

ASSESSING HUMAN AND ORGANIZATIONAL RISK IN UPSTREAM OIL AND GAS SUPPLY CHAINS: AN ISO 31000 PERSPECTIVE



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ABSTRACT

Background: Operational risk management in the upstream oil and gas sector demands a rigorous, integrated approach, particularly within supply chain administration where both technical and non-technical risk factors converge. PT Pertamina Hulu Energi (PHE) Jambi Merang, an upstream natural gas producer in South Sumatra, existing practices still tend to prioritize technical hazards while paying less attention to human and organizational factors.

Purpose: This study aims to identify and evaluate operational risks within the supply chain administration of PHE Jambi Merang, and to formulate risk treatment strategies based on the ISO 31000:2018 framework.

Design/Methodology/Approach: A qualitative descriptive approach was employed, utilizing in-depth interviews, field observation, and questionnaire distribution with five key respondents selected through purposive sampling using a RACI matrix. Risk assessment employed Godfrey (1996) probability and impact scales, with geometric mean aggregation and a 5x5 risk mapping matrix. Risk treatment strategies were formulated based on Flanagan and Norman (1993) typology.

Findings/Result: Twenty-five operational risks were identified across four categories: internal, human resources, technical or system, and external risks. Three risks were classified as extreme, nine as high, eleven as medium, and two as low. The most critical risks include insufficient workforce competency, non-compliance with Corporate Life Saving Rules, and illegal oil and gas activities.

Conclusion: The findings indicate that human and organizational factors represent the most critical operational risk exposures in upstream gas supply chain administration.

Originality/Value: This study applies ISO 31000:2018 with explicit attention to human and organizational factors in upstream oil and gas supply chain administration in Indonesia.

ARTICLE INFO

Keywords:
human and organizational factors, ISO 31000:2018, operational risk management, supply chain, upstream oil and gas

How to Cite: Muthmainah, W. N. W., Nurhayati, P., & Watazawwadu'Ilmi, S. (2026). Assessing human and organizational risk in upstream oil and gas supply chains: An ISO 31000 perspective. *Indonesian Journal of Accounting, Risk and Governance*, 1(1), 8.

INTRODUCTION

The upstream oil and gas industry operates within one of the most complex and high-risk industrial environments globally. Activities spanning exploration, drilling, production, and distribution generate significant operational exposures encompassing equipment failure, human error, environmental hazards, and supply chain disruptions (Cigolini and Rossi, 2010; Al Balushi et al., 2025). Indonesia, as a major hydrocarbon-producing nation, faces additional complexity stemming from fluctuating global oil prices, geopolitical tensions, and an ambitious national production target of one million

barrels per day set by the Ministry of Energy and Mineral Resources (ESDM, 2021).

Within this context, PT Pertamina Hulu Energi (PHE) as the upstream subholding of state-owned enterprise PT Pertamina occupies a strategic role in sustaining national energy security. PT Pertamina Hulu Energi Jambi Merang (PHE Jambi Merang), a wholly owned subsidiary operating a gas production field in South Sumatra, faces layered operational risks inherent to remote-area high-technology gas production. Despite holding certifications under ISO 9001:2015, ISO 45001:2018, and ISO 14001:2015, the company's

risk management practices remain predominantly oriented toward Major Accident Hazards (MAH) and technical factors under its Health, Safety, Security, and Environment (HSSE) system, with insufficient attention to non-technical risks arising from human and organizational factors.

Prior research has consistently highlighted this imbalance. Andersen and Mostue (2012) demonstrated that human and organizational factors are critical determinants of accident risk in oil and gas operations yet are systematically underweighted in conventional risk analysis frameworks. This gap is particularly pronounced within supply chain administration, where informational, contractual, and coordination processes intersect with operational continuity. The limited empirical application of ISO 31000:2018 in the Indonesian upstream oil and gas context, particularly within supply chain administrative processes, constitutes a significant knowledge gap.

Research on operational risk management in oil supply chains has advanced considerably through frameworks such as FMEA, DEMATEL-ANP, and HAZOP (Fazli et al., 2015; Tarei et al., 2018). However, these approaches predominantly address technical dimensions, with limited integration of human-centric assessment methodologies. ISO 31000:2018, as a comprehensive, principle-based risk management standard, offers a structured and adaptable framework that can bridge technical and non-technical risk domains (BSN, 2018). Its application within upstream oil and gas supply chain administration remains underexplored in the Indonesian empirical literature.

This study addresses the gap by applying an ISO 31000:2018-based operational risk assessment to PHE Jambi Merang's supply chain administration. Drawing on Godfrey's (1996) risk assessment methodology and Flanagan and Norman's (1993) risk treatment typology, the research identifies, evaluates, and proposes mitigation strategies for operational risks in the company's supply chain processes. The study objectives are threefold: (1) to identify potential operational risks within PHE Jambi Merang's supply chain administration; (2) to evaluate the probability and impact of each identified risk; and (3) to formulate effective risk treatment strategies aligned with ISO 31000:2018 principles.

METHODS

This study employs a qualitative descriptive research design to examine operational risk management within the supply chain administration of PHE Jambi Merang. The research was conducted between November 2024 and April 2025 using a hybrid approach that combined field research at the Sungai Kenawang Gas Plant, Musi Banyuasin Regency, South Sumatra, with remote data collection and analysis.

Both primary and secondary data sources were utilized. Primary data were collected through three complementary methods: in-depth interviews, direct field observation, and structured questionnaire distribution. Secondary data were sourced from the company's Annual Report, Risk Register, Corporate Life Saving Rules (CLSR) Guideline, operational procedure documents (Tata Kerja Organisasi), and the Berita Acara Penyaluran Gas (BAPG).

Respondents were selected using a non-probability purposive sampling technique. A RACI matrix (Responsible, Accountable, Consulted, Informed) was employed to identify personnel with direct accountability in supply chain administrative processes. Five respondents were selected based on their organizational roles and operational expertise: the Assistant Manager of Facility Operation (19 years of experience), the Assistant Manager of RAM (Reliability, Availability, and Maintainability) (14 years), the Assistant Manager of Production (17 years), the Superintendent of HSSE Operations (1 year), and the Commercial Analyst (8 years). This multi-role composition ensured comprehensive coverage of the supply chain risk landscape.

Risk identification followed the ISO 31000:2018 process framework, incorporating Business Process Model and Notation (BPMN) mapping of supply chain administrative workflows alongside in-depth interviews and documentary analysis. An initial pool of 45 potential operational risks was generated; this was subsequently validated by all five respondents, with risks receiving below 50% endorsement excluded. The validated set comprised 25 operational risks.

Risk assessment was conducted using the methodology of Godfrey (1996), which employs separate Likert scales (1 to 5) for probability and impact measurement. Probability scores range from 1 (improbable) to

5 (frequent), while impact scores range from 1 (negligible) to 5 (catastrophic). Multi-respondent scores for each risk dimension were aggregated using the geometric mean formula:

$$GM = \sqrt[n]{(X_1)(X_2)\dots(X_n)}$$

where n = number of respondents

Geometric mean values were rounded to the nearest integer for risk mapping. Each risk was then plotted on a 5x5 Godfrey risk matrix, categorizing risks as low (green), medium (yellow), high (orange), or extreme (red) based on their probability-impact coordinates. Risk acceptability was assessed through the product of probability and impact scores, yielding four acceptability levels: negligible, acceptable, undesirable, and unacceptable.

Risk treatment strategies were formulated based on the typology of Flanagan and Norman (1993): risk retention (negligible risks), risk reduction (acceptable risks), risk transfer (undesirable risks), and risk avoidance (unacceptable risks). Treatment recommendations were developed through additional in-depth interviews and

literature review, with a company readiness assessment conducted to evaluate implementation feasibility.

The research framework illustrated in Figure 1 describes the systematic analytical procedure applied in this study. Based on the principles of ISO 31000:2018, the framework consists of four sequential stages. The first stage involves defining the scope and context of the study by applying a RACI matrix to clarify administrative responsibilities within the supply chain. The second stage focuses on risk assessment, which includes risk identification through BPMN mapping and in-depth interviews, followed by risk analysis using the Likert scale probability and impact approach proposed by Godfrey (1996). The analysis results are aggregated using geometric means and subsequently evaluated through a 5x5 risk matrix. The third stage addresses risk treatment, which is developed based on the typology proposed by Flanagan and Norman (1993). The final stage involves monitoring and review to ensure continuous improvement. Throughout all stages, communication and consultation with key stakeholders as well as ongoing monitoring and review are integrated as parallel processes in accordance with the principles of ISO 31000:2018.

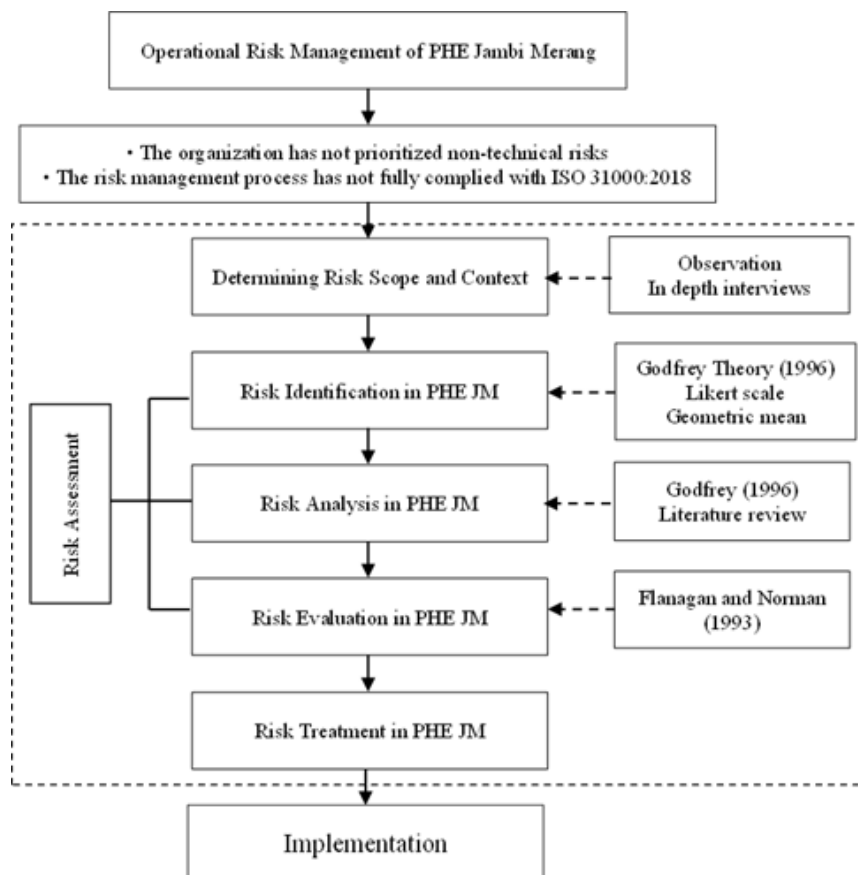


Figure 1. Research Framework

RESULTS

Operational Context and Business Process Mapping

PHE Jambi Merang operates within Regional-1 Sumatera, covering a working area of 973 km² across three zones: Gelam, Sungai Kenawang, and Pulau Gading. The company's primary products are natural gas and condensate, produced through an integrated gas processing facility at Sungai Kenawang Central Gas Plant (SKN CGP). Installed production capacity stands at 165 MMSCFD for gas and 12,500 BPD for condensate. Gas sales are facilitated through parent company PHR (Pertamina Hulu Rokan) under a Gas Sale and Purchase Agreement (Perjanjian Jual Beli Gas or PJBG), while condensate is distributed through Petrochina Jabung as distributor.

BPMN mapping of supply chain administrative processes identified 15 core activities distributed across the Production, Facility Operation, and RAM divisions. The Production division bears primary responsibility (Responsible/Accountable) for gas and condensate reception, negotiation, production, and delivery confirmation, while the Facility Operation division manages billing metering, gas delivery reports

(BAPG), and condensate records. The RAM division is accountable for production facility maintenance and infrastructure upkeep. This cross-divisional interdependence creates multiple coordination interfaces at which operational risks can materialize.

Operational Risk Identification

The validated risk inventory comprises 25 operational risks distributed across four categories: internal risks (6), human resource risks (5), technical and systems risks (8), and external risks (6). Table 1 presents the complete risk register.

The risk identification results align with broader findings in the oil and gas risk management literature. Cigolini and Rossi (2010) identified equipment failure, human error, and environmental hazards as primary risk categories across oil supply chain stages, consistent with the technical and human resource risk categories identified in this study. The post-2020 emergence of remote operations and aging infrastructure as risk vectors documented by Saran et al. (2024) is similarly reflected in R11 (fatigue) and R13 (asset damage) within PHE Jambi Merang's operational context.

Table 1. Validated Operational Risks of PHE Jambi Merang

Risk Code	Risk Category	Risk Description	Potential Impact
R01	Internal	Conflict of interest among senior management	Biased and non-objective decision-making
R02	Internal	Performance data manipulation	Loss of reputation and stakeholder trust
R03	Internal	Suboptimal hazardous work supervision	Work accidents and regulatory violations
R04	Internal	Unplanned operational shutdown	Material losses and buyer confidence erosion
R05	Internal	Production quantity decline	Material losses and reputational damage
R06	Internal	Conflict with subcontractors	Operational performance and image deterioration
R07	Human Resource	Insufficient workforce competency	Safety threats and operational inefficiency
R08	Human Resource	Non-compliance with Corporate Life Saving Rules (CLSR)	Worker health and safety risk
R09	Human Resource	Workers lack understanding of occupational risk mitigation	Fatal occupational safety incidents
R10	Human Resource	Miscommunication among workers	Operational delays and productivity decline
R11	Human Resource	Fatigue due to prolonged remote-area deployment	Reduced personnel and team performance
R12	Technical/Systems	Pipeline inspection failure	Product quality decline and efficiency loss
R13	Technical/Systems	Production asset damage	Suboptimal production operations
R14	Technical/Systems	Billing metering discrepancy	Reporting inefficiencies and financial loss
R15	Technical/Systems	Pipeline network leakage	Environmental and health damage
R16	Technical/Systems	Occupational accidents during operations	Worker health and safety risk

Table 1. Validated Operational Risks of PHE Jambi Merang (continue)

Risk Code	Risk Category	Risk Description	Potential Impact
R17	Technical/Systems	Chemical contamination of the environment	Environmental damage
R18	Technical/Systems	Fire incidents	Environmental and safety damage
R19	Technical/Systems	Oil spills	Environmental damage and regulatory violations
R20	External	Illegal oil and gas activities (tapping, drilling, refining)	Material losses from condensate shipping losses
R21	External	Community conflict	Corporate image decline
R22	External	Carbon emission limit violations	Regulatory violations and stakeholder trust loss
R23	External	Government policy changes	Disruption to production operations
R24	External	Changes in gas delivery quantity	Operational delays in gas distribution
R25	External	Payment delays from buyers	Financial losses and operational disruption

Risk Assessment: Probability and Impact Analysis

Geometric mean aggregation of respondent assessments yielded probability and impact scores for all 25 risks. Risk R20 (illegal oil and gas activities) recorded the highest probability score (3.57), placing it in the probable category, attributable to the company’s 159 km condensate pipeline network which presents extensive and difficult-to-monitor exposure to illegal tapping. Conversely, environmental risks R17 (chemical contamination) and R22 (carbon emission violations) exhibited the lowest probability scores (1.15), reflecting the effectiveness of existing HSSE controls.

Impact analysis revealed the most severe exposures in the human resource domain. Risks R07 (workforce competency) and R08 (CLSR non-compliance) attained the highest impact scores (4.78 each), reflecting the catastrophic potential consequences of competency failures in a high-hazard gas processing environment. This finding corroborates the argument of Andersen and Mostue (2012) that human and organizational factors are frequently underweighted despite their catastrophic impact potential. Research similarly identifies human error, fatigue, and inadequate training as primary operational risk drivers across oil supply chains (Abduljabbar & Breesam, 2022; Al Balushi et al., 2025; Burgherr et al., 2016; Cigolini & Rossi, 2010).

Risk Mapping and Acceptability Classification

Table 2 presents the risk mapping results, categorizing all 25 risks by level and acceptability. The risk

mapping reveals a concentration of extreme and high-level risks within the human resource and technical domains. Three extreme risks (R07, R08, R20) and nine high-level risks were identified, with two low-level risks (R14, R23). This distribution confirms the premise that operational risk in upstream oil and gas is multidimensional, with human factors constituting the most critical exposure category.

The classification of R20 (illegal oil and gas activities) as extreme reflects a unique contextual risk specific to Indonesian upstream operations. The company’s extensive condensate pipeline network of approximately 159 km creates significant vulnerability to illegal tapping. A documented incident in March 2024 involving illegal tapping at pipeline kilometer 85 underscores the material and reputational consequences of this risk. This finding aligns with observations on theft and illegal activities as emerging operational risk vectors in oil supply chains operating in developing country contexts.

Notably, environmental risks (R17, R19, R22) are classified as medium acceptability despite potentially severe ecological impacts, reflecting the effectiveness of existing HSSE mitigation controls. This is consistent with Windratama’s (2015) finding of low environmental risk probability at Pertamina EP and corroborates the prior research synthesis indicating that proactive environmental management programs can substantially reduce the probability of environmental risk materialization even in high-risk production environments.

Table 2. Risk level and acceptability classification

Risk Code	Risk Description	Probability	Impact	Risk Level	Acceptability
R07	Insufficient workforce competency	2.93	4.78	Extreme	Unacceptable
R08	Non-compliance with CLSR	2.55	4.78	Extreme	Unacceptable
R20	Illegal oil and gas activities	3.57	3.73	Extreme	Unacceptable
R03	Suboptimal hazardous work supervision	2.93	4.32	High	Undesirable
R09	Workers lack risk mitigation understanding	2.55	4.37	High	Undesirable
R10	Miscommunication among workers	1.89	4.37	High	Undesirable
R11	Fatigue in remote-area deployment	2.05	4.57	High	Undesirable
R12	Pipeline inspection failure	1.78	4.57	High	Undesirable
R13	Production asset damage	1.78	4.13	High	Undesirable
R15	Pipeline network leakage	2.55	4.32	High	Undesirable
R16	Occupational accidents	1.43	4.57	High	Undesirable
R18	Fire incidents	1.74	4.32	High	Undesirable
R01	Conflict of interest among management	1.74	2.40	Medium	Acceptable
R02	Performance data manipulation	1.32	4.13	Medium	Acceptable
R04	Unplanned operational shutdown	1.78	3.13	Medium	Acceptable
R05	Production quantity decline	2.05	2.61	Medium	Acceptable
R06	Conflict with subcontractors	2.35	2.49	Medium	Acceptable
R17	Chemical contamination	1.15	2.99	Medium	Acceptable
R19	Oil spills	1.43	2.99	Medium	Acceptable
R21	Community conflict	2.05	2.70	Medium	Acceptable
R22	Carbon emission violations	1.15	2.61	Medium	Acceptable
R24	Gas delivery quantity changes	2.70	2.09	Medium	Acceptable
R25	Payment delays from buyers	1.25	2.61	Medium	Acceptable
R14	Billing metering discrepancy	1.43	2.40	Low	Negligible
R23	Government policy changes	1.43	2.05	Low	Negligible

Risk Treatment Strategies

Risk treatment strategies were formulated according to the Flanagan and Norman (1993) typology, aligned with each risk’s acceptability classification. Table 3 summarizes treatment approaches and selected strategic recommendations. The recommendation for Electronic Permit to Work (E-PTW) implementation for R07 addresses both competency verification and supervision efficiency gaps. Current paper-based Permit to Work (PTW) administration creates informational delays and limits real-time supervisor oversight. E-PTW systems enable automated competency qualification checks, electronic approval workflows, and continuous monitoring, substantially reducing the probability of competency-related incidents. This recommendation aligns with findings by Khaqim (2014) demonstrating reductions in incident rate, frequency rate, and severity rate following permit-to-work system improvements.

For R08 (CLSR non-compliance), the recommendation for simulation-based training and gamified learning modules addresses a recognized limitation of brief safety moment presentations. Interactive and scenario-based training approaches have been demonstrated to improve safety rule retention and behavioral compliance (Anas et al., 2021). The integration of CLSR compliance into individual Key Performance Indicators further institutionalizes safety accountability at the personnel level, creating structural incentives for compliance beyond procedural obligation.

The treatment recommendation for R20 (illegal oil and gas activities) involves both technological and collaborative security solutions. The proposed expansion of security zoning to the full pipeline corridor, combined with multi-agency intelligence collaboration and centralized pipeline asset data systems, addresses the surveillance challenges inherent in managing a 159 km pipeline network across remote terrain. Lioty (2017) documented successful reductions

in illegal tapping cases through coordinated security zoning approaches in comparable Indonesian oil and gas contexts.

The treatment of human resource risks R09 and R10 through organizational and technological interventions reflects the broader recognition in operational risk literature that systemic communication failures and knowledge gaps require institutionalized, not merely individual, corrective mechanisms. The proposed Stop Work Authority culture, near-miss reporting, and real-time ICC Team data management align with the organizational resilience principles embedded in ISO 31000:2018 and corroborated by Pham et al. (2023), who found that supply chain integration strategies significantly moderate the negative impact of operational risks on firm performance.

Industry 4.0 technologies play a prominent role in the recommended treatment strategies, particularly for technical and systems risks (R12, R13, R15, R18). Smart pigging for pipeline integrity monitoring, wearable fatigue detection devices, and real-time fire and gas detection systems reflect the growing integration of digital tools in operational risk management. The research by Cigolini & Rossi (2010), Imran et al., (2022), Mazzuto et al., (2025), and Safriyana et al., (2019) documents that digital twins, AI-based predictive maintenance, IoT monitoring, and blockchain for supply chain traceability are transforming risk visibility and resilience in the oil and gas sector. However, implementation challenges including high investment costs, workforce upskilling requirements, and cybersecurity risks must be managed within any digitalization strategy.

Table 3. Risk treatment strategies for high and extreme risks

Risk Code	Risk Level	Treatment Strategy	Key Recommendations
R07	Extreme	Risk Avoidance	Collaboration with professional certification bodies (K3 Migas, IWCF); implementation of Electronic Permit to Work (E-PTW); competency-based training programs with PPSDM Migas
R08	Extreme	Risk Avoidance	Interactive CLSR socialization and simulation-based training; strict monitoring and enforcement with KPI integration; reinforcement of HSSE Golden Rules culture
R20	Extreme	Risk Avoidance	Security zoning expansion along pipeline corridor; multi-agency intelligence collaboration; centralized digital data management for pipeline asset monitoring
R03	High	Risk Transfer	Incentive program (reward system) for active safety reporters; PEKA competency integration into individual KPIs
R09	High	Risk Transfer	Implementation of Stop Work Authority (SWA) culture; near-miss reporting system; mandatory APD compliance with RFID-based verification
R10	High	Risk Transfer	Real-time ICC Team data update system; strategic placement of visual ICC Team boards; NFC sticker-based information dissemination
R11	High	Risk Transfer	Wearable fatigue monitoring devices; fatigue management workshops; enhanced sport day and wellness programs
R12	High	Risk Transfer	Integrated inspection data management system with cloud-based records; API 570 and NACE inspector certification; tag-and-report system for field anomalies
R13	High	Risk Transfer	Vibration sticker-based predictive maintenance; comprehensive planned shutdown cycles; Google Sheets-based equipment monitoring dashboard
R15	High	Risk Transfer	Monthly pipeline joint inspections; semi-annual smart pigging operations; hazard alarm system calibration
R16	High	Risk Transfer	Housekeeping and safety barrier inspections; monthly equipment calibration with digital checklists
R18	High	Risk Transfer	Real-time fire and gas detection technology; Safety Instrumented System (SIS) for automatic shutdown; Blowout Preventer (BOP) installation

Managerial Implications

The study's findings carry significant managerial implications for PHE Jambi Merang and comparable upstream oil and gas operators. First, the predominance of human resource risks in the extreme category necessitates a strategic reorientation of risk governance from its current technical focus toward an integrated human and organizational factor framework. ISO 31000:2018 provides the structural basis for this integration, incorporating the continual improvement principle that has been identified as underpracticed in the company's current risk register management.

Second, the formation of a cross-functional risk management team incorporating Production, Facility Operation, RAM, and HSSE divisions would institutionalize the holistic risk assessment approach currently absent in the company's predominantly HSSE-centric risk governance. This structural reform would align the organization with ISO 31000:2018's inclusivity and integrated principles, ensuring that supply chain administrative risks receive systematic attention alongside technical hazards.

Third, the 26 immediately implementable strategies identified in the readiness assessment represent a practical implementation roadmap. The five strategies requiring further feasibility study, including wearable fatigue monitoring devices, E-PTW system development, smart pigging operations, centralized pipeline data systems, and multi-agency intelligence network expansion, represent medium to long-term investment priorities aligned with the company's digital transformation agenda.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study applied the ISO 31000:2018 framework to assess operational risks in the supply chain administration of PHE Jambi Merang, an upstream natural gas producer in South Sumatra, Indonesia. Through in-depth interviews, field observation, and structured questionnaire administration with five key operational respondents, 25 operational risks were identified and validated across four categories: internal, human resource, technical and systems, and external. Risk assessment using Godfrey's (1996) probability

and impact methodology revealed three extreme risks (R07: insufficient workforce competency; R08: CLSR non-compliance; R20: illegal oil and gas activities), nine high-level risks, eleven medium-level risks, and two low-level risks. Critically, the most severe risk exposures were concentrated in the human resource domain, with non-technical factors driving extreme and high-level classifications. This finding empirically validates the theoretical argument of Andersen and Mostue (2012) regarding the systematic underweighting of human and organizational factors in oil and gas risk analysis.

Risk treatment strategies formulated under the Flanagan and Norman (1993) typology encompass risk avoidance for extreme risks through competency certification, interactive CLSR training, and security zoning; risk transfer for high-level risks through organizational system improvements and technology adoption; risk reduction for medium-level risks through existing controls and enhanced monitoring; and risk retention for low-level risks. A company readiness assessment confirmed that 26 of 31 recommended strategies are immediately implementable.

Recommendations

The study contributes to the empirical literature on operational risk management in the Indonesian upstream oil and gas industry by demonstrating the feasibility and value of ISO 31000:2018 application with an explicit human and organizational factor emphasis. Future research should extend the respondent base to include subcontractor personnel and HSSE management, integrate proactive methodologies such as HAZOP with human factor assessment, and explore cross-company benchmarking to assess risk management maturity across the upstream sector.

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