% of one generator's rating). The calibrated model places the logged consumption at about 6.4 knots, at which one round voyage needs about 19,900 L (23.8 L per nautical mile; about IDR 135.5 million; 53.8 t CO_2 on a fossil-diesel basis). This matches the 20,000 L delivered per bunkering and the 21 kL requested for Voyage 16, whereas the specification figure applied over ten days would nearly double the estimate. Raising speed to 8 knots would add about 43% per voyage, while sailing at 6.0 knots would save about 2,000 L per voyage, or roughly 60,000 L and IDR 411 million over a 30-voyage contract, within the route's schedule margin. Low generator loading points to further savings. The fuel balance for the observation period could not be closed from available records, which makes record-keeping a precondition for efficiency management on small subsidised ships.

Keywords Fuel Consumption; Slow Steaming; Pioneer Shipping; Propeller Law; Generator Load; Biodiesel B50

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INTRODUCTION

Fuel is a ship's largest variable cost and the source of almost all of its greenhouse gas emissions (IMO, 2020). For Indonesia's pioneer fleet, fuel is also public spending. Pioneer ships serve government-contracted routes to remote islands and buy subsidised diesel, which since 1 July 2026 has been a 50% biodiesel blend (B50) under Minister of Energy and Mineral Resources Decree No. 257.K/EK.01/MEM.E/2026.

Every litre therefore affects the operator's margin, the subsidy budget, and national emissions. The biodiesel programme is itself the largest contributor to Indonesia's renewable energy mix (Ahmad et al., 2025), so how efficiently the fuel is used also shapes the benefit of that policy.

Studies of Indonesian pioneer shipping have evaluated route effectiveness, load factors, and cost efficiency (Achmadi et al., 2019), but have not calculated how much fuel these ships actually need. In practice, subsidised fuel requests cite a "tonnes per day" figure from the ship's specification documents. That figure takes no account of speed, route distance, or the number of days the ship actually sails. The international literature on speed and consumption focuses on large container ships, tankers, and bulk carriers (Adland et al., 2020; Psaraftis & Kontovas, 2013), while recent work is moving towards data-driven and machine-learning models that require large volumes of sensor data (Chen et al., 2025; La Ferlita et al., 2023). There are almost no studies of small twin-engine passenger ships of around 1,000 GT that sail slowly between many ports of call and keep only manual log-book records.

This article uses the routine engine-room records of KM. Bung Tomo to answer four questions: (1) what is the fuel consumption per hour, per sailing day, per nautical mile, and per round voyage; (2) how does consumption change with speed, and how heavily are the generators loaded; (3) are the volumes requested and received consistent with voyage demand; and (4) what efficiency and record-keeping measures can be recommended. The contribution is practical: a single reliable log-book page, combined with engine particulars and a simple calibrated model, is enough to establish a defensible per-voyage fuel requirement and to quantify the value of speed discipline on a pioneer route.

METHOD

Design and Object

This is a quantitative descriptive study with modelling. Consumption indicators were calculated from the engine-room log book and then used to calibrate a power–speed model that generates per-voyage fuel demand scenarios. Data were collected during the Lecturer Internship Programme of Politeknik Pelayaran Surabaya on board KM. Bung Tomo from 3 August to 5 October 2026.

Table 1. Principal particulars of KM. Bung Tomo and route R-16

Item	Value
Ship	KM. Bung Tomo, IMO 9848170, steel passenger ship
Dimensions	1,257 GT; LOA 63.0 m; breadth 12.0 m; summer draught 2.79 m

Item	Value
Main engines	2 × Mitsubishi S6R2-T2MTK3L, 759 kW (1,017 HP) at 1,406 rpm
Generators	3 × Mitsubishi S6B3-T2MPTK, about 355 kW (476 HP)
Speed (specification)	Maximum 9 knots; normal 8 knots; economical 6 knots
Fuel (specification)	Bio Solar, 3.30 t/day; tank capacity 213,000 L
Route	R-16: Kalianget – Masalembo – Keramaian – Pelaihari – Matasiri – Maradapan – Marabatuan – Batulicin – Kotabaru – return; 836 nautical miles; 10 days
Contract	30 voyages, 1 January – 27 October 2026

Data

The primary data are the 24-hour consumption entries on one engine-room log-book page for one sailing day in August 2026, signed by the Chief Engineer and acknowledged by the Master. The entries record a previous balance of 18,126 L, main-engine consumption of 2,880 L, auxiliary-engine consumption of 432 L, and a current balance of 14,814 L; the arithmetic closes exactly. The main engines ran in all six watches. Secondary data comprise the ship's specifications, the fuel request for Voyage 16 (21 kL; 192 hours at sea and 48 hours at base), and the delivery documents for two bunkerings of 20,000 L each, 22 days apart, with densities of 0.838–0.843 kg/L. The B50 price used for cost estimates, IDR 6,800/L, was derived from the operator's Pertamina transaction record (IDR 142.8 million for 21,000 L).

Consumption Indicators

Hourly consumption was obtained by dividing the 24-hour volume by 24 hours, and mass was calculated at $\varrho = 0.843$ kg/L. Average power was back-calculated assuming an SFOC of 215 g/kWh for the main engines and 220 g/kWh for the generators, typical of high-speed diesel engines at part load: $P\ (\mathrm{kW}) = \dot{V}\ (\mathrm{L/h}) \times \varrho\ (\mathrm{kg/L}) \div \mathrm{SFOC}\ (\mathrm{kg/kWh})$.

Power–Speed Model

Main-engine power was related to speed through the propeller law, with the maximum speed of 9 knots assumed to be reached at 85% of combined MCR ($0.85 \times 1{,}518$ kW = 1,290 kW), giving $P(v) = 1{,}290 \times (v/9)^3$. The speed equivalent to the logged

power was obtained by inverting this equation. Per-voyage demand was calculated for speeds of 6–9 knots as main-engine fuel for 836 nautical miles plus generator fuel for 240 hours (10 days × 18 L/h = 4,320 L), assumed constant. CO_2 was calculated as volume × 0.843 × 3.206 kg, a fossil-diesel basis that serves as an upper bound for B50.

Methodological Limitations

The log book provides only one complete sailing day, so day-to-day variation cannot be estimated. The reference point (9 knots at 85% MCR) and the SFOC values are assumptions. Following Adland et al. (2020), the cubic exponent may overstate sensitivity below the design speed. The results are therefore presented as calibrated estimates under stated assumptions, not as measurements.

FINDINGS AND DISCUSSION

4.1 Consumption Indicators from the Log Book

Table 2. Fuel consumption indicators from the log book

Indicator	Value	Basis
Main engines (2 units)	120 L/h (about 60 L/h per engine)	2,880 L ÷ 24 h
Generators	18 L/h	432 L ÷ 24 h
Total per sailing day	3,312 L (about 2.79 t)	ϱ = 0.843 kg/L
Main-engine share	87%	2,880 ÷ 3,312
Average main-engine power	about 471 kW (31% of 1,518 kW MCR)	SFOC 215 g/kWh
Average generator power	about 69 kW (19% of one 355 kW unit)	SFOC 220 g/kWh
Remaining stock in sailing days	about 4.5 days	14,814 ÷ 3,312

Consumption on the sailing day, about 2.79 t, is close to the specification figure of 3.30 t/day. This indicates that the specification figure describes one day at sea, not a calendar average. The main engines run at about one third of installed power, while the generators run at only about one fifth of the capacity of a single unit.

4.2 Speed and Per-Voyage Demand

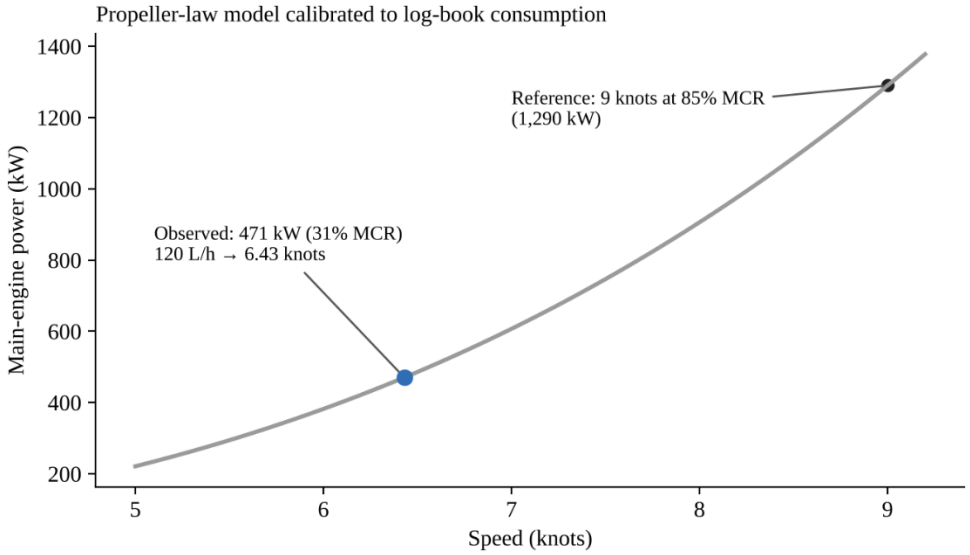


Figure 1. Propeller-law model calibrated to log-book consumption

The model places the logged main-engine power (471 kW) at a speed of about 6.43 knots, close to the specified economical speed (6 knots). At this speed, an 836-nautical-mile round voyage requires 130 hours of steaming and about 19,900 L of fuel.

Table 3. Estimated fuel demand, cost, and emissions per round voyage

Speed (knots)	ME power (kW)	ME (L/h)	ME (L/NM)	Steaming time (h)	Total per voyage (L)	Cost (IDR million)	CO_2 (t)
6.0	382	97.5	16.2	139.3	17,900	121.7	48.4
6.4 (observed)	471	120.0	18.7	130.0	19,920	135.5	53.8
7.0	607	154.8	22.1	119.4	22,810	155.1	61.6
8.0	906	231.1	28.9	104.5	28,470	193.6	76.9
9.0	1,290	329.0	36.6	92.9	34,880	237.2	94.3

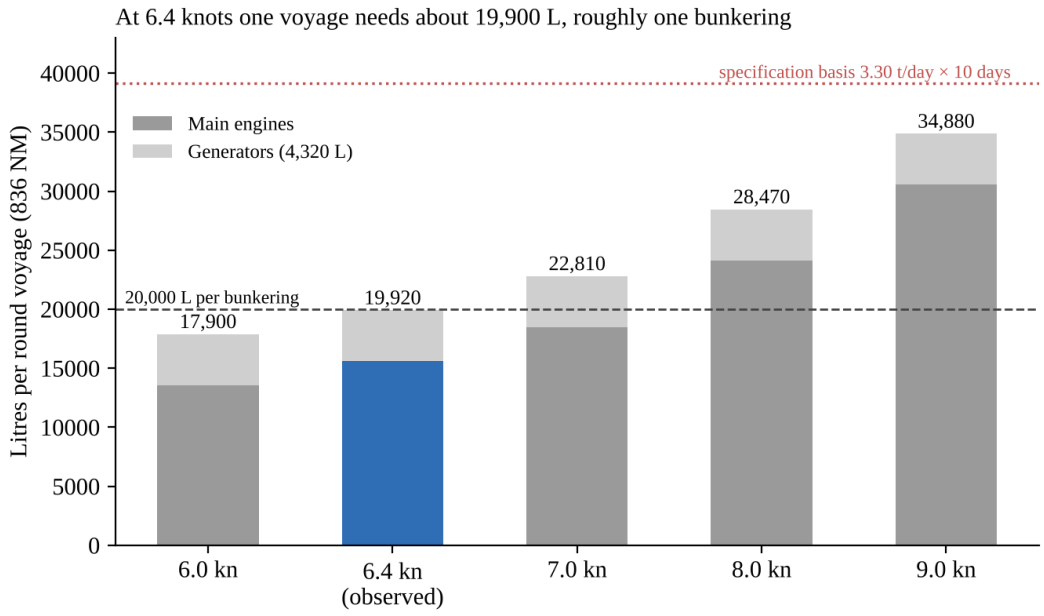


Figure 2. Fuel demand per round voyage at different speeds

Three findings emerge. First, demand at the observed speed (about 19,900 L) is almost the same as the 20,000 L received at each bunkering and about 5% below the 21 kL requested for Voyage 16, so the request contains a reasonable reserve. Second, the specification figure applied over 10 days (3.30 t × 10 ÷ 0.843 ≈ 39,100 L) is nearly double the actual demand and is not a suitable basis for requests. Third, increasing speed from 6.4 to 8 knots adds about 8,550 L (+43%) and IDR 58 million per voyage.

4.3 Time Budget and the Scope for Economical Speed

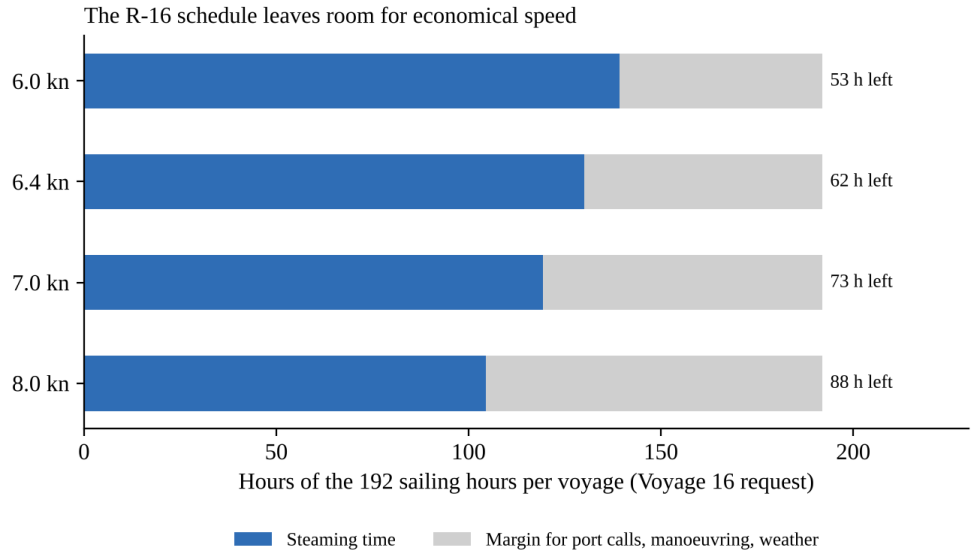


Figure 3. Steaming time and remaining margin within 192 sailing hours per voyage

The Voyage 16 request allocates 192 hours at sea and 48 hours at base. At 6.4 knots, pure steaming takes 130 hours, leaving about 62 hours for calls at 15 ports, manoeuvring, and weather contingency. At 6.0 knots, steaming takes 139 hours and

still leaves 53 hours. The R-16 schedule therefore leaves room to maintain economical speed. Reducing speed by 0.4 knots (from 6.4 to 6.0 knots) saves about 2,000 L or IDR 13.7 million per voyage, or about 60,000 L and IDR 411 million over 30 voyages. The decision remains with the Master, taking into account weather, port-call punctuality, and navigational safety.

This asymmetry matters operationally. Adland et al. (2020) caution that the real sensitivity below design speed may be smaller than the cubic law predicts, so the saving from 6.4 to 6.0 knots may be smaller than estimated. Conversely, the penalty for raising speed towards the design speed of 8–9 knots is captured more accurately by the model. The implication is that making up delays at high speed is expensive, whereas holding economical speed within the schedule margin is cheap. The effect of weather on the open Java Sea leg to Masalembo must still be considered (Taskar & Andersen, 2020).

4.4 Generator Loading

The generators account for 13% of daily consumption but run at about 69 kW, or 19% of the capacity of a single unit. This is a typical pattern on small passenger ships: moderate electrical demand served by units sized for peak air-conditioning and manoeuvring loads. At such low load, SFOC is high and combustion is incomplete. Measures that could be reviewed with the Chief Engineer include running a single generator when electrical demand is low, using the harbour generator during long stays alongside, reducing electrical loads in unoccupied spaces, and logging the running hours of each generator separately. Load management is among the cheapest efficiency measures (Bouman et al., 2017), but the size of the saving cannot be calculated from one day of data and needs to be measured.

4.5 Fuel Balance for the Observation Period

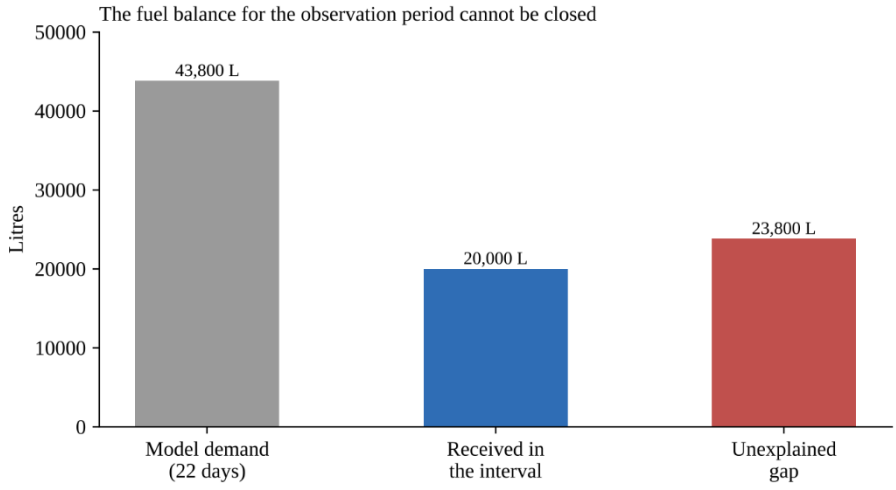


Figure 4. Fuel balance for the observation period

The balance cannot be closed. The two 20,000 L deliveries were 22 days apart, whereas the contract average (10 days per voyage) implies about 2.2 voyages, with a modelled demand of about 43,800 L. The gap of about 23,800 L could be explained by three possibilities: there were other deliveries that were not observed, the ship made fewer voyages than the contract average, or there was a large drawdown of stock. The low remaining stock on the sample day (14,814 L) is consistent with refuelling almost every voyage, but the available records do not allow the gap to be attributed. This is the most important governance finding: the ship's own records cannot yet reconcile deliveries with voyage demand.

4.6 Proposed Efficiency Indicators

Table 4. Per-voyage fuel efficiency indicators

Indicator	Formula	Initial reference value
Fuel per nautical mile	Total voyage fuel ÷ 836 NM	about 23.8 L/NM
Main-engine fuel per steaming hour	ME fuel ÷ ME running hours	about 120 L/h
Generator fuel per hour	AE fuel ÷ AE running hours	about 18 L/h
Average speed	836 NM ÷ steaming hours	about 6.4 knots
Fuel per passenger-mile	Total fuel ÷ (passengers × NM)	From manifest
Balance discrepancy	(opening stock + received − consumed − closing stock) ÷ received	≤ set tolerance

4.7 Emissions and Limitations

On a fossil-diesel basis, one voyage at 6.4 knots emits about 53.8 t CO_2. Because roughly half of B50 is biogenic, fossil tank-to-wake CO_2 is close to half that figure, and fuel saved through economical speed reduces both parts in full. The calibration rests on a single sailing day; the SFOC values and the 9-knot reference point are assumptions; speed was not logged directly but derived from the model; weather and hull condition were not modelled; and generator load was assumed constant at all speeds. Further research should record speed, running hours per engine, and soundings on every voyage over a full contract year so that an empirical speed–consumption curve can be built, as Adland et al. (2020) did for tankers, and data-

driven models such as those examined by Chen et al. (2025) can later be applied.

CONCLUSION

Routine engine-room records are sufficient to establish the fuel requirement of a small pioneer ship in a defensible way. KM. Bung Tomo uses 3,312 L per sailing day (about 2.79 t). The main engines run at about 31% MCR, equivalent to about 6.4 knots, and the generators at about 19% of the capacity of one unit. At this speed one round voyage on route R-16 requires about 19,900 L. This matches the 20,000 L received per bunkering and the 21 kL requested, whereas the specification figure applied over ten days is nearly double. Holding economical speed within the schedule margin could save about 60,000 L and IDR 400 million per 30-voyage contract year, and generator load management offers further savings.

Three recommendations are made. First, subsidised fuel requests should be based on per-voyage demand calculated from distance and calibrated consumption (about 20 kL at economical speed) rather than on a nominal daily figure. Second, an economical speed of 6–6.5 knots should be maintained whenever the schedule and weather allow, with the decision remaining with the Master. Third, soundings, deliveries, running hours per engine, and speed should be recorded every voyage so that the fuel balance can be closed and efficiency monitored with simple indicators.

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