



Technical and Financial Evaluation of Marine Seawater Reverse Osmosis (SWRO) Installation on the Tourism Phinisi Vessel KLM GT 255

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Abstract:

Freshwater availability is a critical operational requirement for liveaboard phinisi vessels, particularly on routes where shore-based supply is limited or costly. This study evaluates the technical feasibility, financial viability, and business-model implications of installing a 15 m³/day marine seawater reverse osmosis (SWRO) system on the tourism phinisi vessel KLM GT 255. The assessment integrates seven-day freshwater balance analysis, engine-room integration and risk assessment using a 5 × 5 risk matrix and Bow-Tie method, financial evaluation using NPV, IRR, BCR, and Payback Period, and strategic analysis using the Business Model Canvas. The results show that the SWRO system can meet the vessel's estimated freshwater demand of 4.7 m³/day and eliminate deficits during seven-day trips under controlled operation. Product-water TDS was measured at 450 mg/L, while identified integration risks can be reduced to acceptable levels through appropriate operational controls. With a CAPEX of Rp214 million, the Sorong-plus-delivery scenario produced an NPV of Rp344.49 million, an IRR of 41.1%, a BCR of 2.61, and a payback period of 2.35 years. However, financial performance is strongly routing dependent and becomes less attractive where low-cost port freshwater is readily available. The BMC analysis indicates that SWRO primarily strengthens operational self-sufficiency, freshwater security, and service continuity rather than creating a new revenue stream. Overall, onboard SWRO is technically feasible and economically attractive for liveaboard operations exposed to high freshwater logistics costs.

Keywords: sustainable maritime supply chain; twin transition; digitalization; green shipping; smart port; maritime logistics.

1. Introduction

Indonesia's extensive archipelagic geography and abundant marine tourism resources have made this sector a major driver of the national economy, and wooden-hulled phinisi vessels operating as liveaboards have become both a transport mode and a premium tourism icon within this sector [1]-[3], [5]. The tourism phinisi vessel KLM GT 255 is one such vessel, operating across the Borobudur,

Lombok, and Labuan Bajo tourism corridors, with a capacity of 10 guests and 14 crew and trip durations of 3-7 days. Freshwater availability is critical to these operations, supporting guest and crew consumption, galley operations, sanitation, and diving-related activities.

However, most phinisi vessels still depend on freshwater supplied from shore or port sources, which exposes operators to high logistics costs, supply uncertainty, and route restrictions when vessels are far from a port

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offering water services. As a wooden-hulled vessel, KLM GT 255 additionally faces engineering constraints in integrating modern high-pressure piping, seawater pumps, generators, and intake systems compared with steel-hulled vessels [4].

Seawater Reverse Osmosis (SWRO) desalination has been widely adopted as an independent freshwater production method, including in marine applications, allowing vessels to produce freshwater directly from seawater during a trip and thereby reduce dependence on port supply [6]-[10], [11]-[13], [25]. While SWRO adoption on commercial and cruise vessels is well documented, its technical and financial feasibility on wooden liveaboard tourism vessels, which have markedly different space, structural, and electrical-load characteristics remains understudied. Increasing system complexity onboard also raises the risk of integration problems between the SWRO unit and existing machinery, electrical, and utility systems, requiring careful engineering and risk assessment before installation [26]-[28].

This study therefore evaluates the installed Marine SWRO system on KLM GT 255 as a post-installation case study. The analysis uses the pre-installation condition as the operational baseline and evaluates the installed 15 m³/day system through technical performance, water balance, engine-room risk, financial scenarios, and business-model implications. The study aims to: (1) evaluate technical feasibility from freshwater production, electrical load, engine-room integration, and technical risk; and (2) evaluate financial feasibility under alternative freshwater procurement conditions and identify the operating-route conditions under which SWRO adoption is economically justified.

2. Materials and Methods

This study is a quantitative engineering case study of the installed Marine SWRO system on the tourism phinisi vessel KLM GT 255, operating in Labuan Bajo, Raja Ampat, and Denpasar waters with trip durations of 3-7 days. The study is framed as a post-installation evaluation: the condition before installation is

used as the baseline, while the 15 m³/day SWRO unit is evaluated as the installed system. Primary data were obtained through semi-structured interviews with five key respondents: a technical sales/application engineer, the Chief Engineer (KKM), a fleet superintendent, a marine surveyor, and a naval architect/marine engineer. The risk assessment was cross-checked through expert review. Secondary data were obtained from the SWRO manufacturer's technical specifications, freshwater and fuel cost data, relevant standards, and academic literature.

2.1 Technical Analysis

Daily freshwater demand was calculated from 10 guests and 14 crew. Guest demand was estimated from drinking, galley, toilet, bathing, laundry, post-dive shower, and diving-equipment rinsing requirements, giving 2.6 m³/day; crew demand was calculated at 150 L/person/day, giving 2.1 m³/day. Total demand was therefore 4.7 m³/day. SWRO production was evaluated from the nominal 15 m³/day capacity (0.625 m³/h) across 8-, 10-, and 12-hour operating scenarios. The minimum operating time was calculated as $4.7/0.625 = 7.52$ h/day and rounded to 8 h/day for the minimum operating scenario. A seven-day water-balance simulation was then performed using a 15 m³ tank capacity, 4.7 m³/day consumption, and a maximum 5.0 m³/day production at the 8-hour scenario, with production suspended when the tank reaches its upper operating level. Electrical energy was calculated as $P \times t$ using the reported 6.8 kW SWRO load. Annual fuel use was calculated from 54.4 kWh/day, an SFC of 0.283 L/kWh, seven days per trip, and 12 trips/year. Product-water quality was assessed using measured TDS; TDS is reported as a dissolved-solids indicator rather than as a complete drinking-water compliance test [14]. Engine-room accessibility was evaluated using the 15-item manufacturer checklist and the cited BKI access requirements.

2.2 Risk Assessment and Bow-Tie Analysis

Technical risks were identified from the 15-item installation checklist and assessed using the documented 5×5 matrix with Likelihood (L,

1–5) $\times$ Severity (S, 1–5) [27], [28]. Risk categories were Low (1–4), Medium (5–9), High (10–16), and Extreme (17–25). The five expert respondents provided the technical basis for the judgement, and the assessment was cross-checked through expert review. The two highest-scoring gap items, C1 (restricted engine-room access, score 16) and C12

(difficult high-pressure-pump oil-change access, score 9), were taken forward to Bow-Tie analysis. Residual risk was re-scored after the stated administrative and operational barriers were applied.

2.3 Financial Analysis

CAPEX includes SWRO equipment procurement, mechanical/electrical installation, fabrication, and commissioning. Annual OPEX is based on the documented fuel/energy cost of Rp31,036,723, maintenance cost of Rp21,200,000, and consumables of Rp2,480,000, giving Rp54,716,723/year. The financial benefit is treated as avoided freshwater-procurement cost rather than new sales revenue. The model uses 12 seven-day trips/year, a 10-year analysis horizon, and a 10% discount rate. Documented freshwater procurement costs are Rp9,870,000/trip for water delivery, Rp5,264,000/trip for Sorong port supply, Rp3,290,000/trip for Denpasar, and Rp3,948,000/trip for Labuan Bajo. NPV, IRR, BCR, and PP are reported [15]–[24]. For scenarios with negative annual net benefit, BCR is reported as not meaningful rather than as a negative ratio. Sensitivity analysis is limited to the variables and threshold results that can be directly reconstructed from the documented thesis model; no unsupported numerical

assumptions are introduced for freshwater-price, fuel-price, or component-replacement sensitivity.

2.4 Business Model Canvas

The Business Model Canvas (BMC) was used [29], [30] with a single unit of analysis: the tourism vessel operator of KLM GT 255. The nine BMC elements therefore represent the vessel's tourism business rather than SWRO equipment supplier. SWRO is treated as a key physical/technological resource that modifies the operator's activities, partnerships, cost structure, and service value proposition.

3. Results

3.1 Existing Conditions and Freshwater Demand

KLM GT 255 has a 15 m³ freshwater tank. Before the current SWRO installation, the vessel had no functioning freshwater-production system; a previous 3 m³/day SWRO unit was already non-operational and was not included in the baseline production calculation. The available documentation indicates that the older unit was aged, had frequent operational problems, and was in a completely non-functional condition when the new unit was installed; a systematic root-cause failure analysis of the old unit was not available. For the representative complement of 10 guests and 14 crew, daily freshwater demand is 4.7 m³/day. A full 15 m³ tank therefore provides approximately 3.2 days of supply without additional production, consistent with the observed need for replenishment from ports or water-delivery sources during longer trips.

Table 1. Simulated Daily Water Balance Without Marine SWRO (7-Day Trip)

Day	Opening Stock (m ³)	Consumption (m ³)	Remaining (m ³)
Day 1	15.0	4.7	10.3
Day 2	10.3	4.7	5.6
Day 3	5.6	4.7	0.9
Day 4–7	Deficit	4.7	Insufficient

3.2 Marine SWRO Capacity Analysis

The installed SWRO unit has a nominal capacity of 15 m³/day (0.625 m³/h). The minimum operating time required to meet 4.7

m³/day is 7.52 h/day, rounded to 8 h/day. The corresponding theoretical production is 5.00 m³/day at 8 h/day, 6.25 m³/day at 10 h/day, and 7.50 m³/day at 12 h/day. The previously stated

'effective capacity' of 12.8 m³/day is not retained in this revised manuscript because its derivation is not consistent with the nominal capacity and operating-hour calculations. The

technical feasibility conclusion is instead based directly on the documented production scenarios and the seven-day water balance.

Table 2. Marine SWRO Production vs. Demand Across Operating Scenarios

Operating Duration	Production (m ³ /day)	Demand (m ³ /day)	Surplus (m ³ /day)
8 hours	5.00	4.7	+0.30
10 hours	6.25	4.7	+1.55
12 hours	7.50	4.7	+2.80

Using the 8-hour operating scenario, the seven-day water balance was recalculated from the documented 15 m³ tank capacity, 4.7 m³/day consumption, and 5.0 m³/day theoretical production. The operating logic assumes level-controlled SWRO operation: production is stopped when the tank reaches

its upper operating level. With an initial full tank of 15 m³, the system therefore maintains the tank at or below 15 m³ while preventing any daily freshwater deficit. The table reports the conservative storage outcome under this level-control assumption.

Table 3. Recalculated seven-day freshwater balance with Marine SWRO (8-hour scenario)

Day	Opening stock (m ³)	Consumption (m ³)	SWRO production (m ³)	Storage (m ³)
Day 1	15.0	4.7	4.7*	15.0
Day 2	15.0	4.7	4.7*	15.0
Day 3	15.0	4.7	4.7*	15.0
Day 4	15.0	4.7	4.7*	15.0
Day 5	15.0	4.7	4.7*	15.0
Day 6	15.0	4.7	4.7*	15.0
Day 7	15.0	4.7	4.7*	15.0

*Although the 8-hour theoretical production is 5.0 m³/day, only 4.7 m³/day is required to replace daily consumption; level control therefore limits actual production to the demand when the tank is full.

3.3 Energy Consumption and Water Quality

The total electrical load of the SWRO system is 6.8 kW (5.5 kW high-pressure pump, 0.75 kW low-pressure pump, and 0.55 kW high-pressure switch). At the 8-hour operating scenario, energy consumption is 6.8 × 8 = 54.4 kWh/day. Relative to the 5.0 m³/day theoretical production at that operating duration, the corresponding SEC is 10.9 kWh/m³. Using the documented Specific Fuel Consumption of 0.283 L/kWh, fuel use is 15.40 L/day, approximately 107.8 L per seven-day trip, and 1,293 L/year for 12 trips/year. At Rp24,000/L, annual fuel cost is approximately Rp31.04 million. The 6.8 kW SWRO load is below the reported 65 kW generator capacity; concurrent vessel loads remain a separate operational consideration. The measured product-water TDS was 450

mg/L. This indicates a dissolved-solids concentration below the 500 mg/L reference value used in the study; however, TDS alone does not establish full drinking-water compliance.

3.4 Engine-Room Access and Risk Assessment

Because engine-room space aboard the wooden-hulled phinisi is limited, the installed SWRO uses a modular configuration. Thirteen of the 15 manufacturer checklist items were met, while C1 (restricted access) and C12 (difficult high-pressure-pump oil-change access) remained technical gaps. C1 scored 16 (High) and C12 scored 9 (Medium). These scores were derived from the five-expert assessment described in Methods. The complete 15-item assessment is provided in Table 7.

Table 4. Complete 15-item risk assessment

Code	Risk item	Status	L	S	Score	Category
C1	Restricted engine-room access	Gap	4	4	16	High
C2	SWRO leakage near access stairs	Compliant	2	2	4	Low
C3	Incorrect operation of inlet valve	Compliant	1	3	3	Low
C4	Water lock/flooding due to inlet position	Compliant	2	3	6	Medium
C5	Pre-filter/strainer blockage	Compliant	3	2	6	Medium
C6	Product-water contamination by brine	Compliant	1	4	4	Low
C7	Booster-pump priming loss above waterline	Compliant with note	2	4	8	Medium
C8	Pre-filter dripping onto work floor	Compliant	2	1	2	Low
C9	Electrical panel above main access route	Compliant	2	3	6	Medium
C10	Operator contact with panel/valve during routine operation	Compliant	3	2	6	Medium
C11	Work hose across clearance below panel	Compliant	2	1	2	Low
C12	Difficult HPP oil-change access	Gap	3	3	9	Medium
C13	Long-term motor-cable insulation degradation	Compliant	2	4	8	Medium
C14	Undetected grounding degradation	Compliant	1	4	4	Low
C15	Generator overload under simultaneous loading	Compliant	1	3	3	Low

The Bow-Tie analysis focuses on the restricted-access top event: worker injury or delayed emergency evacuation in the engine room. The identified causes include the narrow access way, low headroom, single access route, and component congestion. Administrative and operational barriers include handrails and floor markings, protective padding, buddy-system work procedures, housekeeping, PPE, safety

briefings, emergency lighting, and evacuation drills. After mitigation, the residual score for C1 falls from 16 (High) to 6 (Medium). This residual risk does not eliminate the physical access limitation; it indicates that the risk is reduced through continued operational control. A permanent engineering improvement remains possible during future dry-docking or layout modification.

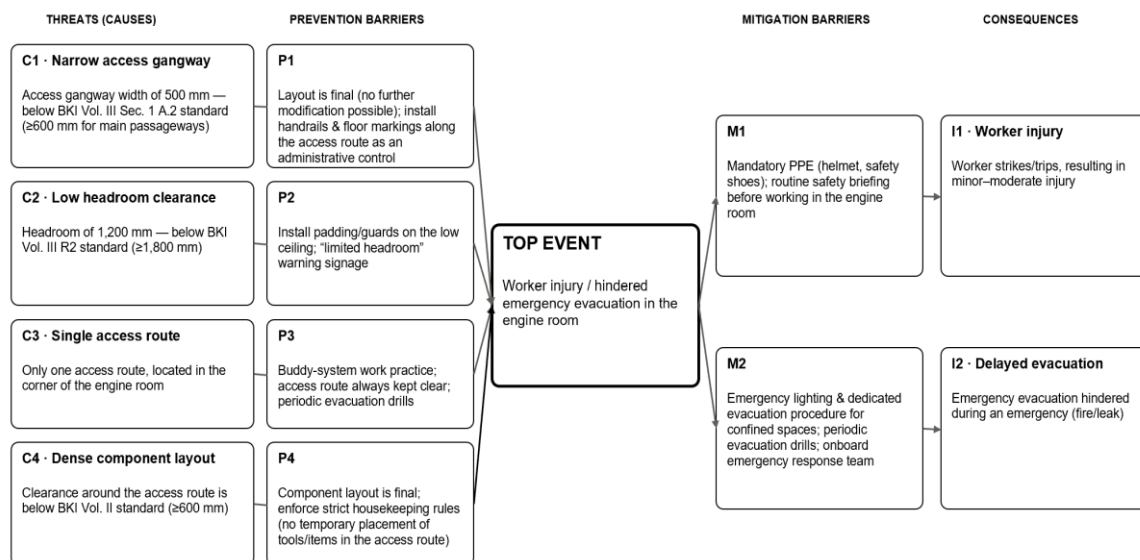


Figure 1. BOW-TIE ANALYSIS Restricted Engine Room Access, Marine SWRO Installation

3.5 Financial Feasibility

Total CAPEX for the 15 m³/day Marine SWRO installation is Rp214,000,000. Documented annual OPEX is Rp54,716,723,

comprising fuel/energy Rp31,036,723, maintenance Rp21,200,000, and consumables Rp2,480,000. The financial benefit represents avoided freshwater-procurement cost. The

seven scenarios differ according to the freshwater source and whether water delivery is required. The financial assumptions are summarized in Table 7.

The Sorong-plus-delivery scenario gives the strongest reported result (NPV approximately +Rp344.5 million, IRR 41.1%, BCR 2.61, PP 2.35 years). Sorong-only remains economically unattractive over the 10-year horizon despite a

positive annual net saving because its payback period is approximately 25.3 years. Denpasar-only and Labuan Bajo-only produce negative annual net savings and negative NPV; their BCR is therefore reported as not meaningful rather than as a negative ratio. The results demonstrate that financial attractiveness is driven primarily by the freshwater logistics cost that SWRO displaces.

Table 5. Financial Feasibility Summary by Operational Scenario (CAPEX = Rp214,000,000; 10-year horizon, 10% discount rate)

Scenario	Net Saving (Rp/yr)	NPV (Rp)	BCR	IRR	PP (years)
Water delivery only	63,723,277	+177,554,048	1.83	27.1%	3.36
Sorong port only	8,451,277	-162,070,283	0.24	<10%	25.3
Denpasar port only	-15,236,723	-307,623,568	n/a	n/a	n/a
Labuan Bajo port only	-7,340,723	-259,105,807	n/a	n/a	n/a
Sorong + delivery	90,891,277	+344,490,541	2.61	41.1%	2.35
Denpasar + delivery	67,203,277	+198,937,256	1.93	28.9%	3.18
Labuan Bajo + delivery	75,099,277	+247,455,017	2.16	33.1%	2.85

Note: For scenarios with negative annual net saving, conventional BCR is not meaningful because the benefit term is not a positive present value of benefits.

3.5.1 Sensitivity Analysis

A one-way sensitivity analysis was reconstructed from the documented Sorong-plus-delivery financial model. The baseline avoided freshwater-procurement cost is derived as annual net saving plus annual OPEX (Rp90.891 million + Rp54.717 million = Rp145.608 million/year). Freshwater procurement cost and fuel price were varied by $\pm 20\%$; discount rate was varied from 8% to 12%; and annual trip frequency was varied from 8 to

16 trips/year. For trip frequency, documented fuel and consumables were treated as trip-dependent while maintenance was held fixed. These assumptions are stated explicitly so that the sensitivity analysis remains reproducible from the reported cost components. Component-replacement cost was not numerically varied because the source model does not document a replacement schedule and cost.

Table 6. Sensitivity analysis for the Sorong-plus-delivery baseline

Sensitivity case	Annual net saving (Rp million)	NPV (Rp million)
Freshwater procurement -20%	61.8	165.5
Freshwater procurement baseline	90.9	344.5
Freshwater procurement +20%	120.0	523.4
Fuel price -20%	97.1	382.6
Fuel price baseline	90.9	344.5
Fuel price +20%	84.7	306.3
Discount rate 8%	90.9	395.9
Discount rate 10%	90.9	344.5
Discount rate 12%	90.9	299.6
8 trips/year	53.5	114.9
10 trips/year	72.2	229.7
12 trips/year	90.9	344.5
14 trips/year	109.6	459.3
16 trips/year	128.3	574.1

Sensitivity case	Annual net saving (Rp million)	NPV (Rp million)
Component replacement	Not quantified	No documented schedule/cost

Table 7. Main financial and cost input

Input	Value	Basis
CAPEX	Rp214,000,000	Equipment, installation, fabrication and commissioning
Annual OPEX	Rp54,716,723	Fuel Rp31,036,723; maintenance Rp21,200,000; consumables Rp2,480,000
Trip frequency	12 trips/year	Seven-day representative trip
Discount rate	10%	Financial model assumption
Analysis horizon	10 years	Financial model assumption
Water delivery cost	Rp9,870,000/trip	Avoided freshwater procurement
Sorong port water	Rp5,264,000/trip	Avoided freshwater procurement
Denpasar port water	Rp3,290,000/trip	Avoided freshwater procurement
Labuan Bajo port water	Rp3,948,000/trip	Avoided freshwater procurement
Fuel price	Rp24,000/L	Used for annual SWRO energy cost
SFC	0.283 L/kWh	Documented generator-based assumption
Replacement cost	Not specified	No documented timing/cost in source model; excluded from quantitative sensitivity

The Sorong-plus-delivery scenario produced the best result across every indicator (BCR 2.61; NPV +Rp344.5 million; IRR 41.1%; PP 2.35 years). By contrast, the Denpasar and Labuan Bajo port-only scenarios generated negative net savings, indicating that SWRO's annual OPEX exceeded the cost of simply buying water locally where port water prices are low. This confirms that the economic benefit of Marine SWRO is not determined by the desalination technology itself, but chiefly by the route's freshwater logistics cost structure.

3.6 Business Model Canvas

The Business Model Canvas (BMC) was developed by integrating the technical, operational, and financial findings presented in the preceding analyses. Rather than representing a new business activity, the canvas illustrates how the installation of the SWRO system modifies the existing operating model of the KLM GT 255. The technical characteristics reported in the previous tables, including the 15 m³ freshwater storage capacity, 15 m³/day SWRO production capacity, 65 kW generator, and associated operating requirements, form the basis of the Key Resources and Key Activities presented in Figure 8. Similarly, the operational assessment identifies freshwater production, system monitoring, preventive maintenance,

and crew competency as additional activities required to maintain reliable onboard freshwater supply.

The Cost Structure in Figure 8 is directly derived from the financial analysis presented in the preceding tables. The SWRO installation requires a capital investment of Rp214 million, while estimated annual SWRO operating expenditure is approximately Rp54.72 million. However, the economic analysis demonstrates that these additional costs may be offset by reductions in freshwater procurement and delivery expenses, particularly on routes with high shore-based freshwater logistics costs. Accordingly, SWRO-related economic benefits are classified as cost avoidance rather than a separate revenue stream. Tourism and trip income therefore remain the principal Revenue Streams of the vessel, while the economic contribution of SWRO is reflected through reduced operating dependence on external freshwater supply.

From the customer perspective, the installation does not fundamentally alter the vessel's Customer Segments, Channels, or Customer Relationships. The primary customers remain liveaboard tourism guests, reached through direct booking, travel agents, digital tourism platforms, and the operator's existing marketing channels. Instead, SWRO primarily

strengthens the Value Proposition by increasing freshwater security, reducing the likelihood of supply-related interruptions, and supporting continuity of onboard hospitality services. Thus,

the technical and economic findings summarized in the previous tables are translated into an operating-model perspective through the BMC shown in Figure 2.



Figure 2. Business Model Canvas for the KLM GT 255

Figure 2 demonstrates that the primary impact of SWRO occurs within the internal operational components of the business model. Key Resources, Key Activities, Key Partners, and Cost Structure experience the most direct changes because the vessel must accommodate new equipment, operating procedures, maintenance activities, technical support, and energy requirements. In contrast, the market-facing components, including Customer Segments, Channels, Customer Relationships, and Revenue Streams, remain largely unchanged. The relationship between the preceding technical-economic tables and Figure 8 therefore shows that the feasibility of SWRO should not be evaluated solely through investment returns; its contribution also includes improved freshwater autonomy, operational resilience, and continuity of tourism services.

4. Discussion

The technical results indicate that the principal integration constraint is the physical

configuration of the engine room rather than the nominal desalination capacity. The modular arrangement enabled the installed system to fit the irregular and constrained machinery space, while 13 of 15 checklist items were met. The remaining access limitations are structural and cannot be fully removed through administrative controls alone. The residual C1 score of 6 should therefore be interpreted as a controlled residual risk requiring continuous supervision, training, housekeeping, and emergency preparedness, with engineering improvement considered during future dry-docking.

The financial results demonstrate strong route dependence. The investment is attractive where the avoided freshwater cost includes expensive delivery, but it is not attractive where the vessel can obtain low-cost port water. This finding is consistent across NPV, IRR, payback period, and the corrected BCR interpretation. The sensitivity evidence available from the thesis also indicates that trip frequency materially affects the low-cost port-only cases: substantially more annual trips would be required for those cases to approach economic

feasibility. The results therefore support an itinerary-specific investment decision rather than a universal recommendation.

The BMC analysis indicates a shift from external freshwater-logistics dependence toward greater onboard control of a critical operating resource. Potential effects on itinerary flexibility, service reliability, and guest experience are strategically plausible, but they are not directly measured economic outcomes in this study. Increased asset value, higher charter rates, investor attractiveness, and willingness-to-pay were not measured and are therefore treated as potential benefits rather than confirmed results.

The previous 3 m³/day SWRO unit is relevant as operational history. The available documentation indicates that the old unit was aged, frequently problematic, and completely non-functional when the new unit was installed. Because no systematic failure investigation was documented, the present study does not attribute the failure to a specific root cause. The current installation addresses the operational requirement through a new 15 m³/day unit, modular configuration, documented operating scenarios, and explicit risk controls; whether these changes improve long-term reliability should be verified through continued operating data.

This study is limited to a single vessel case, a 10-year financial horizon, documented freshwater and fuel prices, and the available technical/risk data. The sensitivity analysis covers freshwater procurement cost, fuel price, discount rate, and annual trip frequency using explicit, source-derived assumptions; component-replacement sensitivity remains a limitation because supplier-specific replacement timing and cost were not documented in the source model. The study does not establish full drinking-water compliance from TDS alone, nor does it quantify guest willingness-to-pay, asset-value changes, charter-price effects, carbon emissions, or life-cycle environmental impacts. Future work should incorporate these parameters and verify long-term SWRO performance across additional vessels and routes.

5. Conclusions

A 15 m³/day Marine SWRO system installed on KLM GT 255 is technically feasible for the documented operating case. The nominal capacity of 15 m³/day corresponds to 0.625 m³/h, while the 4.7 m³/day freshwater demand requires approximately 7.52 h/day of operation. At 8 h/day, theoretical production is 5.0 m³/day and the recalculated seven-day water balance shows no freshwater deficit when production is controlled according to tank level. The measured product water had a TDS of 450 mg/L, which is below the dissolved-solids value used in this study, but this result alone does not demonstrate full drinking-water compliance. The engine-room assessment identified two residual physical access limitations; administrative controls reduced the C1 risk score from 16 to 6, but the underlying access constraint remains and should be considered during future dry-docking. Financial feasibility is route specific. The Sorong-plus-delivery scenario provides the strongest reported result (NPV approximately +Rp344.5 million, IRR 41.1%, BCR 2.61, PP 2.35 years), whereas low-cost port-only scenarios are not financially attractive. The study therefore does not recommend universal SWRO adoption; adoption is most appropriate where freshwater procurement and delivery costs are sufficiently high to offset SWRO capital and operating costs. The revised BMC supports a shift in the vessel operator's resource and cost structure toward greater freshwater self-sufficiency, while strategic benefits such as increased asset value, competitiveness, or willingness-to-pay should be treated as potential rather than measured outcomes.

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References

- [1] S. Rijal, L. D. Hasan, and M. Z. Badollahi, "Ekosistem Wisata Budaya Perahu Pinisi," in *Melalui Kearifan Lokal Kita Bangkitkan Wisata Budaya*, 2021.
- [2] A. Arif Fadillah, K. A. I. Bondan, and S. Manullang, "Desain Kapal Wisata Jenis Pinisi di Perairan Indonesia Timur," 2020.
- [3] N. F. A. Syarif, "Revitalisasi Fungsi Pinisi (Dari Usaha Perdagangan ke Pariwisata Maritim)," 2023.
- [4] G. Gunawan, "Modularization of Ship Engine Room Using Design," *Engineering Journal, Indonesia*, 2020.
- [5] A. S. Khaqiqi and A. H. Dwianto, "Desain Kapal Tradisional Pinisi untuk Jaringan Tujuan Wisata Berkelanjutan: Studi Kasus Gugus Kepulauan Selayar," 2020.
- [6] A. A. Ragetisvara and H. S. Titah, "Studi Kemampuan Desalinasi Air Laut Menggunakan Sistem Sea Water Reverse Osmosis (SWRO) pada Kapal Pesiar," 2021.
- [7] A. R. Calvo, G. A. S. Castro, F. Osorio, J. G. López, and C. Calvo, "Reverse osmosis seawater desalination: current status of membrane systems," *Desalination and Water Treatment*, 2014.
- [8] R. Bahar and M. N. A. Hawlader, "Desalination: Conversion of Seawater to Freshwater," in *2nd Int. Conf. on Mechanical, Automotive and Aerospace Engineering (ICMAAE) – Energy*, vol. 9, pp. 1–8, 2013.
- [9] Heru Sudibyo, "Perencanaan Sistem Penyediaan Air Tawar di Kapal dengan Cara Reverse Osmosis," 1996.
- [10] Suryadi, "Analisa Teknis Ekonomis Perencanaan Sistem Reverse Osmosis untuk Kebutuhan Air Tawar (Domestic Fresh Water System) pada Kapal Niaga (MT. Avila)," 2020.
- [11] A. Al-Karaghouli and L. L. Kazmerski, "Energy consumption and water production cost of conventional and renewable-energy-powered desalination processes," *Renewable and Sustainable Energy Reviews*, vol. 24, pp. 343–356, 2013.
- [12] E. Guler, G. Onkal Engin, M. Celen, and H. Sari Erkan, "Cost analysis of seawater desalination using an integrated reverse osmosis system on a cruise ship," *Global NEST Journal*, vol. 17, no. 2, 2015.
- [13] G. N. Marichal Plasencia et al., "Energy analysis of a seawater reverse osmosis desalination system for small marine vessels," 2021.
- [14] World Health Organization, *Guidelines for Drinking-water Quality*, 4th ed., Geneva: WHO Press, 2017.
- [15] J. P. Gittinger, *Economic Analysis of Agricultural Projects*, 2nd ed., Baltimore: Johns Hopkins University Press, 1982.
- [16] T. T. Wijaksana, R. Nurmalinga, and Burhanuddin, "Analisis kelayakan investasi kapal khusus angkutan ternak di Indonesia: skenario rute Celukan Bawang–Tanjung Priok–Cirebon," *Jurnal Transportasi Laut Indonesia*, 2019.
- [17] R. Nurmalinga, D. K. Sari, and T. Karyani, *Studi Kelayakan Bisnis*, Bogor: IPB Press, 2018.
- [18] A. Ardalan, *Economic & Financial Analysis for Engineering & Project Management*, Graduate School of Management & Technology, 2012.
- [19] J. Berk and P. DeMarzo, *Corporate Finance*, 5th ed., Boston: Pearson, 2020.
- [20] A. E. Boardman, D. H. Greenberg, A. R. Vining, and D. L. Weimer, *Cost–Benefit Analysis: Concepts and Practice*, 5th ed., Cambridge: Cambridge University Press, 2018.
- [21] R. A. Brealey, S. C. Myers, and F. Allen, *Principles of Corporate Finance*, 13th ed., New York: McGraw-Hill Education, 2020.
- [22] A. Damodaran, *Applied Corporate Finance*, 4th ed., Hoboken, NJ: Wiley, 2015.
- [23] S. A. Ross, R. W. Westerfield, and B. D. Jordan, *Fundamentals of Corporate Finance*, 12th ed., New York: McGraw-Hill Education, 2019.
- [24] W. G. Sullivan, E. M. Wicks, and C. P. Koelling, *Engineering Economy*, 16th ed., Boston: Pearson, 2015.
- [25] Y. E. Nazligul, D. Yazir, and B. Sahin, "Selection of desalination system for

- commercial vessels by implementing improved intuitionistic fuzzy TOPSIS method,” *Journal of Marine Science and Engineering*, vol. 9, no. 9, pp. 1–17, 2021.
- [26] I. K. Dagkinis, E. Tzannatos, and A. I. Papadopoulos, “Modelling of the availability for the ship integrated control system sensors,” 2023.
- [27] American Bureau of Shipping, *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries*, Houston: ABS, 2020.
- [28] International Organization for Standardization, *ISO 31000: Risk Management – Guidelines*, Geneva: ISO, 2018.
- [29] M. Fiksdahl and M. G. Wamstad, “Business models in the maritime industry: A study of how Norwegian maritime actors apply and innovate their business models,” M.S. thesis, Norwegian Univ. of Science and Technology (NTNU), Trondheim, 2016.
- [30] A. Osterwalder and Y. Pigneur, *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*, Hoboken, NJ: John Wiley & Sons, 2010.