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Analysis of Environmental, Social, and Governance (ESG) Risks in the Oil and Gas Industry

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Abstract

The oil and gas industry is characterized by high operational risks that significantly affect Environmental, Social, and Governance (ESG) aspects. This study aimed to identify ESG risk events and risk agents, determine the priority levels of risk agents, and formulate effective and efficient mitigation strategies in the oil and gas industry, with PT X as the research object. This research employed a mixed-methods approach. Qualitative risk identification was conducted through document reviews and expert interviews, followed by quantitative assessment using the Analytical Hierarchy Process (AHP) and House of Risk (HOR) Phases 1 and 2 involving 11 expert respondents consisting of professionals, academics, and regulators. The results identified 15 risk events and 15 ESG risk agents. The AHP weighting results showed that the priority order of ESG dimensions was Environmental (40.11%), Social (30.18%), and Governance (29.72%), with an acceptable consistency ratio (CR = 0.0667). Based on the weighted Aggregate Risk Potential (ARP) values and the 80% Pareto principle, 11 priority risk agents were identified, with the highest priority being non-compliance with Bahan Berbahaya dan Beracun (B3) waste management procedures by contractors and subcontractors (ARP = 585.24). The Phase 2 HOR analysis based on the Effectiveness-to-Difficulty (ETD) ratio recommended five priority preventive actions: strengthening workplace safety culture, digitizing the B3 waste audit and reporting system, improving facility safety systems, implementing a Risk-Based Inspection (RBI) program for pipeline integrity management, and integrating ESG targets into management Key Performance Indicators (KPIs).

INTRODUCTION

Risk analysis is essential in the oil and gas industry, considering that this sector involves substantial investment values and highly complex operational systems. Drilling and production activities require significant financial resources and advanced technologies to develop new reserves. Exploration and production operations face various challenges and uncertainties related to economic conditions, technological limitations, government regulations, and occupational health and safety (OHS) risks (Thomas, 2025). Given the operational pressures and complex conditions within the oil and gas industry, risk identification is a critical step in developing appropriate mitigation strategies, ensuring operational success, protecting high-value assets, maintaining worker safety, and minimizing environmental impacts (Albrechtsen et al., 2019; Rivanodi & Noviaristanti, 2025).

The oil and gas industry remains a vital sector in the global economy, as oil and gas continue to serve as major energy sources for transportation, industrial activities, and households (Ogunyemi, 2021; Wibowo & Ahyudanari, 2021). Indonesia is among the countries that still heavily depend on oil and gas resources to fulfill domestic energy demands (Kholid & Harito, 2024). However, based on data from the Central Statistics Agency (Badan Pusat Statistik), national oil and gas production has shown a declining trend over time, highlighting the need for effective resource management and sustainable energy strategies (Ghasemi et al., 2023; Ginting & Oginawati, 2024).

In recent years, the global energy sector has undergone significant transformation, and the oil and gas industry has followed this trend by shifting its focus beyond financial performance toward sustainability commitments. As the industry faces increasing exposure to climate-related risks (Environmental) and regulatory pressures (Governance), Environmental, Social, and Governance (ESG) factors have become integral components of corporate resilience strategies. Pressure from various stakeholders, including environmental organizations, regulators, investors, and the public, has encouraged the industry to adopt more responsible and sustainable business practices.

The urgency of this research is driven by several interconnected factors. The high-risk nature of oil and gas operations requires robust risk identification and mitigation strategies to protect workers, communities, and the environment (Patimah et al., 2023). Increasing regulatory requirements related to ESG performance in Indonesia, supported by sector-specific guidelines that emphasize environmental management documents, human rights principles, and occupational health and safety (OHS) practices, have created a strong need for systematic risk management (Chege et al., 2023; Ye, 2025). Furthermore, the financial sector's growing emphasis on ESG performance, reflected in sustainability-based financing requirements for oil and gas projects, indicates that effective ESG risk management directly influences access to capital and financing costs. In addition, the global energy transition and increasing scrutiny of oil and gas operations have created an urgent need for companies to strengthen their ESG risk management frameworks (Marchello et al., 2023).

The novelty of this research lies in its integrated methodological approach, which combines three key elements. First, the application of the Analytical Hierarchy Process (AHP) to determine the weighting of ESG dimensions based on expert judgments, providing quantitative prioritization of Environmental, Social, and Governance risks. Second, the application of House of Risk (HOR) Phase 1 to rank risk agents based on Aggregate Risk Potential (ARP), enabling the identification of critical risk agents requiring mitigation. Third, the application of HOR Phase 2 to formulate and prioritize preventive actions based on the Effectiveness-to-Difficulty (ETD) ratio, providing practical guidance for resource allocation. This integrated AHP-HOR approach has not previously been applied to ESG risk management in the Indonesian oil and gas industry, thereby contributing both theoretically and practically to the development of ESG risk management practices.

Based on this background, this research applied the House of Risk (HOR) method developed by Pujawan and Geraldine (2009) to analyze and mitigate ESG risks. The HOR framework consists of two phases: HOR Phase 1 ranks risk agents based on their Aggregate Risk Potential (ARP), while HOR Phase 2 determines priority preventive actions that provide guidance for maximizing the cost-effectiveness of mitigation efforts against the selected risk agents. PT X was selected as the research object due to its significant progress in ESG performance, as demonstrated by the improvement of its MSCI ESG rating from A to AA in February 2025 and its achievement of Scope 1 and Scope 2 emission reduction targets.

RESEARCH METHOD

Research Design

This study employed a mixed-methods research approach by integrating qualitative and quantitative methods sequentially (sequential explanatory design). The qualitative stage was conducted to identify and analyze ESG risk events and risk agents through document reviews and expert interviews. The quantitative stage was then carried out to assess, weight, and prioritize risks using structured research instruments (Creswell & Plano Clark, 2018). The research applied a descriptive-analytic design, in which descriptive analysis was used to describe ESG risks in the oil and gas industry, while analytical analysis was conducted to examine the relationships between risk agents and risk events (Bougie & Sekaran, 2019). The research methodology flow integrating the three methods sequentially is presented in Table 1.

Table 1. Stages of Research Methodology

Stages	Activities	Output
1	Field studies and literature studies; identification and formulation of problems; Determination of Research Boundaries and Objectives	Formulation of research problems, objectives, and limitations
2	Primary data collection (AHP and HOR questionnaires, expert interviews) and secondary data (PT X company report 2020–2023)	Questionnaire data and company documents
3	ESG dimension weighting using the AHP method; the construction of paired comparison matrices; Consistency Verification (CR ≤ 0.10)	Dimensional weight W-E, W-S, W-G
4	HOR Phase 1: Identify risk events and risk agents; severity, occurrence, and correlation assessment; weighted ARP calculation; Pareto analysis 80%	Priority risk agent ratings based on ARP
5	HOR Phase 2: Formulation of preventive measures; difficulty level (Dk) and correlation assessment; calculation of Tek and ETDk	Mitigation action ratings based on ETD
6	Analysis of data processing results and recommendation formulation	Conclusions and suggestions

Source: Processed Researcher (2025)

Objects, Subjects, and Data Sources

The object of the research is ESG risks in PT X's operations, including *Environmental*, Social, and Governance *aspects* which include upstream activities (exploration and production), procurement, and distribution. The research subjects are experts who have experience in the oil and gas industry, understand the concept and implementation of ESG in the energy sector, and have positions in the risk, sustainability, and HSE (*Health, Safety, and Environment*) functions. The number of respondents was 11 experts consisting of 3 industry practitioners (professionals), 4 academics, and 4 regulators. Secondary data comes from official documents of PT X's company with the period 2020–2023, namely annual sustainability reports, annual reports, financial statements, HSSE policy documents, as well as scientific publications and reports of ESG rating agencies (GRI and MSCI).

ESG Risk Assessment Indicator System

The risk assessment uses a Likert scale that has been adjusted to the ESG risks of the oil and gas industry, referring to the modification of FMEA and HOR (Cristea & Constantinescu, 2017). Tables 1, 2, and 3 present the rating scales used.

Table 2. ESG Risk Severity Assessment Scale

Value	Categories	Description
1	Neglible	Very small, insignificant impact on the company's operations or reputation
3	Marginal	Small impact, can be treated with routine procedures without significant disruption
5	Moderate	Moderate impact, requiring management attention and allocation of additional resources
7	Critical	Major impact, potentially disrupting operations; cause significant financial or reputational loss
9	Catastrophic	The impact is very large, threatening operational continuity; massive losses or critical regulatory violations

Source: Pujawan and Geraldin (2009) and Nagata et al. (2025)

Table 3. Occurrence Rating Scale of ESG Risk Agents

Value	Categories	Description
1	Remote	It is very rare; frequency of occurrence less than once in 5 years
3	Low	Rare; Frequency of occurrence once in 2–5 years
5	Moderate	Sometimes it happens; frequency of events once in 1–2 years
7	High	It often occurs; frequency of occurrences several times a year
9	Very High	It almost certainly happens; The frequency of events is very high and repetitive

Source: Pujawan and Geraldin (2009)

Table 4. Correlation Rating Scale (Rij) between Risk Agents and Risk Events

Value	Categories	Description
0	No correlation	Risk agents have no relationship with risk events
1	Low Correlation	Risk agents contribute little to the occurrence of risk events
3	Medium Correlation	Risk agents contribute enough to the occurrence of risk events
9	High Correlation	Risk agents are very influential and are the main cause of risk events

Source: Pujawan and Geraldin (2009)

RESULTS AND DISCUSSION

Weighting of ESG Dimensions with the AHP Method

Using the *Analytical Hierarchy Process* (AHP) method, each respondent filled in a paired comparison matrix for three dimensions of ESG, namely *Environmental* (E), *Social* (S), and *Governance* (G). The results of the assessment of 11 respondents were aggregated using geometric *mean* as the recommended aggregation method for AHP with multi-respondent (Saaty & Vargas, 2012). An aggregate paired comparison matrix is presented in Table 5.

Table 5. ESG Dimension Paired Comparison Matrix (Geometric Mean, n = 11)

No.	Dimensions	Environmental (E)	Social (S)	Governance (G)
1	Environmental (E)	1,0000	1,7672	1,0311
2	Social (S)	0,5659	1,0000	1,3399
3	Governance (G)	0,9698	0,7463	1,0000

Table 6. ESG Dimension Weighting and AHP Consistency Verification

No.	ESG Dimension	Weight (Wi)	Percentage (%)	Weighting
1	Environmental (W-E)	0,4011	40,11%	Highest Weight
2	Social (W-S)	0,3018	30,18%	Medium Weight
3	Governance (W-G)	0,2972	29,72%	Lowest Weight

Consistency Parameters	Value
λmax (Maximum Eigenvalue)	3,0773
Consistency Index (CI)	0,0387
Random Index (RI) for n = 3	0,5800
Consistency Ratio (CR)	**0.0667 – Consistent (CR ≤ 0.10) ✓**

The results of the consistency verification showed a CR value of 0.0667, which was below the CR threshold ≤ 0.10. This confirms that the paired assessments provided by the respondents are consistent and can be used as a weight in the calculation of weighted ARP in HOR Phase 1 (Saaty & Vargas, 2012). The weighting results showed that *the Environmental* dimension received the highest weight (40.11%), reflecting the collective perception of experts that environmental risk is the most critical aspect of Indonesia's oil and gas industry, given the potential impact of operations on the ecosystem and increasingly tightened environmental regulations.

House of Risk Phase 1

Based on the results of identification through literature studies and expert validation, 15 risk *events* were obtained which were grouped into three ESG dimensions. Aggregation of severity values (*Severity*) is carried out using geometric averages. The results of the identification and the aggregate severity are presented in Table 12.

Table 7. Risk Event and Aggregate Severity

Code	Risk Event	Dimensions	Yes (Geo Mean)
Environmental Dimension (W-E = 0.4011)			
E1	Scope 1 GHG emissions increase exceeds set reduction targets	*Environmental*	4,70
E2	Oil spills and pipeline leaks that pollute aquatic and soil environments	*Environmental*	8,21
E3	Increased volume of B3 hazardous waste that is not handled according to regulations	*Environmental*	6,73
E4	Deterioration of water quality and disturbance of ecosystems around the operating area	*Environmental*	6,48
E5	Failure to meet energy intensity reduction and operational efficiency targets	*Environmental*	5,39

Social Dimension (W-S = 0.3018)			
E6	Fatality and serious injuries to workers/contractors	*Social*	8,60
E7	Social conflicts with local communities over operational impacts and land ownership	*Social*	6,38
E8	Violations of workers' rights and rights in the supply chain	*Social*	7,38
E9	Low levels of gender diversity and inclusion in leadership positions	*Social*	2,98
E10	Public dissatisfaction and negative reputation due to lack of CSR/empowerment programs	*Social*	4,77
Governance Dimension (W-G = 0.2972)			
E11	Violations of compliance with environmental regulations, taxation, and operational licensing	*Governance*	5,95
E12	The occurrence of acts of corruption, bribery, or fraud in the procurement and operational process	*Governance*	6,89
E13	Non-transparency of financial reporting and disclosure of ESG information	*Governance*	6,24
E14	Weak composition and independence of the board of commissioners in strategic decision-making	*Governance*	5,43
E15	Inalignment of the company's long-term strategy with ESG and energy transition targets	*Governance*	5,56

The risk events with the highest severity were E6 (fatal work accidents and serious injuries, Si = 8.60) from the *Social* dimension, followed by E2 (oil spills and pipeline leaks, Si = 8.21) from the *Environmental* dimension. The severity of E9 (low gender diversity and inclusion, Si = 2.98) was very low, indicating that experts rated this risk as relatively less impactful than other ESG risks.

In addition to risk events, this study also identified 15 risk agents as causative or triggering factors for risk events. The occurrence values (Oj) are aggregated using geometric averages and are presented in Table 8.

Table 8. Risk Agents and Aggregate Occurrence Values

Code	Risk Agent	Dimensions	Oj (Geo Red)
Environmental Dimension			
A1	Lack of emission control and air quality monitoring technology	*Environmental*	5,15
A2	Degradation of pipeline and production facility integrity due	*Environmental*	4,59

	to corrosion and age of infrastructure		
A3	Non-compliance with B3 waste management procedures by contractors and subcontractors	*Environmental*	5,82
A4	Sabotage and vandalism of facilities by external parties	*Environmental*	4,15
A5	Limited capacity of human resources in the implementation of environmental programs	*Environmental*	4,09
Social Dimension			
A6	Weak work safety culture and compliance with K3 procedures in the field	*Social*	4,15
A7	Lack of communication and consultation with local communities before and during operations	*Social*	4,38
A8	Insufficient human rights due diligence in supplier selection and evaluation (Lyukevich et al., 2020)	*Social*	4,15
A9	Recruitment bias and lack of affirmative policies for gender equality	*Social*	4,21
A10	CSR programs are inadequate in responding to the real needs of affected communities	*Social*	3,64
Governance Dimension			
A11	Weaknesses of regulatory compliance monitoring systems and changes in government policies	*Governance*	4,12
A12	Lack of anti-corruption and anti-bribery internal control systems	*Governance*	4,51
A13	Lack of material and independently verifiable ESG disclosures	*Governance*	3,93
A14	Less diverse board composition and lack of ESG expertise at commissioner level	*Governance*	5,35
A15	Weak integration of ESG targets in strategic planning and management KPIs	*Governance*	5,03

The risk agents with the highest emergence value were A3 (Non-compliance with B3 waste management procedures by contractors and subcontractors, Oj = 5.82), followed by A14 (Board composition lacking diversity and lack of ESG expertise, Oj = 5.35) and A1 (Lack of emission control technology and air quality monitoring, Oj = 5.15). The high value of the emergence of A3 indicates that non-compliance with B3 waste management is considered a relatively frequent occurrence in the oil and gas industry supply chain, especially at the contractor and subcontractor layers that tend to have limited environmental monitoring capacity (Hidayati & Vanany, 2024).

Next, the weighted *Aggregate Risk Potential* (ARP) value was calculated with the formula: ARPj = Oj × Σi(Wi × Si × Rij). Table 14 presents the Wi × Si values used as the basis for calculating ARP.

Table 9. Wi × Si Value for Each Risk Event

Code	Risk Event	Wi	Yes	Wi × Si
E1	Scope 1 GHG emissions increase exceeds set reduction targets	0,4011	4,70	1,8852
E2	Oil spills and pipeline leaks that pollute aquatic and soil environments	0,4011	8,21	3,2930
E3	Increased volume of B3 waste that is not handled according to regulations	0,4011	6,73	2,6994
E4	Deterioration of water quality and disturbance of ecosystems around the operating area	0,4011	6,48	2,5991
E5	Failure to meet energy intensity reduction and operational efficiency targets	0,4011	5,39	2,1619
E6	Fatality and serious injuries to workers/contractors	0,3018	8,60	2,5955
E7	Social conflicts with local communities over operational impacts and land ownership	0,3018	6,38	1,9255
E8	Violations of workers' rights and rights in the supply chain	0,3018	7,38	2,2273
E9	Low levels of gender diversity and inclusion in leadership positions	0,3018	2,98	0,8994
E10	Public dissatisfaction and negative reputation due to lack of CSR/empowerment programs	0,3018	4,77	1,4396
E11	Violations of compliance with environmental regulations, taxation, and operational licensing	0,2972	5,95	1,7683
E12	The occurrence of acts of corruption, bribery, or fraud in the procurement and operational process	0,2972	6,89	2,0477
E13	Non-transparency of financial reporting and disclosure of ESG information	0,2972	6,24	1,8545
E14	Weak composition and independence of the board of commissioners in strategic decision-making	0,2972	5,43	1,6138
E15	Inalignment of the company's long-term strategy with ESG and energy transition targets	0,2972	5,56	1,6524

From the weighted ARP value obtained for all risk agents, the ARP value was then ranked from highest to lowest. With a total ARP value of all risk agents of 5,488.39, a risk evaluation using the Pareto principle of 80/20 determined that risk agents that cumulatively contributed 80% of the total ARP were designated as priority risk agents. The results of the rankings are presented in Table 10.

Table 10. Risk Agent Rating Based on Weighted ARP Value

Rank	Code	Risk Agent	Dimensions	Oj	ARPj	% ARP	% Cumulative	Pareto 80%
1	**A3**	Non-compliance with B3 waste management procedures by contractors and subcontractors	Environmental	5,82	**585,24**	10,66%	10,66%	✓ **Priority**
2	**A1**	Lack of emission control and air quality monitoring technology	Environmental	5,15	**453,39**	8,26%	18,92%	✓ **Priority**
3	**A2**	Degradation of pipeline and production facility integrity due to corrosion and age of infrastructure	Environmental	4,59	**443,58**	8,08%	27,01%	✓ **Priority**
4	**A14**	Board composition lacks diversity and lack of ESG expertise	Governance	5,35	**418,02**	7,62%	34,62%	✓ **Priority**
5	**A15**	Weak integration of ESG targets in strategic planning and management KPIs	Governance	5,03	**391,97**	7,14%	41,76%	✓ **Priority**
6	**A6**	Weak work safety culture and compliance with K3 procedures in the field	Social	4,15	**366,80**	6,68%	48,45%	✓ **Priority**
7	**A7**	Lack of communication and consultation with local communities before and during operations	Social	4,38	**353,37**	6,44%	54,89%	✓ **Priority**
8	**A12**	Lack of anti-corruption and anti-bribery internal control systems	Governance	4,51	**343,64**	6,26%	61,15%	✓ **Priority**
9	**A11**	Weaknesses of regulatory compliance monitoring systems and changes in government policies	Governance	4,12	**340,45**	6,20%	67,35%	✓ **Priority**
10	**A13**	Lack of material and independently verifiable ESG disclosures	Governance	3,93	**326,83**	5,95%	73,31%	✓ **Priority**
11	**A4**	Sabotage and vandalism of facilities by external parties	Environmental	4,15	**323,62**	5,90%	79,20%	✓ **Priority**
12	A8	Lack of human rights due diligence in supplier selection and evaluation	Social	4,15	301,24	5,49%	84,69%	–
13	A5	Limited human resource capacity in the implementation of environmental programs	Environmental	4,09	300,83	5,48%	90,17%	–
14	A9	Recruitment bias and lack of gender affirmation policies	Social	4,21	281,64	5,13%	95,30%	–
15	A10	CSR programs are inadequate in responding	Social	3,64	257,77	4,70%	100,00%	–

	to the real needs of affected communities		

Based on Table 10, there are 11 risk agents as priority categories with a cumulative ARP value of 79.20%, close to the Pareto threshold of 80%. The risk agent with the highest ARP value was A3 (ARP = 585.24 or 10.66% of the total). This is due to the high *occurrence* value of A3 (Oj = 5.82) combined with a strong correlation with several high-severity environmental risk events such as E2 (oil spill, Si = 8.21) and E3 (unhandled B3 waste, Si = 6.73). The dominance of Environmental risk agents in the top three is consistent with the AHP weighting results which place *the Environmental* dimension as the most critical (W-E = 0.4011). Although *Governance* has the lowest weight in AHP, risk agents A14 and A15 are ranked fourth and fifth due to their high emergence value and wide correlation to a wide range of cross-dimensional risk events.

House of Risk Phase 2

Eleven priority risk agents from HOR Phase 1 will then be inputs to HOR Phase 2 to formulate the most effective and efficient preventive actions. Eleven preventive measures (PA1–PA11) were validated through the opinions of experts. The difficulty level assessment (Dk) uses a scale of 3 (easy), 4 (moderate/needs moderate investment), and 5 (difficult/requires large investment). Table 11 presents eleven precautions along with their average difficulty scores.

Table 11. The Difficulty of ESG Precautions

Code	Preventive Action	Average Dk	Categories
PA1	Digitization of B3 waste management audit and reporting system	3,82	Medium
PA2	Improvement of Continuous Emission Monitoring System (CEMS) technology for emission control	4,18	Medium
PA3	Risk-Based Inspection (RBI) program and predictive maintenance of pipeline integrity	3,73	Medium
PA4	ESG training and the addition of ESG expertise in the composition of the board of commissioners	4,00	Medium
PA5	Integration of ESG targets into KPIs and management strategic planning	3,91	Medium
PA6	Strengthening the safety culture through the Behavior-Based Safety (BBS) program	3,55	Medium
PA7	CSR funding-based community communication and consultation program	3,73	Medium
PA8	Strengthening of anti-corruption and anti-bribery internal control systems	3,55	Medium
PA9	Automation of government regulatory and policy compliance monitoring systems (Elhosary & Moselhi, 2024)	3,82	Medium
PA10	Independent verification and third-party assurance of ESG disclosures	3,82	Medium
PA11	Facility security system improvement	3,91	Medium

Source: Processed results of the HOR Phase 2 questionnaire (n = 11)

All eleven precautions were in the category of moderate difficulty (Dk = 3.55–4.18). The action with the highest level of difficulty is PA2 (Improvement of CEMS technology, Dk = 4.18), in line with the opinion of experts who mention the technical obstacles to the use of CEMS in the field as well as the need for large investments. In contrast, the actions with the lowest level of difficulty were PA6 (Strengthening the workplace safety culture) and PA8 (Strengthening the anti-corruption internal control system), both of which had a value of Dk = 3.55, because these two practices were considered familiar and had an established system in the oil and gas industry.

The correlation matrix between each preventive measure and eleven priority risk agents as well as the results of the calculation of Total Effectiveness (TEk), difficulty level (Dk), and ETDk ratio are presented in Table 12.

Table 12. House of Risk Phase 2 (HOR 2): Correlation Matrix, ARP, TE, D, and ETD

Risk Agent	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11	ARPj
A3	7,4	4,2	5	2,8	5,8	6,5	3,5	4	4,4	5,1	5,5	**585,24**
A1	5,3	6,3	5,1	4,1	6	5,5	5,2	5	4	4,7	5,5	**453,39**
A2	4,8	3,8	7,9	3,3	4,6	5,8	3,9	4,4	4,3	4,4	6,5	**443,58**
A14	4,9	3,7	4,1	7,2	5,5	4,4	5,5	3,5	4,1	4,2	4,1	**418,02**
A15	5,5	5,1	4,5	5,4	6,8	5,1	3,9	4,3	4,5	4,4	4,7	**391,97**
A6	6,3	5,1	5,5	3,9	4,5	7,4	3,5	3,9	3,6	4	6	**366,80**
A7	5,5	4,1	3,9	4,5	4,2	4	6,8	3,6	4	4,5	5,5	**353,37**
A12	4,5	4,1	4,1	4,5	4,2	4,5	4,1	6,8	4,7	3,6	5,5	**343,64**
A11	6,1	3,9	3,6	4,5	4,9	3,8	4,9	4,4	7,4	4,7	4,3	**340,45**
A13	5	4,4	4,2	3,8	4,9	4,3	4,1	3,9	4,1	6,3	4,9	**326,83**
A4	6	4,9	5,8	4,7	4,2	5,8	5,2	3,6	4	5	8,5	**323,62**
São Paulo	24.535,0	19.603,0	21.507,7	18.987,7	22.350,4	22.928,6	19.756,4	18.702,2	19.264,6	20.085,3	24.024,0	–
Dk	3,82	4,18	3,73	4,00	3,91	3,55	3,73	3,55	3,82	3,82	3,91	–
ETDk	**6.425,9**	**4.687,7**	**5.770,4**	**4.746,9**	**5.717,5**	**6.467,0**	**5.300,5**	**5.275,0**	**5.045,5**	**5.260,4**	**6.145,7**	**–**

Source: Processed results of the HOR Phase 2 questionnaire (n = 11)

The highest correlation values were found in the pairs of preventive measures with the risk agents that were the main targets, e.g. PA1 (Digitization of waste audits B3) against A3 (R = 7.4), PA3 (*Risk-Based Inspection*) against A2 (R = 7.9), PA6 (Strengthening of occupational safety culture) against A6 (R = 7.4), and PA11 (Improved facility safety) against A4 (R = 8.5). This pattern shows the consistency between the design of the preventive measures and the root cause of the risk to be mitigated.

The highest Total Effectiveness (TE) values were obtained for PA1 (24,535.0) and PA11 (24,024.0), driven by the strong correlation between the two risk agents with the highest ARPs, namely A3 and A4. However, the final priority of preventive measures is not solely determined by the TE, but by the ETD ratio which also takes into account the difficulty level of implementation (DC). The action with the highest ETD score gets implementation priority. The full ranking results are presented in Table 13.

Table 13. Preventive Action Rating Based on ETD Value

Rank	Code	Preventive Action	São Paulo	Dk	ETDk
1	**PA6**	Strengthening the safety culture through the Behavior-Based Safety (BBS) program	22.928,6	3,55	**6.467,0**
2	**PA1**	Digitization of B3 waste management audit and reporting system	24.535,0	3,82	**6.425,9**
3	**PA11**	Facility security system improvement	24.024,0	3,91	**6.145,7**
4	**PA3**	Risk-Based Inspection (RBI) program and predictive maintenance of pipeline integrity	21.507,7	3,73	**5.770,4**
5	**PA5**	Integration of ESG targets into KPIs and management strategic planning	22.350,4	3,91	**5.717,5**
6	PA7	CSR funding-based community communication and consultation program	19.756,4	3,73	5.300,5
7	PA8	Strengthening of anti-corruption and anti-bribery internal control systems	18.702,2	3,55	5.275,0
8	PA10	Independent verification and third-party assurance of ESG disclosures	20.085,3	3,82	5.260,4
9	PA9	Automation of government regulatory and policy compliance monitoring systems	19.264,6	3,82	5.045,5
10	PA4	ESG training and the addition of ESG expertise in the composition of the board of commissioners	18.987,7	4,00	4.746,9
11	PA2	Improvement of Continuous Emission Monitoring System (CEMS) technology for emission control	19.603,0	4,18	4.687,7

Source: Processed results of the HOR Phase 2 questionnaire (n = 11)

Based on Table 13, the five preventive measures with the highest priority are in order are PA6 (Strengthening of occupational safety culture, ETD = 6,467.0), PA1 (Digitization of B3 waste audits, ETD = 6,425.9), PA11 (Improvement of facility safety, ETD = 6,145.7), PA3 (*Risk-Based Inspection*, ETD = 5,770.4), and PA5 (Integration of ESG into management KPIs, ETD = 5,717.5). These five measures are recommended to be implemented early because they have a combination of high effectiveness and a relatively controlled level of difficulty.

In contrast, PA2 (CEMS technology upgrade, ETD = 4,687.7) and PA4 (ESG training and board expertise addition, ETD = 4,746.9) ranked the lowest. Both of these actions still have a considerable TE value, but their higher levels of application difficulty (Dk = 4.18 and 4.00) lower their efficiency values. Therefore, these two actions are more appropriately planned as medium-long term programs that require more mature investment allocation and preparation time.

CONCLUSION

This study successfully identified 15 risk events and 15 ESG risk agents in the oil and gas industry through document reviews and interviews with 11 expert respondents consisting of industry practitioners, academics, and regulators, with PT X as the research object. The AHP weighting results showed the priority order of ESG dimensions as Environmental (40.11%), Social (30.18%), and Governance (29.72%), with an acceptable consistency ratio (CR = 0.0667 ≤ 0.10). The calculation of the weighted Aggregate Risk Potential (ARP) using the House of Risk (HOR) Phase 1 approach identified 11 out of 15 risk agents as priority risks based on the

80% Pareto principle. Risk agent A3 (non-compliance with Bahan Berbahaya dan Beracun (B3) waste management procedures by contractors and subcontractors) had the highest ARP value (585.24), followed by A1 (lack of emission control technology, ARP = 453.39) and A2 (degradation of pipeline and production facility integrity, ARP = 443.58). The HOR Phase 2 analysis based on the Effectiveness-to-Difficulty (ETD) ratio formulated five priority preventive actions recommended for short-term implementation, namely strengthening workplace safety culture (PA6, ETD = 6,467.0), digitizing the B3 waste audit and reporting system (PA1, ETD = 6,425.9), improving facility safety systems (PA11, ETD = 6,145.7), implementing a Risk-Based Inspection (RBI) program for pipeline integrity (PA3, ETD = 5,770.4), and integrating ESG targets into management Key Performance Indicators (KPIs) (PA5, ETD = 5,717.5). For future development, PT X is recommended to consider improving Continuous Emission Monitoring System (CEMS) technology (PA2) and implementing ESG training programs for the board of commissioners (PA4) as medium-term initiatives. Future research should expand the generalizability of findings by involving more oil and gas companies, incorporating cost-benefit analysis into ETD calculations, and applying the integrated AHP-HOR methodology to other oil and gas organizations to validate the consistency of findings in emerging economies, including Indonesia.

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