TẠP CHÍ ISSN: 1859-316X, e-ISSN: 3093-3161
KHOA HỌC CÔNG NGHỆ HÀNG HẢI
JOURNAL OF MARINE SCIENCE AND TECHNOLOGY

APPLICATION OF THE ANALYTIC NETWORK PROCESS (ANP) TO EVALUATE THE SIGNIFICANCE OF ECONOMIC RISK FACTORS IN THE OPERATION OF OIL-CHEMICAL TANKER FLEETS IN SOUTHERN VIETNAMESE ENTERPRISES

ÁP DỤNG PHƯƠNG PHÁP PHÂN TÍCH MẠNG ANP (ANALYTIC NETWORK PROCESS) ĐỂ ĐÁNH GIÁ MỨC ĐỘ QUAN TRỌNG CỦA CÁC YẾU TỐ RỦI RO KINH TẾ TRONG CÔNG TÁC KHAI THÁC ĐỘI TÀU DẦU - HÓA CHẤT TẠI CÁC DOANH NGHIỆP PHÍA NAM VIỆT NAM

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DOI: https://doi.org/10.65154/jmst.2025.i84.610

Abstract

This study aims to identify and assess the relative importance of economic risk factors in the operation of oil-chemical tanker fleets in Southern Vietnam using the Analytic Network Process (ANP). The analysis is based on empirical data collected from enterprises engaged in maritime oil and chemical transportation services. Seven key economic risk factors are considered in this research: (1) Commercial pressure on the shipmaster, (2) Wage fluctuations, (3) Payment risk, (4) Variations in the costs of fuel, materials, and spare parts, (5) Risks of uncollected freight charges and demurrage fees, (6) Errors in voyage cost planning, and (7) Extended voyage duration leading to increased costs and reduced number of voyages.

The results reveal that "Extended voyage duration leading to increased costs and reduced number of voyages" is the most influential factor within the economic risk group. This finding indicates that this factor plays a particularly critical role in the management and operation of oil-chemical tanker fleets in Southern Vietnam, as it significantly affects all three key objectives: profitability, transport quality, and maritime safety.

Keywords: *Economic risk, oil-chemical tanker fleets, ANP, risk assessment, risk identification.*

Tóm tắt

Bài báo nhằm tìm ra các yếu tố và đo lường mức độ quan trọng của các yếu tố này khi nhận dạng các yếu tố rủi ro về mặt kinh tế trong công tác khai thác đội tàu dầu - hóa chất tại khu vực phía Nam Việt Nam bằng phương pháp phân tích mạng (ANP) dựa trên nguồn cơ sở dữ liệu thu thập từ các doanh nghiệp trong lĩnh vực kinh doanh dịch vụ vận chuyển dầu/hóa chất bằng đường biển. Trong đó 7 yếu tố rủi ro cần xét tới đó là: Áp lực thương mại lên thuyền trưởng; Tiền lương thay đổi; Rủi ro thanh toán; Chi phí nhiên liệu, vật liệu, phụ tùng thay thế thay đổi; Rủi ro không thu được tiền cước và tiền phạt lưu tàu; Sai sót trong lên kế hoạch về chi phí chuyến đi; Thời gian chuyến đi tăng khiến cho tăng chi phí và giảm số chuyến trong kỳ. Kết quả phân tích trong nghiên cứu này chỉ ra yếu tố "thời gian chuyến đi tăng khiến cho tăng chi phí và giảm số chuyến trong kỳ" có mức độ quan trọng lớn nhất, từ đó thấy được đây là yếu tố quan trọng nhất đối trong công tác khai thác đội tàu dầu/hóa chất tại địa bàn khu vực phía Nam Việt Nam xét với cả ba mục tiêu lợi nhuận, chất lượng vận tải, an toàn hàng hải.

Từ khóa: *Rủi ro kinh tế, đội tàu dầu/hóa chất, ANP, đánh giá rủi ro, nhận dạng rủi ro.*

1. Introduction

Southern Vietnam, encompassing key provinces and cities such as Ho Chi Minh City, Dong Nai, Can Tho, and other coastal areas, serves as the nation's major economic and industrial hub. With its strategic geographic location, the region connects to international maritime routes, facilitating import-export activities and supplying raw materials for the petrochemical and chemical processing industries. Overall, the oil-chemical shipping market in Southern Vietnam is highly dynamic and competitive. Major port terminals and oil/chemical berthing areas such as Go Dau, PV Oil Nha Be, PV Gas Vung Tau,… represent the areas with the highest concentration of maritime transport enterprises in the country, particularly those engaged in the transport of hazardous liquid cargoes, including crude oil, petroleum products, chemicals, and liquefied gases.

The rapid expansion of manufacturing and processing industries, coupled with increasing regional energy demand, has driven the continuous growth of specialized tanker fleets serving both domestic and international markets. The enterprises operating in this sector are diverse in ownership and scale, ranging from state-owned and equitized companies to private firms. Many major operators manage fleets across multiple segments, including crude/product oil tankers, chemical tankers, and LPG/LNG carriers.

However, the operation of oil-chemical tanker fleets can encounter significant difficulties if enterprises fail to recognize the importance of risk management. Considering the three fundamental objectives of tanker operators—profitability, transport quality, and maritime safety—numerous economic risks can directly affect the operational efficiency and business sustainability of these companies. Therefore, examining economic risks in this context is of critical importance.

By applying the Analytic Network Process (ANP) method, this paper aims to provide a comprehensive and detailed assessment of the most significant economic risk factors affecting the operation of oil-chemical tanker fleets in Southern Vietnam, taking into account all three objectives: Profitability, transport quality, and maritime safety. The findings are expected to contribute to the development of targeted preventive strategies that enhance stability and resilience in the oil-chemical maritime transport sector.

2. Theoretical framework

2.1. Definition of Risks

There are numerous definitions of risk in the literature. For example, "Risk is the possibility that an event may occur and adversely affect the achievement of objectives stated in the financial report" [1], or "Risk is measurable uncertainty" [2]. In practice, enterprises engaged in oil and oil-product tanker operations are exposed to a wide range of risks such as piracy, warfare, financial instability, and payment risks.

The implementation of effective risk management plays a crucial role in enhancing the efficiency of fleets operations, mitigating adverse impacts, and optimizing opportunities arising from potential risks. The classical risk management process generally consists of five steps [3]:

(i) Identification and analysis of potential losses;

(ii) Evaluation of feasible response options;

(iii) Selection of the most appropriate alternative;

(iv) Implementation; and

(v) Monitoring and review.

Economic risk is a type of risk, where risk in economics is understood as unforeseen adverse events that occur, which systems cannot predict but must accept and address. Some examples of economic risks include fluctuations in exchange rates, risks related to the prices of raw materials, fuel, wages, and others [24].

2.2. Economic Risk Group in the Operation of Oil-Chemical Tanker Fleets

The economic risk group directly influences the core objectives of maritime transport enterprises, including profitability, service quality, and maritime safety. Consequently, this group has attracted significant attention from scholars and practitioners in the maritime industry. Nguyễn Văn Sơn [4] identified several economic risks commonly encountered in the operation of oil-chemical tanker fleets, such as payment risks, exchange rate fluctuations, interest rate volatility, variations in fuel, materials, and spare parts costs, as well as uncertainties in voyage cost planning. Similarly, Đinh Gia Huy and Nguyễn Thành Nhật Lai [5] highlighted chartering risks in the Middle East market, including the inability to collect freight and demurrage fees or the early return of vessels by charterers.

Stopford [6] systematically analyzed the operational risks of oil tankers, while Santos and Soares [7] proposed an optimization model that considers voyage costs, chartering expenses, and production loss costs to improve fleets scheduling efficiency. To address the challenge of estimating medium-term market risk caused by limited data availability, Kavussanos and Dimitrakopoulos [8] applied the concepts of volatility and quantile ratios within GARCH-based models to derive robust forecasts from high-frequency data. Further developments by Ajith et al. [9] and Bai and Lam [10] employed multivariate GARCH and copula-GARCH models combined with Conditional Value at Risk (CoVaR) to explore interdependencies among tanker routes, revealing significant and asymmetric risk spillover effects within global oil transportation markets.

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Table 1. Summary of Economic Risk Factors

No.	Factor	Code	Source
1	Commercial pressure on the ship master	E1	Samet Bicen & Metin Celik (2022)
2	Changes in crew wages	E2	Nguyen Van Son (2012)
3	Payment risk	E3	Nguyen Van Son (2012); Siddiqui & Verma (2017)
4	Fluctuations in fuel, material, and spare parts costs	E4	Nguyen Van Son (2012)
5	Risk of uncollected freight and demurrage charges	E5	Dinh Gia Huy & Nguyen Thanh Nhat Lai (2021)
6	Errors in voyage cost planning	E6	Nguyen Van Son (2012)
7	Increased voyage duration leading to higher costs and fewer voyages per period	E7	Ozcan Durukan, Emre Akyuz, Orhan Destanoğlu, Yasin Arslanoğlu & Sukru Ilke Sezer (2024)

From a financial perspective, Siddiqui and Verma [11] quantified inherent financial risks and developed a mathematical optimization model to minimize total chartering costs while managing associated financial risks. Similarly, Celik et al. [12] applied the Quality Function Deployment (QFD) method to monitor and forecast dynamic maritime transport parameters such as freight rates, ship purchase and sale prices, fuel prices, and newbuilding trends. Talley [13] utilized the Tobit model to examine determinants of tanker accident costs, concluding that explosion-related incidents caused the highest vessel damage costs but the lowest oil spill costs. Furthermore, Ozcan and Emre [14] emphasized that extended voyage durations significantly increase operational costs and reduce the number of voyages per period, thus decreasing fleets profitability. Lastly, Koza et al. [15] analyzed the impact of infrastructure scale on the cost management of LNG tanker fleets and proposed a nonlinear supply-based optimization model to minimize long-term investment and operating costs.

Overall, the reviewed literature indicates that economic risks play a pivotal role in the operation of oil-chemical tanker fleets, as they not only affect cost structures, revenues, and profitability but also determine the competitiveness and financial sustainability of maritime transport enterprises.

Based on the identification of the scale components, the author designed a quantitative questionnaire and conducted pilot interviews with selected key stakeholders to collect additional expert feedback. The purpose of this pilot phase was to refine and finalize the measurement scale before conducting the main survey. During the pilot interviews, several open-ended questions were posed to respondents to assess the relevance and clarity of the proposed risk factors. For instance, a typical question was: “Regarding factor A, do you find any inconsistencies or impractical aspects in its description?”

Through this consultative approach, valuable insights were obtained from maritime enterprises regarding factors that were not entirely consistent with the actual operating context of the Southern Vietnam region. These responses were then used to modify and finalize the scale to ensure contextual validity. The economic risk factors presented in Table 1 were initially identified based on previous studies focusing on oil-chemical tanker fleets worldwide. In addition, the author updated the contextual characteristics of oil-chemical tanker operations among enterprises in Southern Vietnam and consulted with industry experts. Some economic risk factors were found to be universally applicable to tanker fleets in general. These expert insights were incorporated to refine and complete the list of economic risk factors presented in the table. As a result, seven economic risk factors were confirmed, as summarized in Table 1.

3. Research methodology

3.1. Qualitative Research Stage: Developing the Measurement Scale for Assessing the Importance of Economic Risk Factors Affecting Transport Quality Objectives in Oil-Chemical Tanker Fleets Operations in Southern Vietnam

The development of the measurement scale for evaluating the significance of economic risk factors was carried out in two main steps:

1. Literature review and factor identification:

Relevant research papers, industry reports, and documents concerning risks related to cost and revenue management in tanker fleets operations were collected and analyzed. Based on the synthesis of these materials, seven key economic risk factors were proposed:

(1) Commercial pressure on the ship master;

(2) Changes in crew wages;

(3) Payment risk;

(4) Fluctuations in fuel, material, and spare parts costs;

(5) Risk of uncollected freight and demurrage charges;

(6) Errors in voyage cost planning;

(7) Increased voyage duration leading to higher costs and fewer voyages per period.

2. Preliminary survey and expert validation:

A pilot survey was conducted among representatives of maritime transport enterprises specializing in oil and chemical shipping in Southern Vietnam. The responses were collected, categorized, and analyzed to identify dominant factors and refine the measurement scale accordingly,…

3.2. Quantitative Analysis Stage: Application of the Analytic Network Process (ANP)

The Analytic Network Process (ANP) is a multi-criteria decision-making method designed to handle complex decisions in which the determining elements-referred to as nodes, such as criteria and alternatives-are interrelated through dependencies and feedback loops [16]. ANP represents an extension of the widely used Analytic Hierarchy Process (AHP), in which decision elements are structured hierarchically according to goals, criteria, and alternatives (Saaty, 1980).

The AHP method serves as the foundation of ANP. Since its development by Thomas L. Saaty, AHP has attracted considerable attention from researchers and decision-makers worldwide for its utility in supporting systematic decision-making processes [17]. However, while AHP effectively addresses many decision-making scenarios, its applicability becomes limited in more complex contexts-specifically when strong interdependencies exist among elements at the same or different hierarchical levels. This limitation arises because AHP does not account for mutual dependence among peer elements or for feedback effects from alternatives to criteria [18].

To overcome these constraints, Saaty proposed a generalized framework that allows for the inclusion of both interdependence and feedback among decision elements-known as the Analytic Network Process (ANP) [16].

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

Contingency theory asserts that management activities-such as decision-making-must take situational factors into account [19]. Multi-Criteria Decision-Making (MCDM) methods have been developed to support one of the most essential managerial activities-decision-making-which, according to the contingency approach, must consider contextual factors that may influence the outcome of the decision process. Different MCDM methods vary in their suitability and capacity to incorporate and address such random or situational factors. Since not all decision-making techniques can adequately accommodate every type and situation of decision, when exploring the application of ANP within MCDM analysis, these contextual contingencies should be taken into account [20].

Generally, two types of situational factors are considered relevant for decision-making purposes: content factors and contextual factors. Both types of contingencies are recognized as influencing the available alternatives, the expected benefits, and the decision-making procedures (such as analytical or evaluative methods) to be applied [21].

The ANP method assists decision-makers in determining how many times one element is dominant over another and in identifying their relative importance values with respect to the relevant criteria. It also allows for the integration of expert knowledge and practical experience in an intuitive manner. The ANP employs a ratio scale using absolute numbers rather than intervals or ranks. In this method, experts' judgments are converted into numerical values. For instance, in the comparison matrix, the value 1 denotes the equal importance of two elements, whereas 9 represents the extreme importance of one element over another-where the element in the row cluster is compared against the column cluster in the matrix.

For reciprocal comparisons, the inverse value is applied. In the comparison equation, the coefficient a_{ij} represents the relative importance of element i compared to element j. Within the ANP framework, a pairwise comparison matrix is used to illustrate these relationships [20].

Let the elements to be compared be denoted as $x_1,\dots,x_n$ and their respective importance weights as $w_1,\dots,w_n$. The pairwise comparison of their relative importance can then be represented in matrix form as follows:

$$\text{With: } A=(a_{ij}) \text{ where } a_{ij},\ a_{ij}=\frac{1}{a_{ij}},\ a_{ij}=1$$

Accordingly, i represents the element in row i and j represents the element in column j; therefore, a_{ij} denotes the relative importance of element i compared to element j. Saaty T. L. and Vargas L. G. [35] pointed out that the pairwise comparison matrix is utilized to determine the weights of importance for all elements within the model. At present, various methods have been developed to derive the priority weights (w-matrix) that quantify the relative significance of all elements in the model.

Based on the risk factors related to cost management and revenue sources that influence the quality objectives of oil/chemical tanker fleets operations, the research model is established as follows:

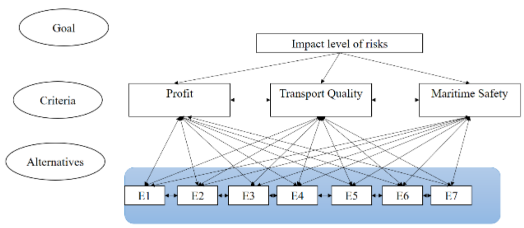

Figure 1. Proposed Research Model

The first stage involves modeling the research problem in the form of a network, which includes identifying the constituent factors, grouping them according to their functions or characteristics, and determining the interrelationships among factors and among groups of factors within a complex network structure. The subsequent stage quantifies the relative importance of these factors through a sequence of weight computation steps. Specifically, the process includes: defining the degree of influence among factors and clusters, constructing pairwise comparison matrices, calculating the unweighted supermatrix, normalizing it to obtain the weighted supermatrix, and finally deriving the limit supermatrix to determine the convergent weights of each factor in the network.

The detailed computational procedures for these matrices were presented in Study Module 1. The pairwise comparison method follows the procedure proposed by Saaty (1980), using a nine-point scale to express the relative importance between two elements under a common criterion. However, a major challenge in data collection lies in the potentially large number of pairwise comparisons, which can cause inconsistency in expert evaluations. To overcome this limitation, several studies have suggested refining Saaty's qualitative scale using a PairWise Table, which enables more systematic and convenient quantification of expert judgments. In practice, the factors in the model are presented to experts in the form of structured evaluation tables, from which relative influence scores are collected. These scores are then used to construct pairwise comparison tables and corresponding matrices. For instance, when assessing the impact on maritime safety, if the technical risk group is assigned a score of 7 and the economic risk group a score of 6, the relative comparison ratio is 7/6 ≈ 1,167. According to Saaty's scale, this indicates that technical risk is approximately 1,167 times more important than economic risk in the context of maritime safety.

4. Research results

The survey was conducted through both direct (in-person) and online methods. To ensure confidentiality, the names and professional positions of the participating experts are not disclosed. A total of 95 fully completed questionnaires were collected, including 60 from in-person surveys and 35 from online surveys. Therefore, 95 valid responses were used for analysis in this study. The experts selected for participation were from enterprises directly involved in the operation of oil and chemical tanker fleets in southern Vietnam, such as Nhat Viet Shipping Joint Stock Company, Vietnam Oil and Chemical Transportation Joint Stock Company, Marine Management Joint Stock Company, and Au Lac Joint Stock Company, among others. In southern Vietnam, oil, chemical, and LPG carriers vary in size and are designed to meet both domestic and international transportation demands. Oil tankers typically have a deadweight tonnage (DWT) ranging from 45,000DWT to 150,000DWT, while chemical tankers generally range from 13,000DWT to 25,000DWT. Depending on the vessel type, LPG carriers have

Table 2 . Information on Official Survey Respondents

No.	Criteria	Number of Respondents	Proportion (%)
1	**Years of experience in the maritime transport sector**		
	Over 20 years	1	1,053
	15-20 years	11	11,579
	10-15 years	14	14,737
	5-10 years	40	42,105
	Under 5 years	29	30,526
2	**Educational level**		
	Bachelor's degree	82	86,316
	Postgraduate degree	13	13,694
3	**Affiliation**		
	Shipowners	73	76,842
	Cargo owners	4	4,211
	Ports	4	4,211
	Repair companies	3	3,158
	Pilots	3	3,158
	Brokers	7	7,368
	Classification societies	1	1,052

capacities ranging from 6,000 to 12,000 cubic meters. The operational routes of enterprises in this region include both domestic routes from refineries and international shipping routes. Additionally, respondents included representatives from repair companies, cargo owners, and relevant state management agencies. These participants possessed adequate knowledge and practical experience to assess operational risks associated with oil-chemical tanker fleet management. Detailed information about the surveyed respondents is presented in Table 2.

The results indicate that the majority of respondents (69.474%) have more than five years of professional experience. Regarding educational background, 86.316% of the surveyed experts hold a bachelor's degree, while 13.694% possess a postgraduate qualification. Most of the participants were shipowners, accounting for 73 responses (76.842%), whereas the remaining 23.158% were from cargo owners, repair companies, brokers, classification societies, and pilot organizations.

The consistency verification in the ANP method requires the calculation of the Consistency Ratio (CR), expressed as:

$$CR = CI/RI \quad (2)$$

Where:

CI (Consistency Index): A measure that indicates the degree of logical consistency within the pairwise comparison matrix.

RI (Random Index): The average CI value derived from a large number of randomly generated matrices. The RI value depends on the matrix size and is typically obtained from standardized reference tables.

The closer the CI value is to zero, the higher the matrix consistency. If $CR<0.1$, the pairwise comparison matrix is considered consistent and acceptable. Conversely, if $CR>0.1$, the matrix is deemed inconsistent and must be revised accordingly. The raw data and questionnaire used in this study can be found at Mendeley Data: doi: 10.17632/kxxzwfxzrn.1.

The results of the pairwise comparison matrix among the three objectives-profitability, transport quality, and maritime safety-within the economic risk group indicate a high level of consistency, with a consistency ratio of CR = 0.00021, confirming the reliability of expert data in the ANP analysis process. Specifically, the profitability criterion was evaluated as the highest priority, with a relative weight greater than that of transport quality (by 1.112 times) and maritime safety (by 1.116 times). This finding suggests that, in the context of oil-chemical tanker fleets operations, economic-related risks exert the strongest influence on a company's profitability.

However, the differences among the matrix values

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Table 3. Results of Pairwise Comparison of the Importance among Criteria within the Economic Risk Group

Criterion	Profitability	Transport Quality	Maritime Safety	CR
Profitability	1	1,112	1,116	0,00021
Transport Quality	0,9	1	1,004	
Maritime Safety	0,896	0,996	1	

Table 4. Results of Pairwise Comparison among Economic Risk Variables with Respect to the Profitability Criterion

Risk Variables	E1	E2	E3	E4	E5	E6	E7	CR
E1	1,000	0,974	0,970	0,943	0,931	0,950	0,907	0,0424
E2	1,026	1,000	0,995	0,968	0,955	0,975	0,931	
E3	1,031	1,005	1,000	0,972	0,960	0,980	0,935	
E4	1,061	1,033	1,029	1,000	0,987	1,007	0,962	
E5	1,075	1,047	1,042	1,013	1,000	1,021	0,975	
E6	1,053	1,026	1,021	0,993	0,980	1,000	0,955	
E7	1,102	1,074	1,069	1,039	1,026	1,047	1,000	

Table 5. Results of Pairwise Comparison among Economic Risk Variables with Respect to the Transport Quality Criterion

Risk Variables	E1	E2	E3	E4	E5	E6	E7	CR
E1	1,000	0,973	1,039	1,044	1,084	1,033	0,964	0,000034
E2	1,028	1,000	1,069	1,074	1,114	1,062	0,991	
E3	0,962	0,936	1,000	1,005	1,043	0,994	0,927	
E4	0,958	0,931	0,995	1,000	1,038	0,989	0,923	
E5	0,923	0,898	0,959	0,964	1,000	0,953	0,889	
E6	0,968	0,942	1,007	1,011	1,049	1,000	0,933	
E7	1,038	1,009	1,078	1,084	1,124	1,071	1,000	

Table 6. Results of Pairwise Comparison among Economic Risk Variables with Respect to the Maritime Safety Criterion

Risk Variables	E1	E2	E3	E4	E5	E6	E7	CR
E1	1,000	1,002	1,041	1,016	1,060	1,009	0,971	0,00000098
E2	0,998	1,000	1,039	1,014	1,058	1,007	0,969	
E3	0,961	0,963	1,000	0,976	1,019	0,970	0,933	
E4	0,985	0,987	1,025	1,000	1,044	0,994	0,957	
E5	0,943	0,945	0,982	0,958	1,000	0,952	0,916	
E6	0,991	0,993	1,031	1,006	1,050	1,000	0,963	
E7	1,029	1,031	1,071	1,045	,091	1,039	1,000	

are not substantial, indicating a relatively balanced relationship among the three objectives. Therefore, although profitability is regarded as the dominant factor, companies continue to place considerable emphasis on transport quality and maritime safety as essential conditions for ensuring sustainability and overall operational efficiency-particularly in relation to economic risk factors. The author employed the Super Decisions software to process and analyze the data. The results of the pairwise comparison matrix among the economic risk variables, considering their importance to the profitability criterion, are shown in Table 4.

The results of the pairwise comparison matrix among the economic risk variables, considering their importance to the transport quality criterion, are shown in Table 5.

Table 7. Summary of the Limiting Matrix Results and Risk Priority Indices of Economic Risk Variables using the ANP method

Risk Variables	**Total Risk Priority Index** (TRPI)	**Normalized Risk Priority Index** (NRPI)	**Ideal Risk Priority Index** (IRPI)	**Priority Ranking**
E1	0,095	0,1425	0,9751	4
E2	0,0958	0,1436	0,9829	2
E3	0,0943	0,1414	0,9678	6
E4	0,095	0,1425	0,9749	5
E5	0,0941	0,1411	0,9653	7
E6	0,0951	0,1427	0,9764	3
E7	0,0974	0,1461	1	1

The results of the pairwise comparison matrix among the economic risk variables, considering their importance to the maritime safety criterion, are shown in Table 6.

The results of the overall priority assessment of economic risks are synthesized and presented in Table 6.

The findings indicate that the dominance of economic risks arises from the methodological strength of the ANP approach, which effectively captures interdependencies among criteria and risk groups. Within the economic risk category, "Extended voyage duration" (E7) emerges as the most critical factor (NRPI = 0,1461), primarily due to port congestion, prolonged inspections, and customs delays in Southern Vietnam, leading to higher operating costs and reduced voyage frequency. "Wage fluctuations" (E2) ranks second (NRPI = 0.1436), reflecting challenges in maintaining crew stability amid rising labor costs and workforce migration to foreign fleets. "Errors in voyage cost planning" (E6) follow closely (NRPI = 0.1427), resulting from unstable fuel prices and inaccurate expense forecasting. Other notable risks include "Variations in costs of fuel, materials, and spare parts" (E4), "Payment risk" (E3), and "Uncollected freight charges and demurrage fees" (E5), which collectively expose operators to financial instability and cash flow disruptions. To verify the stability of the risk factor rankings, three sensitivity analysis scenarios were conducted. In the first scenario, the weights of the criteria were modified by increasing the weight of the IRPI by a factor of 1,1. The results indicate that although E7 maintained its leading position, other factors such as E2, E3, and E6 experienced considerable changes in their rankings. This suggests that adjustments in weighting can result in substantial shifts in the ranking of risk factors.

In the second scenario, the TRPI values of E1 and E2 were reduced to 95% of their original values. This adjustment caused a significant decline in E1's ranking from fourth to seventh position, while E2 dropped from second to sixth place. Other factors such as E6 and E3 also experienced minor ranking changes. These findings imply that variations in the magnitude of risk factor values can greatly influence their relative rankings.

The third scenario involved a change in the normalization method, in which the mean normalization approach was applied to recalculate the rankings. Although E7 remained in the top position, slight changes in ranking occurred for some factors, particularly E4, which moved up from fifth to fourth position. This result indicates that altering the normalization technique can affect certain rankings; however, factors such as E7, E2, and E1 consistently retained high positions across all scenarios.

The sensitivity analysis results reveal that the rankings of risk factors can vary notably when the weights or the factor values are adjusted. Nevertheless, in practical situations, factors such as E7 and E2 consistently maintained their top rankings, demonstrating their stability and robustness in the decision-making process.

Overall, the analysis underscores that economic risks are the most dominant group, shaped by structural factors such as congested port infrastructure, dependency on imported spare parts, volatile global oil prices, and a shortage of skilled maritime labor. These characteristics heighten the vulnerability of Southern Vietnam's oil-chemical tanker operators, emphasizing the need for comprehensive ANP-based risk management strategies to enhance operational resilience and decision-making efficiency.

The research results indicate a difference between the AHP and ANP approaches. In the AHP method, the objectives—profitability, transport quality, and maritime safety—are considered independent from one another. In contrast, under the ANP approach, these objectives are interrelated and influence one another, with the evaluation priorities arranged in the following order: maritime safety, transport quality, and profitability. The difference in the ranking results between AHP and ANP for risk factors mainly arises from the way these factors are evaluated and how their interrelationships are treated, clearly reflecting the distinct perspectives of each method in capturing the mutual influences among factors.

The Analytic Hierarchy Process (AHP) is a method used to determine the priority order of factors that are assumed to be independent. The analytical model based on AHP is illustrated in the following Figure 2.

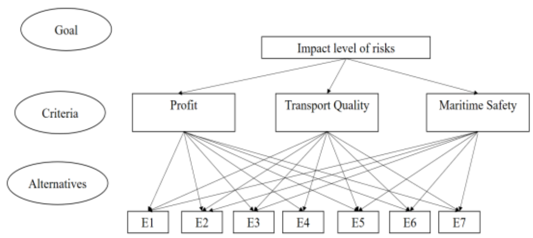

Figure 2. AHP hierarchical model of risk impact assessment

In AHP, each risk factor-such as E1, E2, and so on-is assessed according to its individual level of importance, without considering any interrelationships or interactions among them. This means that each factor is treated as an independent entity, and its priority index reflects only its own importance within the overall system, without any adjustment from the influence of other factors.

Although in this case the ranking results obtained from the AHP and ANP methods may appear similar (with differing priority indices), the AHP method still exhibits clear limitations compared to ANP. The AHP approach fails to capture the interrelationships among objectives and the feedback interactions between risk factors and objectives. AHP assumes that the factors involved in the decision-making process are independent and mutually exclusive, which prevents it from modeling the interactions among risk factors. This limitation reduces its ability to reflect changes in the priority levels of factors when interdependencies exist.

In contrast, the ANP method is capable of modeling the complex interactions between risk factors and objectives, thereby allowing for a dynamic assessment of changing priorities and a more accurate representation of real-world interdependencies among factors. Therefore, the ANP approach is more advantageous than AHP in handling situations where interactions exist between factors and objectives, leading to more precise and realistic decision-making outcomes.

5. Conclusion

This study focuses on evaluating and analyzing the priority of economic risk factors affecting enterprises engaged in oil and chemical tanker fleets operations in the southern region of Vietnam. The analysis considers three core organizational objectives: Profitability, transport quality, and maritime safety. The results reveal the following priority order of economic risk factors: (1) increased voyage duration leading to higher costs and reduced trip frequency; (2) fluctuations in crew wages; (3) errors in voyage cost planning; (4) commercial pressure on the ship's master; (5) variations in fuel, material, and spare part costs; (6) payment risks; and (7) risks of uncollected freight and demurrage charges. This study has certain limitations that should be acknowledged. First, the evaluation of economic risks in the operation of oil and chemical tanker fleets in southern Vietnam was primarily based on expert judgments collected through the ANP method. Although the experts were selected for their extensive experience and professional knowledge, the results may still be influenced by subjective perceptions and limited sample size. Second, the study focused specifically on enterprises operating in the southern region of Vietnam; therefore, the findings may not fully represent the economic risk characteristics of the entire national tanker industry.

These findings provide valuable implications for maritime transport enterprises in enhancing their risk management practices. By identifying and prioritizing the most influential economic risks, companies can make more informed strategic decisions and allocate resources more effectively. The application of the Analytic Network Process (ANP) in this study provides valuable managerial insights for enterprises operating oil-chemical tanker fleets and for port authorities responsible for maritime safety and economic supervision in the southern Vietnam region.

For enterprise managers, the ANP results emphasize that economic risk factors are not independent but mutually influencing, particularly their impacts on key operational objectives, namely profitability, transport quality, and maritime safety.The findings reveal the following priority order of economic risk factors. These results indicate that prolonged voyage duration and cost management inefficiencies exert the most substantial impact on operational performance and profitability. Therefore, shipping enterprises should prioritize optimizing voyage scheduling and enhancing voyage cost planning accuracy to mitigate financial losses. Flexible wage management mechanisms and dynamic fuel procurement strategies should also be adopted to reduce exposure to market volatility.

In addition, managers need to establish integrated risk monitoring systems based on ANP outcomes to capture the interdependencies between economic and safety factors. For instance, cost escalation or delayed voyages may indirectly increase safety risks due to crew fatigue or maintenance deferrals. By modeling such feedback effects, enterprises can proactively allocate resources to maintenance planning, crew training, and safety assurance programs, ensuring that operational decisions balance both economic efficiency and maritime safety.

For port authorities and regulatory agencies, the ANP-based analysis provides a scientific foundation for designing more adaptive and interconnected risk management frameworks. Strengthening coordination among port management units, shipping companies, and maritime safety centers is essential to mitigate cascading impacts arising from voyage delays, cost fluctuations, or commercial pressures. Moreover, ANP-based assessments can support data-driven policymaking by identifying which economic risk factors have the strongest systemic influence on port operations and regional logistics stability.

In summary, the adoption of the ANP approach enables both enterprises and port authorities to better understand the complex interrelationships among economic, operational, and safety risks in oil-chemical tanker operations. This facilitates more precise prioritization, proactive risk mitigation, and sustainable management aligned with the principles of maritime safety and economic resilience.

Furthermore, the results contribute to the establishment of a comprehensive and efficient risk management framework, supporting the long-term sustainability and overall operational performance of maritime transport businesses.

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TẠP CHÍ ISSN: 1859-316X, e-ISSN: 3093-3161
KHOA HỌC CÔNG NGHỆ HÀNG HẢI
JOURNAL OF MARINE SCIENCE AND TECHNOLOGY

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Received:	15/10/2025
Revised:	01/11/2025
Accepted:	06/11/2025