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Evaluating Chemical/Oil Tanker Investments using DEMATEL and ANP: A Case Study in PT ABC

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Abstract

This research addresses challenges in ship investments that often fail to meet targets in technical performance, regulatory compliance, and cost efficiency. It proposes a structured decision support framework integrating the *Decision-Making Trial and Evaluation Laboratory* (*DEMATEL*) and the *Analytic Network Process* (*ANP*) to improve chemical/oil tanker investment decisions. *DEMATEL* identifies cause-effect relationships among factors, prioritizing dominant influences. The resulting supermatrix is analyzed through *ANP* to determine final investment priorities. Data were collected via questionnaires and interviews with stakeholders, including top management and experts. Key factors identified by *DEMATEL* include Initial Investment, Operating Costs, Regulatory Compliance, Market and Geopolitical Risks, and Technological Risks. These were analyzed with *ANP* to build a decision model based on pairwise comparisons. Results show that new Japanese-built ships (*Newbuild Japan*) are the most recommended for the global market, with an aggregate value of 0.362, followed by new Chinese-built ships (*Newbuild China*) at 0.320. The model provides systematic decision support but relies on expert judgment, introducing subjectivity, and does not yet incorporate dynamic market changes. Future studies should apply sensitivity analysis or hybrid models to improve adaptability and robustness in ship investment decisions. This approach aims to enhance the effectiveness of investment strategies in the complex and evolving maritime industry.

Keywords: Ship Investment, Chemical/Oil Tanker, DEMATEL, ANP, Strategic Decision

INTRODUCTION

The maritime industry is critical in supporting global trade and national economic development, especially for archipelagic countries such as Indonesia (Nguyen et al., 2023; Pavlinović et al., 2023; Razmjooei et al., 2023; Shahbakhsh et al., 2022). Chemical/oil tankers are essential for transporting hazardous and liquid bulk cargoes, enabling industrial supply chains and export activities among the various vessel types. However, the growth of chemical/oil tankers in several Indonesian shipping companies remains limited. This condition is particularly evident in a leading tanker ship owner involved in international trade.

Internal and external factors influence the growth of the company's chemical/oil tanker segment. Internally, the dominance of substandard vessels, characterized by outdated systems, high maintenance and docking costs, and recurring compliance failures, has constrained operational flexibility and competitiveness. Limited business development into new or emerging market regions has also left the company with fewer growth opportunities.

Externally, the situation is exacerbated by uncertainty in global conditions, volatile market dynamics, and ambiguous signals in emerging economies. These factors collectively contribute to delayed investment decisions, especially regarding capital-intensive ship acquisition programs. The inability to respond to dynamic changes in market structure and regulatory landscapes has created a gap between operational capabilities and strategic aspirations.

To address these challenges, a structured and systematic evaluation of its ship procurement strategy can support the company's fleet development, particularly the selection between newbuilding and secondhand chemical/oil tankers for the trading area worldwide. The goal is to obtain the best alternative regarding cost efficiency, technical reliability, compliance, and long-term residual value.

The following research questions are the basis for this investigation: (1) What factors influence chemical and oil tanker investment choices? (2) Which type of investment, newbuilding or second-hand ship, offers the most value for worldwide trading area?

By incorporating decision-making techniques to rank investment options in intricate, high-risk settings, the study closes a gap and improves the relationship between strategic investment planning and operational limitations. This study responds to that need, providing a practical decision-support framework for future investment policies.

Overview of Ship Investment Strategy

The shipping industry is the cornerstone of global logistics and economy activity, as shipping investments play a critical role in sustaining and enhancing this sector. (Kim & Park, 2025) explored ship investment patterns and performance of 4 (four) major maritime countries – Greece, China, Japan and South Korea – highlighting the strategic differences and policy frameworks that influence their competitiveness. They employed a comparative analysis of the multidimensional performance indicators to examine the operational income and capital gains from both newbuilding and secondhand vessels. The development of shipping companies depends on multiple financing channels and requires decisions to be made regarding fleet management. (Bazaluk et al., 2022) developed a quantitative approach for determining the investment portfolio of a shipping company considering the value of equity. Investment decisions in the shipping industry are a strategic choice between acquiring new ships (newbuilding) or used ships (second-hand). New ships generally offer higher operational efficiency, cutting-edge technology, and a longer lifespan, but require a significant initial investment. Conversely, second-hand ships have lower purchase costs and faster procurement times, but often incur higher maintenance costs, carry reliability risks, and face challenges in complying with increasingly stringent regulations (Fan et al., 2021). The price of second-hand ships in the secondary market is greatly influenced by their compatibility with future fuel technologies, which can enhance the final economic value of the ship's lifecycle (Banna, 2019).

Martin Stopford (2008) emphasized the importance of comprehensive analysis in ship investment decision-making, going beyond a mere focus on price.

Prior studies on ship valuation, lifecycle cost, and compliance.

The study of ship valuation and life cycle costs is crucial in investment decision-making. Manias (2015) evaluated the feasibility of the new and used crude oil tanker market using statistical models to analyze economic indicators and tanker prices. This study shows that the prices of new ships continue to rise steadily, influenced by material and construction costs, as well as the need for ships to comply with international emission regulations. At the same time, the prices of used ships also experience parallel increases . Ramadhan et al. (2023) analyze the financial feasibility and strategic implications of purchasing new versus used tankers, using metrics such as Net Present Value (NPV) and Internal Rate of Return (IRR), concluding that systematic financial and strategic evaluations are essential for fleet renewal. The concept of life cycle cost encompasses all expenses and revenues throughout the ship's cycle, from construction to scrapping, including capital and operational costs and resale or scrap value. Investment decisions in the shipping industry are a strategic choice between acquiring new ships (newbuilding) or second-hand ships. New ships generally offer higher operational efficiency, cutting-edge technology, and a longer lifespan, but require a significant initial investment. Conversely, second-hand ships have lower purchase costs and faster procurement times, but often incur higher maintenance costs, have reliability risks, and face challenges in complying with increasingly stringent regulations (Fan et al., 2021). Martin Stopford (2008) emphasized the importance of comprehensive analysis in ship investment decision-making, going beyond a mere focus on price. The price of second-hand ships in the secondary market is greatly influenced by their compatibility with future fuel technologies, which can enhance the final economic value of the ship's lifecycle.

Overview of Multi-Criteria Decision Making (MCDM)

Considering the complexity of the factors influencing ship investment decisions, the traditional evaluation approach that focuses on initial costs is no longer adequate. Therefore, Multi-Criteria Decision Making (MCDM) has become essential for integrating various non-financial criteria in the investment evaluation process. MCDM allows decision-makers to make optimal trade-offs between financial and non-financial aspects. It is capable of managing complex decisions and generating objective choices.

Previous applications of DEMATEL and ANP in maritime or logistics.

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP) methods are often integrated in multi-criteria decision-making to address dependencies and feedback among factors. In the previous research, (Baihaqi et al., 2023) utilized DEMATEL and AHP to assess the criteria cause-effect and weight ranking analysis considering the causal and affected groups while prioritizing the criteria and sub-criteria ranking. Lin (2022) used the DEMATEL-ANP integration for maritime safety management, improving risk assessment and reducing accidents by identifying important factors such as sailor education and emergency response capabilities. Milenković et al. (2021) applied the DEMATEL-ANP approach to evaluate innovative value propositions in rail freight transportation, identifying critical factors such as timeliness and investment costs. Keyghobadi et al. (2020) also used the MCDM method in the shipbuilding industry to identify and evaluate strategic alternatives based on economic, environmental, and social criteria. Additionally, Kundakcı et al. (2014) demonstrated that combining DEMATEL and ANP effectively solves the problem of selecting cargo shipping companies, with DEMATEL identifying cause-and-effect relationships and ANP determining the best alternative.

Although many studies are using MCDM, as well as separate applications or combinations of DEMATEL and ANP in various maritime industries, there has been no study specifically applying the integration of DEMATEL and ANP methods to evaluate investment strategies for chemical/oil tanker fleets in Indonesian shipping companies, especially in the context of fleet renewal facing internal challenges such as aging ships and external pressures from stringent global regulations. This research aims to fill that gap by providing a structured and applicable decision support framework.

RESEARCH METHODS

This research uses a leading ship owner/operator in Indonesia as a case study, a leading shipping and logistics company in Indonesia that operates globally. This company was chosen because of its diverse fleet of chemical/oil tankers and its active involvement in international trade. However, it faces significant challenges related to the ageing of its fleet. Most of the chemical/oil tankers owned by the Company are over 15 years old (nearly 60% of the 17 tankers), which results in high maintenance costs, the risk of detention by Port State Control (PSC), and rejection by major oil and gas companies (Oil Major Rejection). This condition directly limits operational flexibility and hinders the company's strategic competitiveness. Thus, the Company requires strategic investment for fleet regeneration to enhance its competitiveness in the global market. Information regarding the operational coverage of the Company's Chemical/Oil Tanker ships over the past three years shows an expansion of trade areas to various destination countries worldwide.

This study adopts an integrated Multi-Criteria Decision Making (MCDM) framework, which combines the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method and the Analytic Network Process (ANP). This approach addresses the complexity of ship investment decisions by considering various interdependent criteria, including Cost, Benefit, Opportunity, and Risk. MCDM allows systematically evaluating alternatives based on several criteria, helping reduce decision-making bias. The integration of DEMATEL-ANP was chosen due to its ability to handle complex issues and account for the interdependencies among elements.

Figure 1 illustrates the research flow, summarizing each stage, from data collection and criteria formulation to decision design, and ranking of alternatives.

DEMATEL Application

The DEMATEL method is applied to identify cause-and-effect relationships between sub-criteria within each leading evaluation group (Cost, Opportunity, Benefit, Risk). This process begins with collecting data on the direct influence between criteria and sub-criteria using a scale of 0-4 (0=no influence, 4 = very high influence) from experts or decision-makers. The results of this assessment form the Direct Influence Matrix. Subsequently, calculations are performed to generate the Total Relation Matrix, which allows for determining dominant and effect factors (cause factors). Through the DEMATEL method, eleven sub-criteria were identified as cause factors, including Initial Investment, Operational Costs, Regulatory Compliance Costs, Government Incentives, Geopolitical Opportunities, Asset Residual Value, Operational Flexibility, Market Risk, Compliance Risk, Geopolitical Risk, and Technological Risk. The results of the DEMATEL analysis, including the Ri+Ci and Ri–Ci values, are visually represented in Figure 2 to 5, highlighting the causal relationships among sub-criteria across the four main evaluation categories.

ANP Framework

Construction of the Network Structure

ANP, as an extension of the Analytic Hierarchy Process (AHP), is designed to model decision-making problems involving interdependencies and feedback among criteria and alternatives, without the assumption of element independence. The ANP network structure is built to integrate the research objective (investment in chemical/oil tankers for global trade), four main criteria (Cost, Opportunity, Benefit, Risk), eleven sub-criteria determined by DEMATEL, and four ship investment alternatives (new ships made in Japan, new ships made in China, used Japanese ships aged 3-10 years, and used Japanese ships aged 11-17 years). This network represents the reciprocal relationships between elements within a single cluster (inner dependency) and the dependencies between elements from different clusters (outer dependency), such as the influence of Geopolitical Risk on Operational Costs or ship alternatives on risk perception. The constructed ANP model structure and its implementation using Super Decisions software are illustrated in Figure 6 and 7, respectively, showcasing the interdependencies among criteria, sub-criteria, and alternatives.

Pairwise Comparisons

After the network design is established, the pairwise comparisons process is conducted to determine the priority weights of each element in the network structure. This comparison involves main criteria, sub-criteria, and alternatives, with preferences assessed using the Saaty 1-9 scale from expert respondents. This process is carried out for each node in the cluster, including

comparisons between main criteria (Level 1), comparisons between sub-criteria within each criterion, and comparisons of alternatives against each sub-criterion. In addition, feedback and interdependence comparisons between sub-criteria and between criteria are also determined. A sample questionnaire item format is as follows:
"Please rate the influence of Geopolitical Risk on Operational Costs (1 = equal influence, 3 = moderate preference for one over the other, 9 = extreme preference)." The pairwise comparison matrices used to derive priority weights are provided in Table 1 through 7, representing expert assessments across all decision levels in the ANP network.

Use of Super Decisions Software

The data from the pairwise comparisons were processed using the Super Decisions software. This software builds the ANP network, processes the relationships and dependencies between criteria, and determines accurate weights. Super Decisions calculates local priority values, forms a supermatrix (unweighted, weighted, and limiting supermatrix), and analyzes it until it produces final priorities (global priority weights) to determine the best alternative. The process includes the following steps: (1) entering cluster and node relationships, (2) inputting pairwise comparisons, (3) verifying consistency ratios (<0.1), (4) generating supermatrix forms, and (5) computing the limiting matrix to extract final rankings.

Data Collection

This research utilised structured questionnaires and in-depth interviews with 35 stakeholders from the maritime sector, chosen for their roles and expertise in ship investment decision-making. The sample consisted of 80% experts and 20% decision-makers, representing professional backgrounds in ship owning, ship management, shipyards, classification societies, and academia. Respondents exhibited a variety of expertise, including Technical/Engineering (26%), Compliance (17%), Business Development (17%), Finance (14%), Commercial (14%), and Operations (12%), with work experience spanning from 6 to over 35 years. Most resided in Indonesia (88.57%), predominantly in Jakarta, while the remainder were in Singapore, Dubai, Glasgow, and Melbourne. Primary data and secondary sources, including company performance reports, operational metrics (e.g., fuel consumption, docking costs), and industry publications (e.g., IHS Maritime, Drewry), were employed to enhance the analysis and maintain contextual relevance.

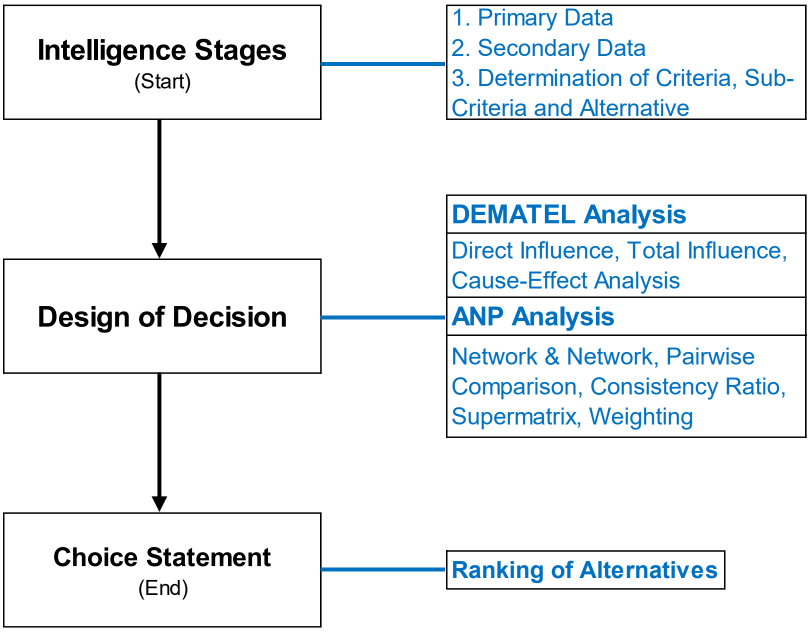

Figure 1 Research Methodology

RESULTS AND DISCUSSION

DEMATEL Findings

The DEMATEL method successfully identified the cause-and-effect relationships among the ship investment sub-criteria. In the Cost group, the Initial Investment, Operational Costs, and Regulatory Compliance Costs sub-criteria were identified as cause factors because they have a positive Ri–Ci value. On the other hand, life cycle cost and funding cost are effective factors. Initial Investment is the most strategic component in the Cost criteria with the highest total influence value (Ri + Ci).

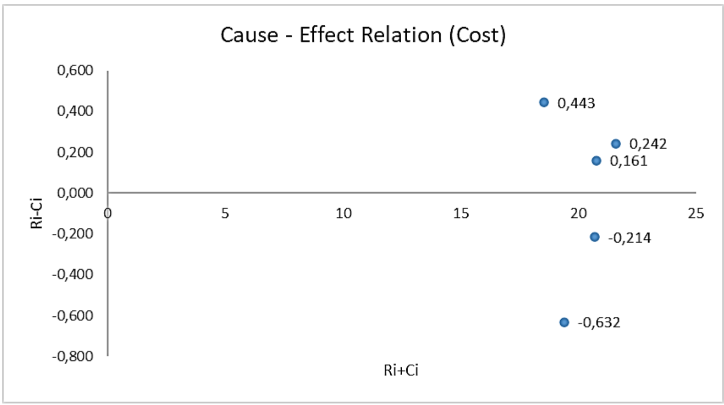

Figure 2 Ri–Ci Cause–Effect Sub-criteria Cost → Ri-Ci Graph: Sub-criteria Cost

Government Incentives and Geopolitical Opportunities are identified as the causal factors in the Opportunities group. These factors influence the sub-criteria of Market Opportunity, Environment, and Brand.

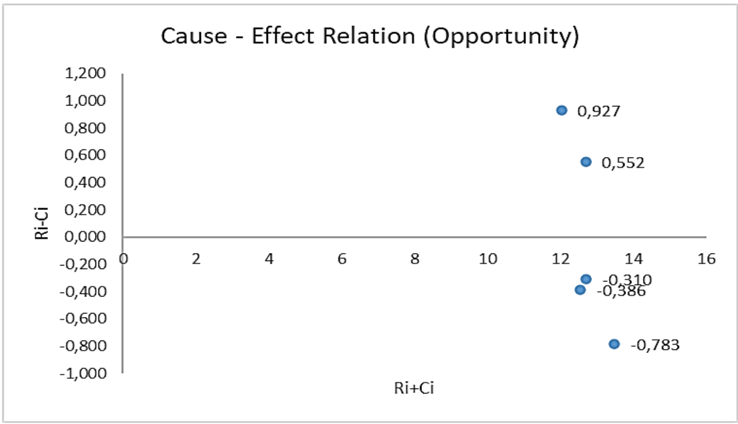

Figure 3 Ri–Ci Cause–Effect Sub-criteria Opportunity → Ri-Ci Graph: Sub-criteria Opportunity

For the Benefit group, the Asset Residual Value and Operational Flexibility sub-criteria were identified as causal factors. Meanwhile, the resulting factors are the highest revenue, competitive advantage, and charter contract. Operational Flexibility is considered the most strategic in this category.

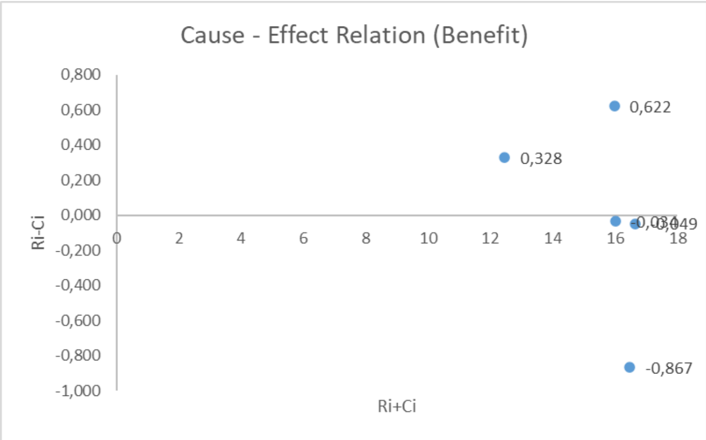

Figure 4 Ri–Ci Cause–Effect Sub-criteria Benefit → Ri-Ci Graph: Sub-criteria Benefit

Finally, in the Risk group, the sub-criteria of Market Risk, Compliance Risk, Geopolitical Risk, and Technological Risk are identified as causal factors. Financial Risk and Operational Risk are the resulting factors. Overall, the Risk criteria have the highest influence on the system, and the most influential sub-criteria overall are Technological Risk and Market Risk.

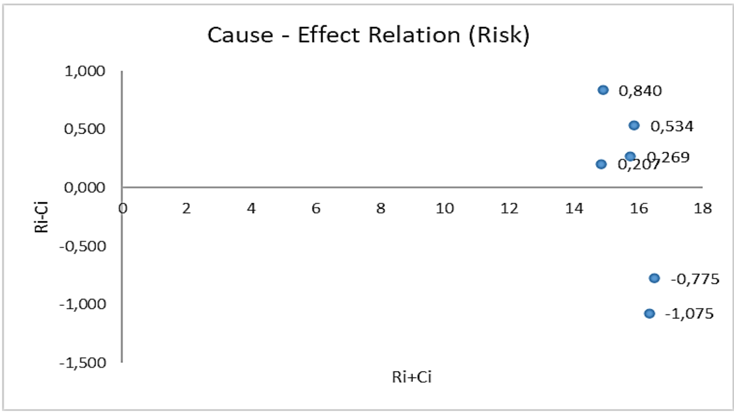

Figure 5 Ri–Ci Cause–Effect Sub-criteria Benefit → Ri-Ci Graph: Sub-criteria Risk

ANP Network Construction

Based on the output from DEMATEL analysis, this study constructs an ANP network structure. This structure integrates the research objective: investment in chemical/oil tankers for global trade, four main criteria (Cost, Opportunity, Benefit, Risk), eleven sub-criteria identified as causal factors by DEMATEL, and four ship investment alternatives. Unlike the Analytic Hierarchy Process (AHP), which is hierarchical, ANP is capable of modelling interdependence and feedback among elements in the system, such as the influence of Geopolitical Risk on Operational Costs.

Table 1 Pairwise Matrix 1 – Criteria

	Cost	**Opportunity**	**Benefit**	**Risk**
Cost	1	…	…	…
Opportunity	…	1	…	…
Benefit	…	…	1	…
Risk	…	…	…	1

Table 2 Pairwise Matrix 2 – Sub-criteria Cost

	Initial Invest.	**Ops. Cost**	**Reg. Compl. Cost**
Initial Invest.	1	…	…
Ops. Cost	…	1	…
Reg. Compl. Cost	…	…	1

Table 3 Pairwise Matrix 3 – Sub-criteria Opportunity

	Govern. Incent.	Geopol. Opport.
Government Incentives	1	…
Geopolitic Opportunity	…	1

Table 4 Pairwise Matrix 4 – Sub-criteria Benefit

	Residue Value	Ops. Flexibility
Residue Value	1	…
Ops. Flexibility	…	1

Table 5 Pairwise Matrix 5 – Sub-Criteria Risk

	Market Risks	Compl. Risks	Geo. Risks	Tech.Risks
Market Risks	1	…	…	…
Compl. Risks	…	1	…	…
Geopol. Risks	…	…	1	…
Techno. Risks	…	…	…	1

Table 6 Pairwise Matrix 6 – Alternative

	NB Japan	NB China	Sec. 3-10 y	Sec. 11-17 y
NB Japan	1	…	…	…
NB China	…	1	…	…
Second 3-10 y	…	…	1	…
Second 11-17 y	…	…	…	1

Table 7 Pairwise Matrix 7 – Criteria/Sub-criteria/Alternative vs Criteria/Sub-criteria/Alternative (Inter-dependence)

	Cost	Opportunity	Benefit	Risk
Cost	1	…	…	…
…	…	…	…	…
…	…	…	…	…
Etc.	…	…	…	…

The weight determination process is carried out through pairwise comparisons involving expert input, using the Saaty scale of 1-9. This comparison is conducted for the main criteria, sub-criteria within each criterion, and investment alternatives against each sub-criterion. The reciprocal relationships and interdependencies between sub-criteria and between criteria are also determined in this process.

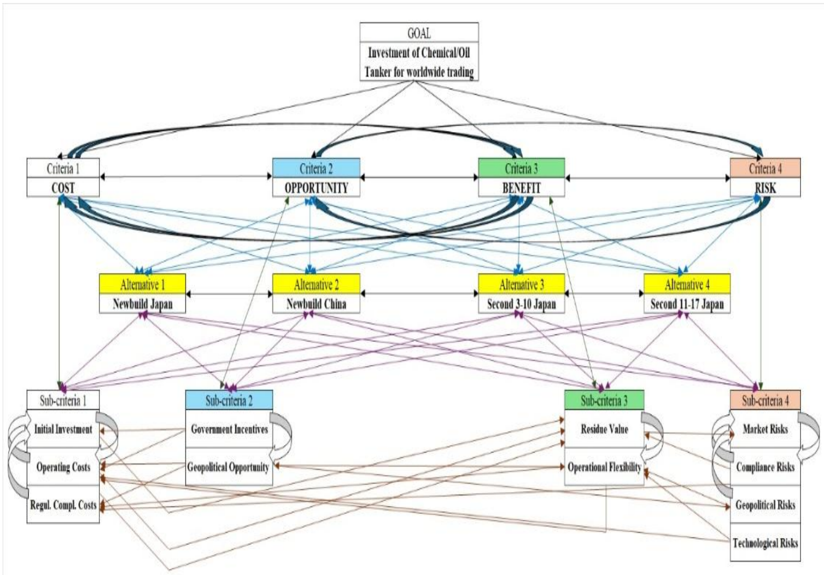

Figure 6 ANP Model Network for Investment of Chemical/Oil Tanker

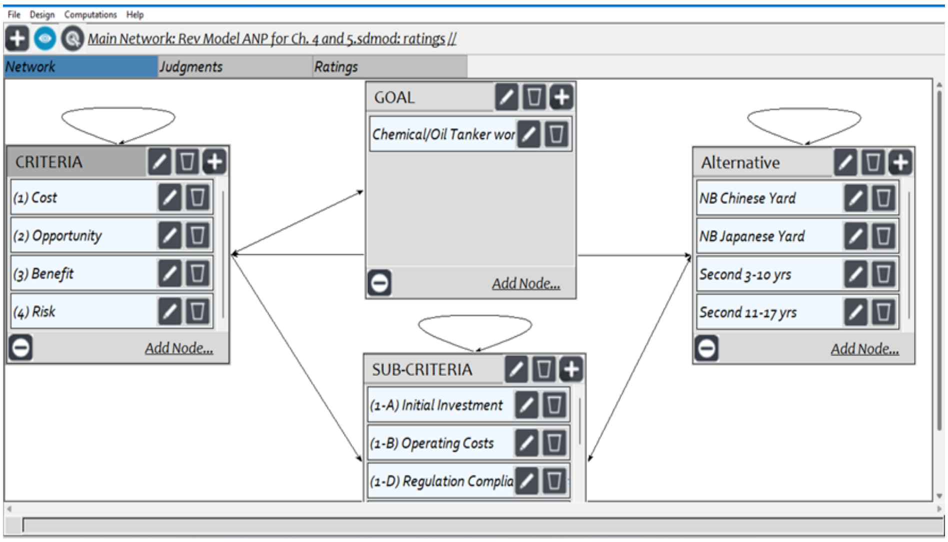

Figure 7 ANP Model Network programmed by Super Decisions software

Supermatrix Calculation and Weights

The data from the pairwise comparisons were processed using the Super Decisions software. This software facilitates the construction of the ANP network, the processing of relationships and dependencies between criteria, and the calculation of priority weights. Super Decisions is used to form and normalize the supermatrix until it produces the final priorities (global priority weights) for each alternative.

The results show that the new ship built in Japan (Newbuild Japan) ranks first as the most recommended alternative with an aggregate value of 0.362.

The second rank is the new ship built in China (Newbuild China) with an aggregate value of 0.320.

Alternative Evaluation

The new Japanese-made ship achieved the highest ranking because it offers optimal performance and low risk. This alternative excels in almost all criteria, particularly in Technology Risk and Asset Residual Value. The high reputation of Japanese shipyards, the potential for greater revenue from long-term contracts, operational efficiency, and technological reliability are supporting factors.

New ships made in China rank second and are identified as a cost-efficient yet competitive alternative. Although more cost-effective than Japanese ships, high-class charterers prefer Japanese-made vessels. However, Chinese ships have compliance risks equivalent to those of Japanese ships and still offer good technological efficiency.

Table 8 Ranking of Aggregated Value

No	Alternative	Aggregated Value	Ranking	Notes
1	Newbuild Japan	0.362	1	Excellent performance, Low risk
2	Newbuild China	0.320	2	Cost efficiency option, Remain competitive
3	Secondhand 3–10 years	0.185	3	Compromise between vessel price and age
4	Secondhand 11–17 years	0.133	4	High risk, Low residue value

Meanwhile, second-hand Japanese ships aged 3-10 years rank third, as a compromise option between price and the ship's age. This alternative requires a relatively low initial investment, and its technology is still viable. 11-17 years old used Japanese ships rank last, indicating high risk and low residual value. These ships are the least cost-efficient, face significant technical risks, and are less favoured by major charterers. The final global priority weights and investment alternative rankings are presented in

Table 8, indicating Newbuild Japan as the most preferred option.

Discussion

The results of this research provide important implications for investment decision-making in the company's strategic fleet. Since most of the Company's chemical/oil tanker fleet is over 15 years old and faces challenges such as high maintenance costs, Port State Control (PSC) detention risk, and rejection by major oil and gas companies, strategic investment in new ships becomes crucial. This integrated DEMATEL-ANP MCDM approach provides a systematic framework for evaluating the complexity of this decision, considering the interdependent relationships between the criteria of Cost, Benefit, Opportunity, and Risk.

The strong recommendation for investment in new Japanese-made ships reflects the need for a highly competitive and long-term-oriented fleet, in line with global market trends and increasingly stringent regulations. New ships from Japan or China offer better compliance with evolving regulations such as IMO 2020, EEXI, and CII and more environmentally friendly technology. The Technology Risk and Market Risk factors identified by DEMATEL as dominant causes further emphasize the urgency of fleet renewal to mitigate future operational and market risks. Investment in more modern and efficient ships will also provide a "green premium" on the residual value of assets, supporting the sustainability of the Company's business in the competitive global market. This approach supports the Company in securing revenue through long-term contracts, reducing spot market volatility, and enhancing the company's image.

CONCLUSION

This research employs an integrated Multi-Criteria Decision Making (MCDM) framework, combining the *Decision-Making Trial and Evaluation Laboratory* (*DEMATEL*) and the *Analytic Network Process* (*ANP*), to assess investment alternatives for chemical/oil tankers. By using *DEMATEL* to map cause-and-effect relationships and determine dominant factors, and then applying these insights within the *ANP* to prioritize investment options, the study finds that new Japanese-built ships (*Newbuild Japan*) are the most favorable choice, with an aggregate value of 0.362, reflecting their superior performance and lower risk profile. This approach underscores the strategic advantage of structured decision-making tools in overcoming challenges such as aging fleets, high maintenance costs, and the risk of charter rejection. The integration of *DEMATEL* and *ANP* offers a robust and objective solution for fleet renewal and strategic investment planning in the global maritime sector. For future research, it is recommended to enhance this framework by incorporating sensitivity analysis or hybrid models, allowing for even greater adaptability to evolving market conditions and regulatory changes.

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