



Research on the Optimal Economic Life of Operational Ships of Antong Holdings

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Abstract: Aiming at the aging pressure faced by the operational ships of Antong Holdings, this study systematically explores the optimal economic life of various types of ships and formulates scientific ship renewal decision suggestions based on the historical operational data of the company's 63 operational ships through data collection, preprocessing, trend fitting, model construction, and multi-scenario verification. The research constructs a ship operating cost data analysis model and a multi-dimensional renewal model, clarifies the optimal economic life intervals of container ships, bulk carriers, and multi-purpose ships, and provides core support for the enterprise to optimize the fleet structure, reduce operating costs, and improve economic benefits.

Keywords: operational ships; economic life; data fitting; renewal model; decision suggestions

1. Introduction

Against intensified shipping competition and upgraded environmental/technical standards, Antong Holdings' 63 operational ships (container, bulk, multi-purpose) face physical wear (higher maintenance/energy costs) and intangible wear (technological lag, compliance costs), leading to inefficient operations. Traditional experience-based renewal decisions lack quantitative support, risking asset waste or cost overruns.

To address this, this study collects core ship data (original value, maintenance costs, operating rate, etc.), preprocesses it (inflation elimination, outlier repair), fits indicator trends (exponential growth for costs, logarithmic decay for efficiency), and builds renewal models. Under diverse scenarios, it calculates optimal economic life for each ship type and forms hierarchical renewal suggestions.

The study aims to construct an operating cost analysis model, a scientific renewal model, and targeted economic life decisions. Following the "data-model-decision" logic, it provides support for fleet optimization, cost reduction, and benefit improvement.

2. Constructing the Ship Economic Life Model

2.1 Problem Modeling

The economic life of a ship is the service lifespan that maximizes whole-life-cycle economic benefits by accounting for both physical and intangible wear, differing from natural life (physical consumption) and technical life (technological advancement) and serving as the core basis for renewal decisions; its key feature is that maintenance cost growth outpaces operating income growth after a certain ship age, causing a sharp drop in annual net benefits. Data preprocessing uses 2015 as the benchmark year to eliminate inflation, standardizes cost and income statistics, supplements missing data via interpolation and same-type ship mean filling, and removes outliers using the Z-score method to ensure reliability. Trend fitting selects functions based on indicator behavior: exponential growth for rising indicators like maintenance costs, logarithmic decay for declining indicators like operating rate, and linear functions for partially correlated indicators. Ship economic life is determined by cost drivers (rising maintenance costs, falling depreciation costs forming an annual average cost curve), benefit drivers (declining operating rate and income reducing annual benefits), and external adjustments (interest rates, inflation, compliance costs that influence calculation results).

2.2 Model Construction

Based on the above mechanism analysis and research objectives, three core renewal models are constructed:

Operating Cost Data Analysis Model: This model quantifies the correlation between ship age and operating costs, providing basic input for renewal models. With maintenance costs as the core output, it integrates influencing factors such

as ship age, deadweight tonnage, and main engine power. The model expression is:

$$MC(x) = ae^{bx} \times (k_1D + k_2P) \quad (1)$$

(Note: $MC(x)$ =annual maintenance cost at ship age x ; a, b =trend fitting parameters; D =deadweight tonnage; P =main engine power; $k_1 = 0.6, k_2 = 0.4$ =weight coefficients determined by data calibration)

Minimum Annual Cost Renewal Model: Targeting the minimization of the annual average cost of the ship's whole life cycle, this model integrates asset cost, maintenance cost, and fund cost. The expression is:

$$AC(x) = \frac{K_0 - S}{x} + \frac{1}{x} \sum_{t=1}^x MC(t) + K_0 \times \frac{r(1+r)^x}{(1+r)^x - 1} \quad (2)$$

(Note: $AC(x)$ =annual average total cost; K_0 =ship original value; S =residual value; x =service life; $MC(t)$ =maintenance cost in the t -th year; $r=4.8\%$ =annual interest rate) The x that minimizes $AC(x)$ is the optimal economic life.

Maximum Net Benefit Renewal Model: Targeting the maximization of the annual average net benefit of the ship's whole life cycle, this model integrates income and total cost. The expression is:

$$NR(x) = \frac{1}{x} \sum_{t=1}^x R(t) - AC(x) \quad (3)$$

(Note: $NR(x)$ =annual average net benefit; $R(t)$ = total income in the t -th year)

The x that maximizes $NR(x)$ is the optimal economic life.

Based on the preprocessed data, the least square method is used to calibrate the model parameters: for the operating cost data analysis model, fitting parameters a, b are calibrated by ship type (container ships: $a=120, b=0.08$; bulk carriers: $a=150, b=0.07$; multi-purpose ships: $a=130, b=0.09$); for the renewal models, the residual value $S = K_0 \times$ residual value rate (determined by accounting book data).

3. Results of Data Trend and Economic Life Calculation

Fitting the operational data of different ship types shows that maintenance costs grow exponentially with age (Figure 1, $R^2=0.85-0.89$), accelerating sharply after 10 years with 15 years as the inflection point; operating rate and total income decay logarithmically with age (Figures 2–3, $R^2=0.78-0.83$), with the operating rate dropping 15–20% over 0–15 years and income declining faster after 13 years — all ship types follow these consistent trends (only parameter differences). Using parameters including a 4.8% annual interest rate, 2% inflation rate, and 1.05 compliance cost coefficient, the model calculates that container ships have a comprehensive optimal economic life of 13.5 years (12–14-year interval), while bulk and multi-purpose ships have 12.5 years (11–13-year interval), where the comprehensive life is the average of the minimum-cost and maximum-benefit models, and the interval is ± 1 -year fluctuation range.

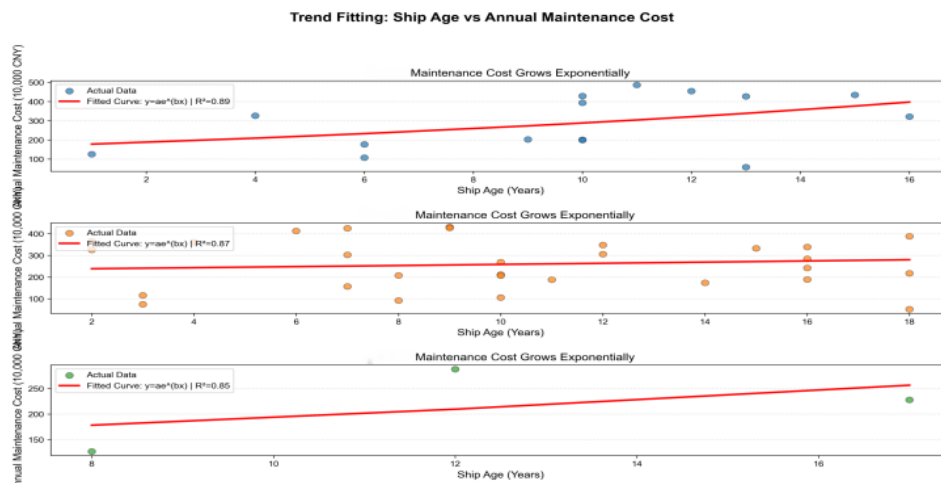


Figure 1. Ship Age_Maintenance Cost

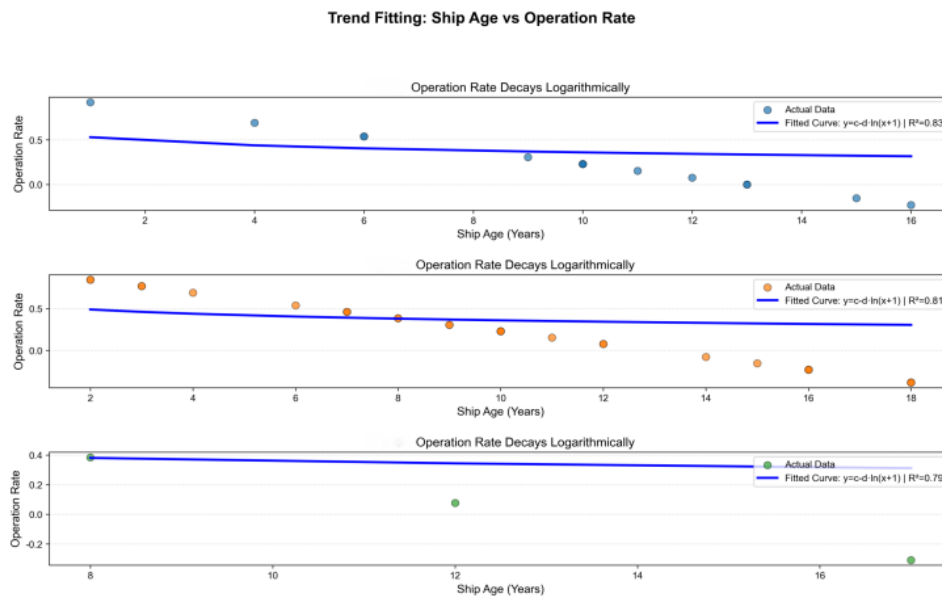


Figure 2. Ship Age Operation Rate

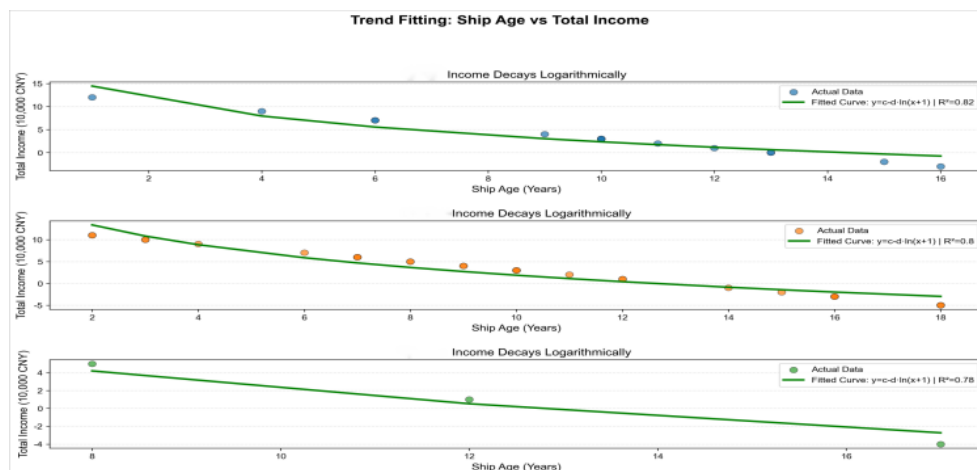


Figure 3. Ship Age Income

Combined with ship operational status (age, remaining life, risk), hierarchical renewal plans are proposed:

High-priority (19 ships): For ships over economic life (remaining life ≤ 0 , high maintenance costs), renew within 1 year with large-tonnage, low-energy vessels to cut costs.

Medium-priority (19 ships): For ships near economic life (remaining life 1-3 years, rising costs), renew in batches within 3 years, aligning with market cycles to balance investment and benefits.

Low-priority (25 ships): For stable ships (remaining life > 3 years), maintain operation, monitor costs dynamically, and strengthen preventive maintenance.

Supporting measures: Real-time indicator monitoring; advance fund reservation; optimize fleet structure (prioritize container ships, reduce old multi-purpose ships).

4. Conclusion

4.1 Research Results

Focusing on Antong Holdings' ship optimal economic life, this study yields three core outcomes:

An operating cost analysis model quantifying ship age, tonnage, power, and maintenance cost correlations for cost monitoring;

A ship renewal model (including minimum cost and maximum benefit sub-models) enabling scientific economic life

calculation;

Targeted renewal suggestions clarifying each ship type's economic life interval and hierarchical update plans.

4.2 Research Prospects

Future work will optimize the model via AI (e.g.,LSTM) for better trend fitting, supplement green shipping indicators (e.g., new energy ships, carbon costs), and build a fleet-wide optimization model to integrate ship renewal, capacity allocation, and route planning for higher benefits.

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