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Cost Optimization and Risk Management Program for the Fuel Supply Network in an Oil & Gas Swamp Operation

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ABSTRACT: Marine activity is a critical part of an oil & gas company that operates in the swamp area. The company utilizes rigs, barges, and boats to achieve maximum production. Fuel supply for marine fleets is highly essential to ensure smooth operation. Since fuel cost becomes one of the biggest components of operating expenses (OPEX), the stakeholders highly encourage cost optimization programs to ensure business profitability. However, any optimization program shall have a robust risk management program to avoid disturbance in the operation and potential financial losses.

The research aims to select the best fuel supply network in the swamp operation area of an oil & gas company using four criteria (operational expenses, service reliability, value creation, and health safety & environment) based on the literature review and subject matter experts' analysis. The study will analyze several alternatives using the Analytical Hierarchy Process (AHP) as a decision-making tool and Failure Mode Effect Analysis (FMEA) as the risk management method. The result shows that the hybrid network has the highest rating in AHP with a 33.7% rating and the lowest total risk priority number with 212 points.

KEYWORDS: cost optimization, fuel supply network, risk management, AHP, FMEA

INTRODUCTION

An upstream oil & gas company maintains its business by generating revenue through oil and gas sales while optimizing its production cost. The biggest challenge of brownfield activities is fighting the declining oil and gas production output. Furthermore, the capital and operating expenses continue to soar due to their production facilities' maturity and reservoir characteristics. Company revenue is getting lower as the production figures and oil prices lower. Thus, cost optimization is highly critical to ensure company profitability. Stakeholders require cost optimization for all business activities, including marine fleet operational figures that are managed under the SUP division. The marine fleet budget consists of daily vessel charter rates and fuel expenses. The company spends more enormous yearly budget on fuel to support day-to-day operations. Since fuel cost has become a major component of operational expenses, a cost optimization program is highly needed to reduce the yearly budget and ensure business continuity. The stakeholders urged to evaluate and optimize the fuel budget, including its supply network.

Generally, fuel cost component reduction is considered a hard and strenuous program since the reduction in fuel consumption will directly impact the lower performance of exploration and production activities. For instance, the fuel consumption reduction in a rig will decrease its drilling capacity, thus lessening the daily target depth target and lowering oil production. Thus, the delivery cost component is becoming the main area to optimize for, especially with the enormous fuel budget. Thus, any cost reduction initiative will give the company immense benefits. However, the optimization program shall be carefully managed to ensure the implementation plan does not wreak havoc on the company's profitability. A change in the supply network may create potential fuel shortages and non-productive time during the standby period while waiting for upcoming supply. It will generate a production shortfall and reduce the company's revenue. Risk analysis and mitigations shall be properly carried out as part of change management. Hence, supply chain risk management is essential to ensure any cost optimization initiative will generate the maximum profit gain for the company.

LITERATURE REVIEW

The research employs Analytic Hierarchy Process (AHP) as the decision-making tool that depends on expert judgment to determine priority scales. These scales evaluate the relative value for each alternative and criterion. The comparisons are made using a scale that indicates how much more valuable one factor is than another in terms of a particular attribute. AHP will be commonly used in developing countries' decision-making processes (Vaidya, O.S. et al. 2006). AHP also measures inconsistency in the judgments.

The result shall show the priority of the alternative and value regarding the fundamental objective. AHP is done through the following steps:

Step 1. Build a hierarchy.

Step 2. Establish the problem criteria and identify the alternatives.

Step 3. Designate the pairwise comparison matrix based on the relative importance as per Table 1.

Table 1. Relative importance scale

Intensity	Definition
1	Equal Importance
2	Weak or Slight
3	Moderate Importance
4	Moderate Plus
5	Strong Importance
6	Strong Plus
7	Very Strong or demonstrated importance
8	Very, very strong
9	Extreme importance

Step 4. Compute the calculation and evaluate the inconsistency.

Inconsistencies during pairwise comparison are calculated by determining the consistency index (CI) and consistency ratio (CR) using the formula below.

$$CI = \frac{\lambda_{max} - n}{(n-1)}$$

$$CR = \frac{CI}{RI}$$

Where λ_{max} is the maximum eigenvalue and n is the matrix dimensions.

Random Index (RI) is the consistency index of a randomly generated pairwise comparison matrix with a dependent value based on the matrix size, as shown in Table 2.

Table 2. Random Index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Then, pairwise comparison is considered acceptable if the $CR \leq 0.1$.

Step 5. Results will show the alternatives' priority as the best solution according to the research objectives.

The risk management program will be determined to ensure minimal impact on the operation while optimizing the total expenses. Failure mode and effects analysis (FMEA) will be used to map supply chain risk management associated with alternatives for fuel provision methods in swamp operations. FMEA is a broadly employed reliability management methodology that is extensively used across multiple industries to check and verify the safety and dependability of a particular system (Lie et al., 2013). FMEA was developed by the United States Defense Department in 1949 and became an integral part of Appolo reliability system enhancement in 1960 (Bowles et al., 1995). FMEA has been widely adopted in the maritime industry in compliance with international marine regulations (Pillay et al., 2001).

The FMEA method utilizes the risk priority number (RPN) system by calculating three factors: failure probability (P), severity (S), and detection probability (D). The mathematical equation will be RPN = P x S x D. Detail probability breakdowns are shown in Table 3, Table 4, and Table 5.

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Table 3. FMEA scale for failure probability

Probability of Occurrence	Rating	Possible failure rate (operating days)
Remote	1	< 1: 20,000
Low	2	1: 20,000
	3	1: 10,000
Moderate	4	1: 2;000
	5	1: 1,000
	6	1: 200
High	7	1: 100
	8	1: 20
Very High	9	1: 10
	10	1: 2

Table 4. FMEA scale for severity

Severity	Rating
Remote	1
Low	2
	3
Moderate	4
	5
	6
High	7
	8
Very High	9
	10

Table 5. FMEA scale for detection probability

Detection Probability	Rating	Probability of detection (%)
Remote	1	86-100
Low	2	76-85
	3	66-75
Moderate	4	56-65
	5	46-55
	6	36-45
High	7	26-35
	8	16-25
Very High	9	6-15
	10	0-5

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RESEARCH DESIGN

In order to answer the research objectives, several actions will be taken to complete the research.

1. Business Issue Exploration

The research will discuss the cost optimization strategy in marine operations in swamp area. The researcher needs to look up the detailed cost breakdown in marine expenses. This part shall involve subject matter expert (SME) within the company organization and historical data from past performance.

2. Problem Identification

In this step, the researcher shall find the underlying problem and brainstorm the possible alternatives. Apart from the company's expertise, the researcher may liaise with external parties to observe and identify the potential root causes and issues.

3. Stakeholder Mapping

Stakeholder mapping will be done to identify all parties involved and related to the research agenda. Their roles in the research will defined by the power interest matrix to determine their involvement throughout the study until the implementation plan.

4. Literature Study and Data Collection

In order to enrich and strengthen further analysis and research objectives parts, a literature review from a previous study is conducted by examining related journals, books, and other materials. Then, data collection is done to help find the best solution.

5. Criteria Development

Criteria and sub-criteria shall be determined according to the literature review and discussion with SMEs as part of the decision-making and risk-management process.

6. Generate Alternatives

This step will generate contract strategy and business process alternatives by considering previous analyses and interviews with subject matter experts.

7. Multi-Criteria Decision Making

The decision-making process using the Analytical Hierarchy Process (AHP) will involve subject matter experts and consider decision hierarchy and criteria.

8. Failure Mode Effect Analysis (FMEA)

Risk management using the FMEA method will be carried out to check the associated risk. Evaluation is done by examining probability events, severity ratings, and detection. The FMEA report will be generated to assist in the implementation of the solution.

9. Best Alternatives and Implementation Plan

Based on AHP, the decision-making process shall choose the best alternatives from

A detailed timeline will be set to ensure the implementation is in place accordingly. The schedule shall consider lag time for the approval process from related stakeholders and the best strategy to ensure smooth implementation.

The detailed framework and step-by-step on how the research is carried out is shown in Figure 1.

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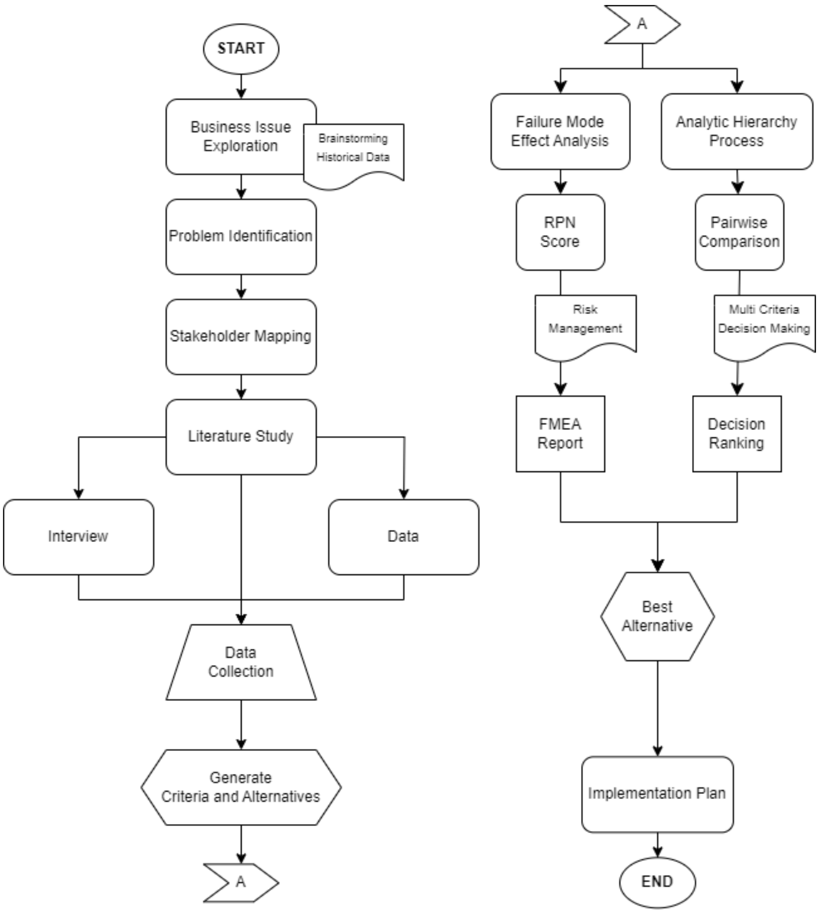

Figure 1. Research Design

RESULT AND DISCUSSION

The business solution shall be carried out based on the results of the Analytic Hierarchy Process (AHP) and Failure Mode Effect Analysis (FMEA) based on interviews and discussions with subject matter experts (SME). As part of the risk management and decision-making process, criteria are developed to help the evaluation system. Table 6 shows the criteria and sub-criteria that are used in the study.

Table 6. Description of Criteria and Sub-Criteria

Criteria	Sub Criteria	References
Operational Expenses	Transportation Cost	Zulficar et al. (2022) Ernesto et al. (2020) Chia-Nan et al. (2018)
	Material Cost (Diesel Fuel)	Rakesh et al. (2022) Chia-Nan et. al. (2018)
	Stock losses and discrepancy	Expert feedback
Health, Safety, and Environment (HSE)	Personnel Injury	Joachim et al. (2023) Rakesh et al. (2022) Amindoust et al. (2012)
	Fire Accident	Expert feedback

	Oil Spill Accident	Rakesh et al.(2022) Baskaran et al. (2018) Amindoust et al. (2012)
Service Reliability	On-Time Delivery	Joachim et al (2023) Zulficar et al. (2022) Chia-Nan et al. (2018)
	Perfect Quantity Shipment	Rakesh et al. (2022) Chia-Nan et al. (2018)
	Flawless Product Quality	Zulficar et al. (2022) Chia-Nan et al. (2018)
Value Creation		Expert feedback

After conducting a literature review and interviews with subject matter experts (SME), some new alternatives can be implemented to optimize fuel provision in swamp operation. Four alternatives were used in the decision-making process, as follows:

1. Direct Shipment with Milk Runs (existing method)

In this particular network, the supplier will deliver the required fuel at the delivery point based on a purchase order from the company. After delivery from the fuel supplier, the company may redistribute it again to their other units. The company will pay a lump sum fee as transportation costs are calculated based on the amount of fuel delivered (Rp/Liter). The contractual agreement obliges the fuel supplier to provide a minimum of three self-propelled oil barges (SPOB) to accommodate the company's operational requirements. This method enhances consumer satisfaction by ensuring timely deliveries, securing fast response time, and maintaining fuel quality while at the same time minimizing the company's liabilities. The fuel supply network is shown in Figure 2.

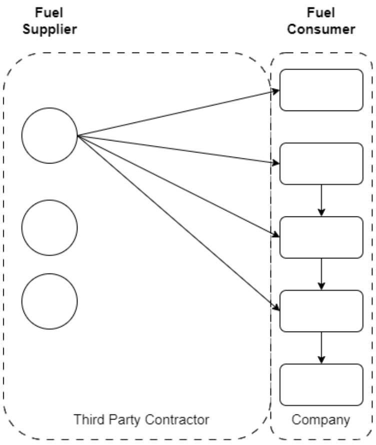

Figure 2. Direct Shipment with Milk Runs (Alternative #1)

2. Shipment via Distribution Center

This method will require the fuel supplier to place a vast floating oil barge as a distribution center point in the swamp area. The company will procure self-propeller oil barges (SPOB) by itself as fuel transporter from the distribution center as the custody point until the end consumer, as shown in Figure 3. The fuel supplier is responsible for managing bulk deliveries to the oil barge and inventory and distribution center. The company shall set the minimum amount of fuel that has to be maintained by the fuel supplier at the oil barge. The company will carry additional risk and responsibility for managing fuel transportation from the distribution center to the end customer.

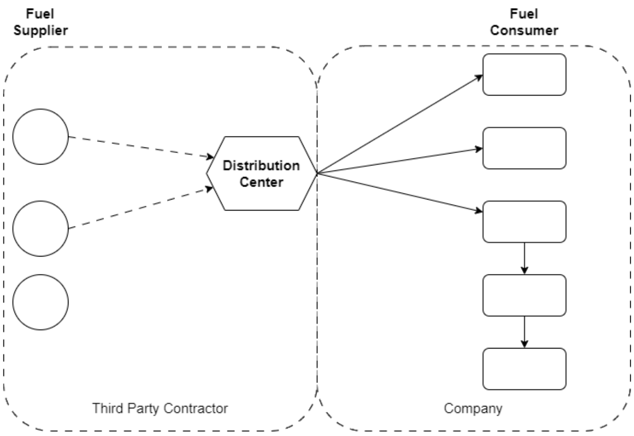

Figure 3. Shipment via Distribution Center (Alternative #2)

3. Hybrid Network (Distribution Center & Direct Shipment)

As shown in Figure 4, the hybrid network will combine the utilization of a distribution center and a direct shipment approach. The fuel supplier shall provide an oil barge in the company's vicinity as a distribution hub. The company's fleets will be dispatched to the barge and conduct refueling activities. The fuel supplier must maintain an agreed amount of fuel at the barge as a minimum stock level to ensure the fleets will obtain sufficient reserve. In addition, the fuel supplier has to arrange self-propeller barges (SPOB) operation to supply diesel fuel directly to the end customers.

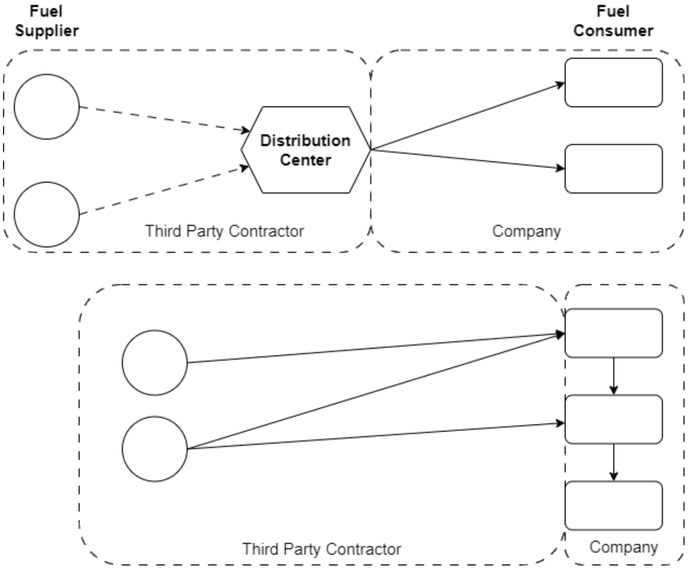

Figure 4. Hybrid Fuel Supply Network (Alternative #3)

By replacing one or two SPOBs with an oil barge (OB), the company shall benefit from responsiveness to respond to fluctuating demand levels while securing the fuel stock at the strategically positioned inventory. Since the operating expense of an oil barge is generally lower than a self-propelled oil barge, the company may renegotiate the transportation cost to the fuel supplier.

4. Vendor Managed Inventory (VMI)

By implementing the VMI method, the fleet owner is responsible for providing their fuel, as depicted in Figure 5. The owners shall manage the whole supply chain of the fuel from supply, inventory, and consumption of their units. The company shall streamline operations by minimizing the fuel procurement process. On the other hand, fleet owners shall liaise with reliable fuel suppliers to ensure adequate supply and avoid disruption in charterer operations.

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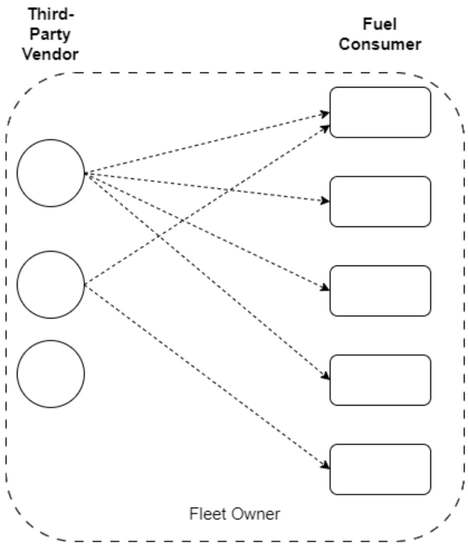

Figure 5. Fuel Supply using Vendor Managed Inventory (Alternative #4)

Based on the discussed criteria and alternative development, the hierarchy model is established and shown in Figure 6 below

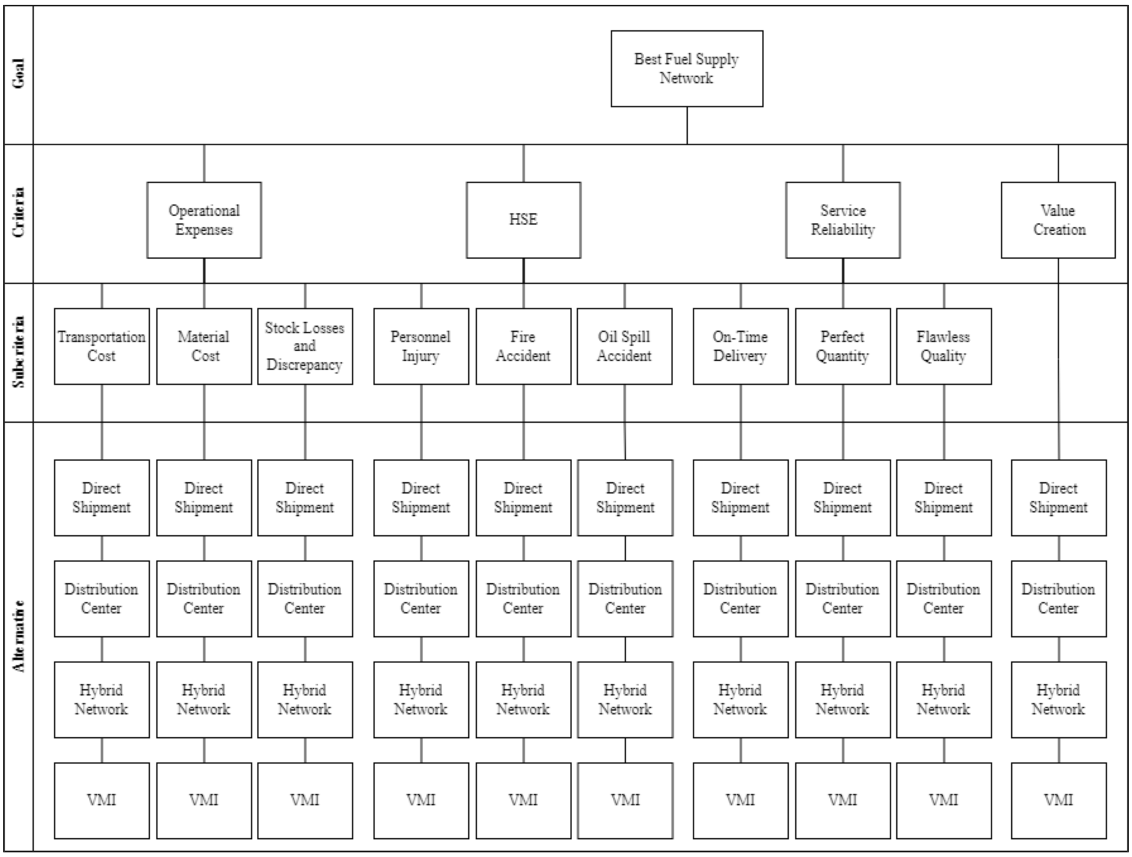

Figure 6. Hierarchy Model

Once the hierarchy model is set up, the research develops AHP and FMEA model based on the professional judgment of subject matter experts listed in Table 7.

Table 7. List of Experts for AHP Evaluation

Experts	Area of Expertise	Experience
Expert A	Marine & Logistic Operation	29 Yrs.
Expert B	Health, Safety & Environment (HSE)	24 Yrs.
Expert C	Fuel Management & Control	13 Yrs.

Pairwise comparisons between criteria, sub-criteria, and alternatives are made by the SMEs as depicted in Table 9. For criteria ranking, the ideal supply network shall create the biggest value creation, the highest HSE performance, the most excellent service reliability, and the least operation expenses. Those four parameters are appraised to seek the weight rating for each criterion. Then, pairwise comparisons between alternatives are conducted concerning each criterion and sub-criterion as shown in Table 10.

Table 8. Consistency Ratio in Pairwise Comparison

Pairwise Comparison	Consistency Ratio (CR)	Note
Criteria	0.007	Consistent
Sub criteria		
Operational Expenses	0.034	Consistent
HSE	0.013	Consistent
Service Reliability	0.000	Consistent
Alternatives		
Value Creation	0.019	Consistent
Material Cost	0.004	Consistent
Transportation Cost	0.043	Consistent
Stock losses and discrepancies	0.028	Consistent
Personnel Injury	0.006	Consistent
Fire Accident	0.002	Consistent
Oil Spill Accident	0.005	Consistent
On-Time Delivery	0.039	Consistent
Perfect Quantity	0.025	Consistent
Flawless Quality	0.005	Consistent

Table 9. Priority Ranking for Criteria and Sub criteria

Criteria/Sub criteria Ranking	Group Result
Value Creation	0.125
Material Cost	0.037
Transport Cost	0.049
Losses & Discrepancies	0.052
Personnel Injury	0.284
Fire Accident	0.140
Oil Spill Accident	0.086
On-Time Delivery	0.126
Perfect Quantity	0.045
Flawless Quality	0.056

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Table 10. Priority Ranking for Alternatives

Alternative Ranking	Direct Shipment	Distribution Centre	Hybrid Network	VMI
Value Creation	0.332	0.181	0.392	0.094
Material Cost	0.311	0.197	0.315	0.177
Transport Cost	0.179	0.354	0.230	0.238
Losses & Discrepancies	0.396	0.180	0.257	0.167
Personnel Injury	0.293	0.248	0.335	0.124
Fire Accident	0.314	0.264	0.314	0.108
Oil Spill Accident	0.320	0.252	0.309	0.119
On-Time Delivery	0.127	0.369	0.421	0.083
Perfect Quantity	0.212	0.358	0.352	0.077
Flawless Quality	0.266	0.363	0.304	0.067

Based on the results of the pairwise comparisons of criteria, subcriteria, and alternatives, the decision matrix is calculated by calculating the summary of each subcriteria weight ratio with each alternative. The supply network decision hierarchy's consistency ratio (CR) is at 4.3%. The consolidated matrix concludes that:

1. Hybrid network is the most preferred alternative, with a score of 33.7%.
2. Direct shipment becomes the second preference, with a 27.8% rating.
3. Distribution center is the third priority alternative, with a 26.9% rating.
4. Vendor-managed inventory is the least preferred alternative, with an 11.7% score.

FMEA is a method for evaluating potential problems within systems or the products they generate. This systematic approach involves assigning weights to establish rankings based on the Risk Priority Number (RPN), calculated by multiplying severity, occurrence, and detection weight values. These weight values are assigned based on the consequences of errors, the probability of their occurrence, and the measures in place for detection. In Table 11, the probability of occurrence is analyzed based on the root cause of each scenario. The ratings are given based on the SMEs' evaluation of each alternative. Severity ratings are provided for each scenario and shown in Table 12. The table represents the magnitude of both tangible and non-tangible impacts on the organization in case of failure. Then, the detection rating is analyzed for each framework as depicted in Table 13.

Table 11. Probability Ranking Analysis

			Probability Ranking			
Criteria	Sub Criteria	Root Cause	P1	P2	P3	P4
Operational Expenses	Transportation Cost	High complexity in the supply chain network	6	3	4	2
	Material Cost (Diesel Fuel)	Overpriced fuel quotation	2	2	2	1
	Stock losses and discrepancy	Insufficient control and equipment failure	2	5	3	1
Health, Safety, and Environment (HSE)	Personnel Injury	Poor HSE management system	2	3	3	7
	Fire Accident	Poor HSE management system	1	2	2	8
	Oil Spill Accident	Poor HSE management system	2	3	3	7
Service Reliability	On-Time Delivery	Lack of transporter unit from supplier	5	3	2	8
	Perfect Quantity Shipment	Lack of fuel stock from the supplier	4	3	2	6
	Flawless Product Quality	Improper quality assurance system	1	1	1	7
Value Creation	Domestic Component Level Value (TKDN) and Corporate Synergy	Low domestic component level	1	2	2	5

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Table 12. Severity Ranking Analysis

Criteria	Sub Criteria	Effect	Severity Ranking			
			S1	S2	S3	S4
Operational Expenses	Transportation Cost	Increase operational expense (OPEX) and reduce operating profit	4	2	2	1
	Material Cost (Diesel Fuel)	Increase operational expense (OPEX) and reduce operating profit	2	2	2	1
	Stock losses and discrepancy	Increase operational expense (OPEX) and reduce operating profit	2	6	4	1
Health, Safety, and Environment (HSE)	Personnel Injury	Reputation impact, legal lawsuit, and financial liability	4	4	4	2
	Fire Accident	Reputation impact, legal lawsuit, and financial liability	8	8	8	6
	Oil Spill Accident	Reputation impact, legal lawsuit, and financial liability	6	6	6	5
Service Reliability	On Time Delivery	Loss of revenue from declining production rate and Increase operational expense due to non-productive time (NPT) for idle activity. Decline production rate	6	6	6	5
	Perfect Quantity Shipment	Loss of revenue from declining production rate and Increase operational expense due to non-productive time (NPT) for idle activity. Decline production rate	2	4	2	3
	Flawless Product Quality	Equipment failure and breakdown time.	6	7	7	2
Value Creation	Domestic Component Level Value (TKDN) and Corporate Synergy	Diminished total return from value creation synergy	5	5	5	6

Table 13. Detection Ranking Analysis

Criteria	Sub Criteria	Control Measure	Detection Ranking			
			D1	D2	D3	D4
Operational Expenses	Transportation Cost	Optimum supply chain design	2	2	2	1
	Material Cost (Diesel Fuel)	Robust tender process	1	1	1	1
	Stock losses and discrepancy	Fuel management system implementation	2	4	3	1
Health, Safety, and Environment (HSE)	Personnel Injury	HSE scoring & evaluation in the Pre-qualification process	3	3	3	7
	Fire Accident	HSE scoring & evaluation in the Pre-qualification process	2	2	2	7
	Oil Spill Accident	HSE scoring & evaluation in the Pre-qualification process	2	2	2	7
Service Reliability	On-Time Delivery	Minimum unit availability and contingency plan from the supplier	3	3	2	9

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	Perfect Quantity Shipment	Contractual agreement for minimum safety fuel stock level	4	2	1	5
	Flawless Product Quality	Certificate of quality (CoQ) from laboratory testing	2	2	2	5
Value Creation	Domestic Component Level Value (TKDN) and Corporate Synergy	TKDN evaluation and scoring	1	1	1	3

Risk priority number (RPN) is calculated for each scenario by multiplying the probability rating (P), severity rating (S), and detection rating (D). RPN represents the risk of each failure mode in the fuel supply network. The alternative with the lowest RPN score is considered the least risky alternative and preferred by the experts. Table 14 shows the risk priority number evaluation for all criteria, sub criteria, and alternatives.

Table 14. Risk Priority Number Analysis

		Risk Priority Number (P x S x D)			
Criteria	Sub Criteria	R1	R2	R3	R4
Operational Expenses	Transportation Cost	48	12	16	2
	Material Cost (Diesel Fuel)	4	4	4	1
	Stock losses and discrepancy	8	120	36	1
Health, Safety, and Environment (HSE)	Personnel Injury	24	36	36	98
	Fire Accident	16	32	32	336
	Oil Spill Accident	24	36	36	245
Service Reliability	On-Time Delivery	90	54	24	360
	Perfect Quantity Shipment	32	24	4	90
	Flawless Product Quality	12	14	14	70
Value Creation	Domestic Component Level Value (TKDN) and Corporate Synergy	5	10	10	90
	Total RPN	263	342	212	1293

The FMEA method concludes that:

1. Hybrid network is the least risky alternative, with an RPN score of 212.
2. Direct shipment becomes the second preference, with an RPN score of 262.
3. Distribution center is the third alternative preference, with an RPN score of 342.
4. Vendor-managed inventory is the highest-risk option, with an RPN score of 1,293.

CONCLUSION

Based on the result of AHP to set up the best alternative solution, the hybrid network has the highest rating, with 33.7%. In the FMEA study, the hybrid network has the lowest RPN among other alternatives, with a 212 score. Therefore, the hybrid network is selected as the best solution for the fuel supply network in swamp operation area. Regarding the FMEA evaluation result, the failure probability, severity rating, and detection probability are analyzed for each criterion and sub-criterion. The research selects the top three issues that need to be highlighted based on the highest RPN score.

a. Personnel Injury (RPN: 36)
b. Oil Spill Accident (RPN: 36)
c. Stock Losses and Discrepancy (RPN: 36)

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