Optimizing Risk Management and Operational Efficiency in Self-Propelled Oil Barge Operations Using AHP and FMEA: A Case Study at PT. Faher Hayat Bersatu

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Abstrak
Penelitian ini bertujuan untuk mengoptimalkan manajemen risiko dan efisiensi operasional pada kapal tongkang minyak self-propelled milik PT. Faher Hayat Bersatu. Dalam industri pelayaran dan logistik maritim yang sangat kompetitif dan penuh tantangan, pengambilan keputusan yang tepat memerlukan pendekatan yang terstruktur dan berbasis data. Oleh karena itu, penelitian ini menggabungkan dua metode analisis yang saling melengkapi, yaitu Analytic Hierarchy Process (AHP) dan Failure Mode and Effects Analysis (FMEA). AHP digunakan untuk menetapkan prioritas dari berbagai kriteria dan sub-kriteria operasional yang memengaruhi kinerja, di mana hasil menunjukkan bahwa "Biaya BBM" dan "Ketepatan Waktu" merupakan faktor paling krusial. Di sisi lain, FMEA diterapkan untuk mengidentifikasi potensi kegagalan dalam operasi, dan hasilnya menunjukkan bahwa "Kebocoran Bahan Bakar" memiliki nilai Risk Priority Number (RPN) tertinggi, sehingga menjadi risiko paling signifikan. Integrasi kedua metode ini memberikan pendekatan komprehensif bagi perusahaan untuk memahami aspek paling penting yang harus diperhatikan, sekaligus menilai dan memitigasi risiko-risiko yang dapat menghambat efisiensi operasional secara menyeluruh dan berkelanjutan.

Kata kunci: AHP, FMEA, Manajemen Risiko, Efisiensi Operasional, Tongkang Minyak.

Abstract
This study aims to optimize risk management and operational efficiency in self-propelled oil barge operations at PT. Faher Hayat Bersatu. As part of the maritime logistics sector, the company operates in an environment that demands both high reliability and strong risk mitigation strategies. Effective decision-making under such conditions requires a structured, data-driven approach that can address both performance priorities and operational vulnerabilities. To achieve this, the study integrates two well-established methodologies: the Analytic Hierarchy Process (AHP) and Failure Mode and Effects Analysis (FMEA). The AHP method is used to determine the relative importance of various operational criteria and sub-criteria, with results indicating that "Fuel Cost" and "Timely Delivery" are the most critical factors. Concurrently, FMEA is utilized to assess potential failure modes, identifying "Fuel Leakage" as having the highest Risk Priority Number (RPN), marking it as the most severe risk. The integration of AHP and FMEA provides a comprehensive framework that enables companies to prioritize operational focus areas while systematically addressing the risks associated with them, thereby supporting strategic planning and continuous performance improvement.

Keywords: AHP, FMEA, Risk Management, Operational Efficiency, Oil Barge

I. INTRODUCTION

PT. Faher Hayat Bersatu is a company engaged in the distribution of fuel oil using self-propelled oil barges. The company has been operating for over a decade, navigating challenges related to delivery logistics, environmental safety, and cost control. These challenges underline the necessity for systematic and structured methods to evaluate operational performance and identify potential risks.

To address this, the research applies the Analytic Hierarchy Process (AHP) and Failure Mode and Effects Analysis (FMEA) as decision support tools. AHP helps determine priority aspects of operations based on stakeholder preferences, while FMEA identifies potential failure modes and assesses their severity, frequency, and detectability. By combining both, this study provides a strategic framework that PT. Faher Hayat Bersatu can use for ongoing risk management and process improvement.

II. LITERATURE REVIEW

A. Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making method developed by Saaty (1980). The Analytic Hierarchy Process (AHP) is a comprehensive decision-making instrument utilized to establish priorities and rankings of variables through a systematic assessment of their relative importances. This study employs AHP to identify and prioritize operational and risk management elements influencing self-propelled oil barge operations. The subsequent detailed steps delineate the application of AHP (Saaty, 1990, as cited in Afif & Okdinawati, 2024).

B. Failure Mode Effect Analysis (FMEA)

failure mode and effect analysis (FMEA), first invented and used in the aerospace industry dated back in 1960s Mascia et al. (2020) for identifying and prioritizing potential failure modes in a system. It evaluates failure based on Severity (S), Occurrence (O), and Detection (D) scores to calculate the Risk Priority Number (RPN), with main objective to aid decision-making by collecting the related information of products or systems Mascia et al., (2020); Zhu et al., (2021). FMEA is a widely utilized method for identifying potential failures in a system and for evaluating their effects by ranking severity, occurrence, and detection.(Hendayani et al., 2021).

C. Research Framework

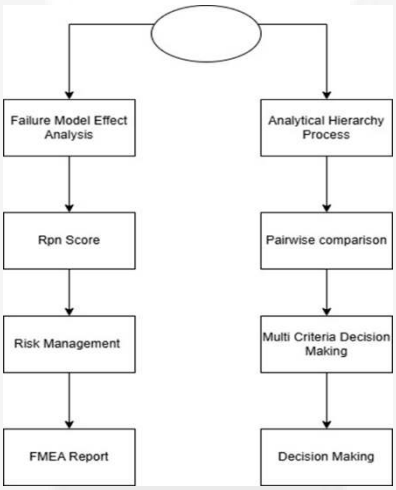

Figure 1 Research Framework source:(Nuur Afiif & Okdinawati, 2024)

Figure 1 presents the integrated research framework combining AHP and FMEA. The AHP component structures the decision problem into a hierarchy of goals, criteria, and sub-criteria, enabling pairwise comparisons and priority ranking. Simultaneously, FMEA identifies potential failure modes and evaluates them based on Severity, Occurrence, and Detection to generate Risk Priority Numbers (RPN).

This framework supports a dual analysis: AHP clarifies operational priorities, while FMEA highlights critical risks. Integrating the two ensures that improvement initiatives target both high-priority and high-risk aspects of the operation.

III. RESEARCH METHODOLOGY

This research employs a **quantitative method** to assess risk management and operational efficiency challenges in the self-propelled oil barge operations of PT. Faher Hayat Bersatu. It utilizes both primary and secondary data sources, including structured pairwise comparison questionnaires, internal company documentation, and expert input from professionals in logistics, operations, and safety.

The study applies a **descriptive approach** to systematically analyze operational aspects and risk elements using the AHP and FMEA frameworks. AHP is used to determine the weight and priority of criteria and sub-criteria, while FMEA is applied to assess potential failure modes based on severity, occurrence, and detection (Ghaffar & Indrawati, 2024; Hendayani & Rahmadina, 2021). The research is cross-sectional in nature, conducted in a real-world (non-contrived) operational environment, with PT. Faher Hayat Bersatu as the unit of analysis (Sekaran & Bougie, 2025).

IV. RESULT AND ANALYSIS

A. Analytical Hierarchy process (AHP)

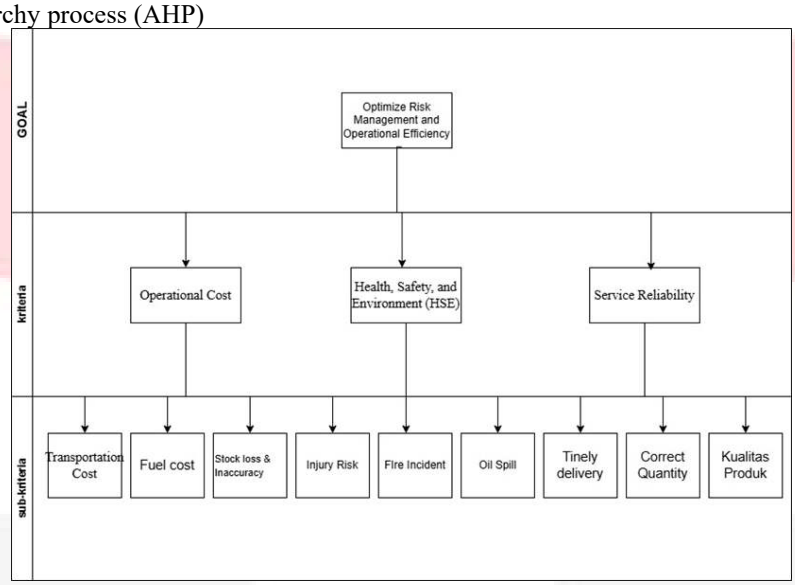

Figure 2 AHP Hierarchy

AHP Analysis: The three main criteria were Operational Cost, Health-Safety-Environment (HSE), and Service Reliability. The highest global weights were assigned to Fuel Cost (0.2424), Timely Delivery (0.1527), and Transportation Cost (0.1562). This highlights that fuel efficiency and delivery timeliness are top priorities.

B. Failure Mode Effect Analysis (FMEA)

Table 1 FMEA TABLE

Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN
Fuel Leakage	9	4	5	180
Engine Failure	7	3	4	84
Inaccurate Route Planning	6	5	3	90
Fire Incident	10	2	6	120
Delivery Delay	5	6	3	90
Oil Spill Incident	9	2	6	108
Stock Loss & Inaccuracy	6	5	4	120

Personnel Injury	8	3	5	120

FMEA Analysis: Based on the FMEA analysis, the failure mode with the highest RPN is "Fuel Leakage" (RPN = 180), followed by "Delivery Delay" and "Inaccurate Route Planning". Although the company has not recorded major incidents in the past 10 years, this evaluation is preventive in nature and can be used for future decision-making.

C. Integration of AHP and FMEA

by combining priority weights from AHP and risk scores from FMEA, the company can focus on aspects that are not only important but also most at risk. For example, Fuel Cost (AHP: 0.2424) corresponds with Fuel Leakage (FMEA: RPN 180), indicating an urgent need to improve fuel monitoring systems.

V. CONCLUSION AND SUGGESTION

A. Conclusion

This research demonstrates the effective integration of the Analytic Hierarchy Process (AHP) and Failure Mode and Effects Analysis (FMEA) in optimizing operational performance and risk management in self-propelled oil barge operations at PT. Faher Hayat Bersatu. AHP helped identify the most critical operational factors, such as fuel cost and delivery timeliness, while FMEA provided a preventive risk assessment to prioritize potential failure modes, with fuel leakage being the highest. This dual-method framework enables data-driven decision-making that is both priority- and risk-sensitive.

B. Recommendation

1. PT. Faher Hayat Bersatu is advised to adopt the integrated AHP–FMEA framework as a routine decision-support tool to evaluate and improve operational processes. The use of AHP can help align decision-making with strategic priorities, while FMEA enables proactive identification of high-risk failure modes. It is recommended that the company begin developing an internal incident database to support future FMEA updates with empirical evidence.
2. For academic and educational purposes, this study contributes to the application of multi-method decision-making frameworks in maritime logistics. Future research can explore integrating AHP and FMEA with other tools such as Monte Carlo simulation or Bayesian networks to improve predictive accuracy. This study can serve as a reference for students and researchers working on decision-making models in operations and risk management.

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