Evaluating the Impact of Scope 3 Decarbonization Mandates on Upstream Supplier Selection and Green Procurement Practices in the Oil and Gas Sector of Developing Economies

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Abstract

The global energy transition has placed unprecedented pressure on oil and gas operators to decarbonize not only their direct operations but also their complex value chains, with Scope 3 emissions—representing over 90% of total sector emissions—emerging as the critical compliance frontier. This study investigates how mandatory Scope 3 decarbonization mandates reshape upstream supplier selection and green procurement practices in developing economies, where institutional capacity limitations, data infrastructure gaps, and competing developmental priorities create unique implementation challenges. Using a mixed-methods research design combining Analytic Hierarchy Process (AHP) and TOPSIS multi-criteria decision analysis with qualitative case study evidence from Nigeria, Indonesia, and Colombia, the research evaluates 187 supplier selection decisions across 24 procurement categories. The findings reveal that environmental criteria now account for 44% of supplier evaluation weight, with environmental management systems (15.1%) and occupational health and safety (14.4%) emerging as the dominant sub-criteria. The integrated AHP-TOPSIS framework achieved an 89.4% predictive accuracy in identifying compliant suppliers, significantly outperforming traditional cost-centric approaches (62.3%). The study concludes that Scope 3 mandates are fundamentally restructuring supplier markets, creating bifurcation between early-mover suppliers capable of meeting decarbonization requirements and laggards facing market exclusion. The validated multi-criteria framework offers a replicable procurement decision-support tool for oil and gas operators navigating the transition to low-carbon value chains in developing economy contexts.

Keywords: Scope 3 emissions, decarbonization mandates, green procurement, supplier selection, oil and gas sector, developing economies, AHP-TOPSIS, supply chain management

1. Introduction

1.1 Background

The oil and gas sector stands at a pivotal juncture in the global energy transition. As the primary source of approximately 40% of global carbon emissions through direct combustion of extracted hydrocarbons, the industry faces intensifying regulatory and investor pressure to decarbonize across all operational scopes . Historically, sustainability efforts in the sector have focused on Scope 1 (direct emissions from owned or controlled sources) and Scope 2 (indirect emissions from purchased energy) emissions, reflecting the relative ease of measurement and control within operational boundaries. However, these scopes represent only a fraction of the industry's total carbon footprint.

Scope 3 emissions—encompassing all other indirect emissions occurring across the value chain, including those from upstream suppliers, logistics, and downstream product use—constitute the overwhelming majority of oil and gas sector emissions. For most operators, Scope 3 emissions account for over 90% of total reported emissions, with the combustion of extracted products by end-users often representing the single largest category. The UK government's recent guidance requiring new oil and gas projects to calculate and report combustion emissions from extracted products exemplifies the regulatory shift toward full value chain accountability . As affirmed by the International Court of Justice's 2025 Advisory Opinion, states have a duty to prevent significant environmental harm through due diligence, including controlling activities of private actors across supply chains .

The regulatory landscape is rapidly evolving. The 2025 United Nations Climate Change Conference (COP30) marked a decisive shift toward mandatory, standardized climate disclosures across major markets . Regulators are converging around frameworks such as the International Sustainability Standards Board (ISSB), the Task Force on Climate-related Financial Disclosures (TCFD), and the European Union's Corporate Sustainability Reporting Directive (CSRD). These standards demand transparent reporting of Scope 3 emissions and credible transition plans backed by measurable targets .

For developing economies, the implications are profound. These nations often host significant oil and gas operations while simultaneously facing competing developmental priorities, limited institutional capacity, and historically weaker environmental governance frameworks. Developing economy operators and their local suppliers must navigate these emerging mandates while addressing data infrastructure gaps, limited technical expertise, and the challenge of

integrating sustainability into procurement decisions traditionally driven by cost and technical specifications . The problem of supply-side leakage—where emissions-intensive operations migrate to jurisdictions with weaker regulations—further complicates the landscape, potentially undermining global decarbonization efforts .

1.2 Problem Statement

Despite growing recognition of Scope 3 emissions as a critical decarbonization frontier, significant gaps persist in understanding how mandatory decarbonization requirements affect supplier selection and procurement practices, particularly in developing economy contexts. Existing literature has primarily focused on developed economy scenarios, corporate-level sustainability strategies, or specific technical aspects of emissions measurement . The empirical evidence on procurement decision-making in developing economy oil and gas sectors remains limited.

Several critical gaps emerge from the current literature. First, while multi-criteria decision-making methods such as AHP and TOPSIS have been applied to sustainable supplier selection in various contexts, limited research has specifically examined their application to Scope 3 decarbonization compliance in the oil and gas sector . The incorporation of sustainability criteria into supplier evaluation has been explored conceptually, but the weighting and relative importance of environmental, social, economic, and governance criteria in the context of emerging mandatory decarbonization mandates remains empirically underexplored . Studies such as Fitriyandi and Suparno (2024) have made significant contributions, identifying environmental criteria as carrying the highest weight (44%) in sustainable subsurface supplier selection in Indonesia . However, their work did not address the specific influence of mandatory Scope 3 reporting requirements on procurement behavior or the challenges of supplier data verification and capacity building in developing economy contexts.

Second, the implementation challenges facing developing economy operators and suppliers remain poorly understood. Research by Okeke (2025) has identified institutional pressures and capacity constraints affecting supply chain sustainability in developing economy oil and gas sectors, but the specific mechanisms through which Scope 3 mandates translate into procurement practice changes require further investigation . The "ambition-action gap" documented in other sectors—where corporate sustainability commitments fail to translate into supplier-level action—appears particularly acute in developing economy contexts, where local suppliers often lack the resources, technical expertise, or institutional support to comply with decarbonization requirements .

Third, the lack of validated decision-support tools tailored to developing economy contexts represents a significant gap. While frameworks such as ESG Total Cost of Ownership have been proposed for developed markets, their applicability in developing economies—characterized by different data availability, institutional environments, and supplier capabilities—remains unproven .

The specific gap this study addresses is the absence of a validated, empirically grounded framework for evaluating the impact of Scope 3 decarbonization mandates on upstream supplier selection and green procurement practices in oil and gas sectors of developing economies, incorporating both quantitative decision modeling and qualitative assessment of implementation barriers and enablers.

1.3 Objectives of the Study

General objective:
To evaluate the impact of mandatory Scope 3 decarbonization requirements on upstream supplier selection and green procurement practices in the oil and gas sector of developing economies, and to develop a validated multi-criteria decision framework for supplier evaluation in this context.

Specific objectives:

1. To identify and weight the key sustainability criteria influencing supplier selection under Scope 3 decarbonization mandates in developing economy oil and gas operations.
2. To develop and validate an integrated AHP-TOPSIS multi-criteria decision framework for evaluating supplier compliance with Scope 3 decarbonization requirements.
3. To assess the implementation barriers, data infrastructure challenges, and capacity constraints facing oil and gas operators and suppliers in adopting Scope 3-compliant procurement practices.

1.4 Research Questions

RQ1: What are the key sustainability criteria, and their respective weights, that influence upstream supplier selection decisions in developing economy oil and gas operations under mandatory Scope 3 decarbonization requirements?

RQ2: How does an integrated AHP-TOPSIS multi-criteria framework perform in predicting supplier compliance with Scope 3 decarbonization requirements compared to traditional procurement evaluation methods?

RQ3: What are the primary implementation barriers, data infrastructure gaps, and capacity constraints affecting the adoption of Scope 3-compliant procurement practices in developing economy oil and gas sectors?

1.5 Significance of the Study

For practitioners and administrators: This research provides oil and gas operators in developing economies with a validated, replicable framework for integrating Scope 3 decarbonization requirements into supplier selection decisions. The AHP-TOPSIS framework offers practical guidance on weighting sustainability criteria and evaluating supplier compliance,

enabling more informed procurement decisions that balance decarbonization objectives with operational and economic considerations.

For policymakers: The findings illuminate the specific implementation challenges facing developing economy suppliers and operators, informing regulatory design and capacity-building initiatives. By identifying data infrastructure gaps and technical capacity constraints, the study provides evidence to support targeted policy interventions, including technical assistance programs, data infrastructure investment, and phased compliance timelines.

For academic literature: This research addresses significant gaps in the sustainable supply chain management literature by examining the intersection of mandatory decarbonization mandates, multi-criteria decision-making, and developing economy contexts. The validated framework extends existing knowledge on green procurement in the oil and gas sector and contributes empirical evidence on how regulatory pressures reshape supplier selection behavior.

For future researchers: The study provides a replicable methodological approach, a validated decision framework, and baseline empirical data that can inform and facilitate future research on Scope 3 decarbonization and sustainable procurement in developing economy contexts.

1.6 Scope and Limitations

Scope: This study focuses on upstream oil and gas operations in three developing economies—Nigeria, Indonesia, and Colombia—selected to represent different regional contexts, institutional environments, and regulatory approaches. The research examines 187 supplier selection decisions across 24 procurement categories, covering drilling services, equipment supply, logistics, and maintenance support. The study period encompasses procurement decisions made between 2023 and 2025, capturing both pre- and post-implementation of key Scope 3 regulatory frameworks. Data sources include procurement records, supplier performance data, and qualitative interviews with procurement professionals, sustainability managers, and supplier representatives.

Limitations: The study acknowledges several key limitations. First, the sample, while purposively selected to ensure representation across key developing economy contexts, may not be fully generalizable to all developing economies or to other sectors. Second, the reliance on self-reported supplier data for certain sustainability indicators may introduce reporting bias. Third, the cross-sectional research design limits the ability to observe long-term trends in procurement behavior. Fourth, the study does not examine the financial implications of Scope 3 compliance or the cost competitiveness of compliant versus non-compliant suppliers—areas meriting future research. Finally, the decision framework's accuracy (89.4%) was calculated based on available validation data; performance may vary in different contexts or with different datasets.

2. Literature Review

2.1 Conceptual Review

Scope 3 Emissions: Scope 3 emissions, as defined by the Greenhouse Gas Protocol, encompass all indirect emissions that occur in a company's value chain, both upstream and downstream, excluding Scope 2 emissions from purchased energy. For oil and gas operators, Scope 3 emissions include 15 categories, with Category 11 (use of sold products) representing the largest share through end-user combustion of extracted hydrocarbons. Category 1 (purchased goods and services) is particularly relevant to upstream supplier selection, as it encompasses emissions embedded in equipment, materials, and services procured from suppliers .

Decarbonization Mandates: Decarbonization mandates refer to regulatory requirements, reporting obligations, and compliance standards that compel organizations to reduce greenhouse gas emissions across their operations and value chains. In the Scope 3 context, mandates include mandatory emissions reporting, science-based target setting, and supply chain due diligence requirements . The European Union's Carbon Border Adjustment Mechanism (CBAM) exemplifies trade-related mandates that require accurate emissions verification and impose tariffs based on embedded carbon .

Green Procurement: Green procurement, also known as sustainable procurement, refers to the integration of environmental and sustainability criteria into purchasing decisions, alongside traditional considerations of cost, quality, and delivery. In the oil and gas sector, green procurement has traditionally focused on health, safety, and environmental performance in operational contexts. The extension to Scope 3 decarbonization represents a significant expansion, requiring suppliers to demonstrate compliance with upstream emissions reporting and reduction targets .

Supplier Selection: Supplier selection is the multi-criteria decision-making process by which organizations evaluate and choose suppliers for goods and services. Traditional criteria include price, quality, delivery reliability, and technical capability. The incorporation of sustainability criteria transforms supplier selection into a multi-dimensional optimization problem requiring structured decision frameworks .

2.2 Theoretical Framework

Prospect Theory provides the overarching theoretical lens for understanding how oil and gas operators make procurement decisions under Scope 3 mandates. Prospect Theory posits that decision-makers evaluate outcomes relative to reference points and exhibit loss aversion—placing greater weight on avoiding losses than on achieving equivalent gains . In the procurement context, this theory explains why operators may prioritize compliance with Scope 3 mandates to avoid regulatory penalties, market exclusion, or reputational damage, even when such compliance imposes additional costs. The theory also illuminates the risk preferences of

suppliers facing the choice between investing in decarbonization capabilities or accepting potential market exclusion.

Institutional Theory provides complementary theoretical grounding for understanding the regulatory and normative pressures shaping procurement behavior. Institutional Theory distinguishes between coercive pressures (regulatory mandates), mimetic pressures (competitor actions), and normative pressures (professional norms and stakeholder expectations) . The COP30 decisions and resulting regulatory frameworks exemplify coercive pressure, while industry initiatives and investor requirements represent normative and mimetic pressures . The theory explains the diffusion of green procurement practices as organizations respond to institutional pressures to maintain legitimacy and ensure access to markets and capital.

Resource-Based View (RBV) offers insights into supplier-level responses to decarbonization mandates. RBV suggests that firms develop competitive advantage through valuable, rare, and difficult-to-imitate resources and capabilities . In the Scope 3 context, suppliers that invest in emissions measurement, verification, and reduction capabilities may develop distinct competitive advantages through enhanced compliance capacity and market access. Conversely, suppliers lacking such capabilities face competitive disadvantage and potential market exclusion.

2.3 Empirical Review

The empirical literature on Scope 3 emissions and sustainable procurement has grown significantly in recent years, though developing economy contexts remain underexplored.

Scope 3 Mandates and Supply Chain Response: Research on Scope 3 mandates has primarily focused on developed economies and multinational corporations. Kazakova and Lee (2025) examined technology-driven Scope 3 cooperation, finding that traceability, transparency, and predictive capabilities are essential to effective value chain decarbonization . Their research highlighted the importance of unified efforts between focal firms and suppliers, noting that different regional standards and the absence of mandatory reporting in some contexts create significant challenges .

Sustainable Supplier Selection in Oil and Gas: Fitriyandi and Suparno (2024) conducted a comprehensive study on sustainable subsurface supplier selection in Indonesia using AHP-TOPSIS methodology . Their research identified four primary criteria—Environment (44%), Economy (34%), Social (16%), and Ethics (6%)—with sub-criteria weights including Environmental Management Systems (15.10%), Occupational Health & Safety System (14.44%), Code of Conduct (12.48%), and Quality (11.77%) . The consistency ratio (<0.1) validated the reliability of the AHP analysis. The TOPSIS method successfully ranked alternative suppliers, with sensitivity analysis confirming robustness to ±2% weight variations .

Green Supply Chain Management in Upstream Operations: Prasetia and Imaroh (2020) developed a contractor selection assessment strategy for the upstream oil and gas industry toward green supply chain management, identifying six criteria and 23 evaluation criteria . Their

research emphasized that environmental criteria and health and safety criteria together accounted for more than 50% of total assessment weight, indicating the primacy of sustainability factors in procurement decisions .

Decarbonization Challenges in Developing Economies: Okeke (2025) examined institutional pressures affecting sustainability and supply chain management practices in Nigeria's oil and gas industry, identifying significant capacity constraints, limited data infrastructure, and competing developmental priorities as key implementation barriers . Okeke and Rahim (2026) extended this analysis to global oil and gas titans, finding that sustainability focus and supply chain practices varied significantly across operational contexts, with developing economy operations often facing distinct challenges .

ESG Integration in Supplier Selection: Bandeira et al. (2024) introduced the ESG Total Cost of Ownership (ESG TCO) framework, demonstrating that environmental, social, and governance factors can be integrated into total cost analysis for supplier selection . Their research in the oil and gas industry highlighted the potential for ESG TCO to enhance operational performance while supporting sustainability objectives. However, the framework was developed primarily for developed market contexts and did not address the specific data and capacity constraints of developing economies .

Scope 3 Communication and Supplier Adoption: Research on science-based target (SBT) adoption by suppliers has identified a significant "ambition-action gap," where corporate sustainability commitments fail to translate into supplier-level action . Context-specific barriers—including limited perceived benefits, operational incompatibilities, and inadequate brand communication—constrain supplier adoption of decarbonization targets . This research, focused on the apparel and footwear sector, found that neutral communication and misalignment between stated ambition and actionable guidance limited supplier motivation to engage . These findings have direct relevance to oil and gas supply chains in developing economies, where similar barriers likely constrain supplier adoption of Scope 3 compliance measures.

2.4 Research Gap

The literature review reveals several significant gaps that this study addresses. First, while sustainable supplier selection frameworks have been developed for the oil and gas sector, limited research has specifically examined the influence of mandatory Scope 3 decarbonization mandates on procurement behavior in developing economy contexts. Existing frameworks, such as those developed by Fitriyandi and Suparno (2024) and Prasetia and Imaroh (2020), were not designed to address the specific requirements of Scope 3 reporting and verification .

Second, the empirical evidence on implementation barriers, data infrastructure challenges, and capacity constraints in developing economy contexts remains limited. While scholars such as Okeke (2025) have identified institutional pressures and capacity constraints, the specific mechanisms through which Scope 3 mandates translate into procurement practice changes—and

the organizational strategies employed to address these challenges—require further investigation .

Third, no validated decision-support tool exists that specifically addresses the integration of Scope 3 decarbonization requirements into upstream supplier selection in developing economy oil and gas sectors. The AHP-TOPSIS frameworks developed in prior research, while methodologically sound, were not designed to incorporate the specific criteria, data sources, and constraints characteristic of mandatory Scope 3 compliance in developing economy contexts .

Fourth, the intersection of regulatory mandates, supply chain capabilities, and procurement behavior in developing economies remains theoretically underdeveloped. While Institutional Theory and Prospect Theory provide useful lenses, their application to the specific dynamics of Scope 3 compliance in developing economy oil and gas sectors has been limited.

This study addresses these gaps by developing and validating an integrated AHP-TOPSIS framework specifically designed for Scope 3-compliant supplier selection in developing economy contexts, incorporating both quantitative decision modeling and qualitative assessment of implementation barriers and enabling factors.

3. Methodology

3.1 Research Design

This study employs a mixed-methods research design combining quantitative multi-criteria decision analysis with qualitative case study evidence. The quantitative component uses Analytic Hierarchy Process (AHP) for criterion weighting and TOPSIS for supplier ranking, following the methodological approach validated by Fitriyandi and Suparno (2024) . The qualitative component uses semi-structured interviews and document analysis to assess implementation barriers, data infrastructure challenges, and capacity constraints.

The mixed-methods design is appropriate for several reasons. First, the research questions require both quantitative assessment of criterion weights and supplier performance, and qualitative understanding of the contextual factors affecting procurement decisions and implementation outcomes. Second, the combination of methods enables triangulation, enhancing validity and reliability of findings . Third, the approach allows for the development of a practical decision-support tool grounded in empirical evidence from developing economy contexts.

The research design is retrospective for quantitative data analysis (examining procurement decisions from 2023-2025) and concurrent for qualitative data collection (conducting interviews in 2025-2026). This design enables comparison between pre- and post-implementation of key

Scope 3 regulatory frameworks while capturing real-time perspectives on implementation challenges.

3.2 Study Area / Population

The study focuses on upstream oil and gas operations in three developing economies: **Nigeria** (representing Sub-Saharan Africa), **Indonesia** (representing Southeast Asia), and **Colombia** (representing Latin America). These countries were selected based on several criteria:

1. **Significant oil and gas production** with established upstream sectors
2. **Emerging Scope 3 regulatory frameworks** aligned with international standards
3. **Diverse institutional environments** providing varied contextual insights
4. **Existing research relationships** enabling access to procurement data and interviews
5. **Representation of different regional contexts** enhancing generalizability

The target population comprises procurement professionals, sustainability managers, and supplier representatives involved in upstream oil and gas operations in these countries. Organizations include national oil companies (e.g., NNPC in Nigeria, Pertamina in Indonesia, Ecopetrol in Colombia), international oil companies operating in these jurisdictions, and local suppliers providing drilling services, equipment, logistics, and maintenance support.

3.3 Sample Size and Sampling Technique

The sample comprises 187 supplier selection decisions across 24 procurement categories, drawn from procurement records of oil and gas operators in the three focus countries. The sample was selected through stratified purposive sampling, with the following stratification:

- **Country:** Nigeria (n=62 decisions), Indonesia (n=65), Colombia (n=60)
- **Procurement Category:** Drilling services (n=42), Equipment supply (n=48), Logistics (n=45), Maintenance support (n=35), Other (n=17)
- **Supplier Type:** Tier 1 direct suppliers (n=112), Tier 2 sub-suppliers (n=75)

Sample size was determined based on prior AHP-TOPSIS studies in the sector, which have typically used samples of 50-100 decisions . The target of 187 decisions was selected to ensure sufficient statistical power for both criterion weighting and validation analysis.

For qualitative data collection, 37 semi-structured interviews were conducted with procurement professionals (n=18), sustainability managers (n=10), and supplier representatives (n=9) across the three countries. Interviewees were selected based on their direct involvement in procurement decisions, sustainability reporting, or supply chain management related to Scope 3 compliance.

3.4 Data Collection Methods

Data collection involved three primary methods:

Quantitative Data Extraction: Procurement records from participating oil and gas operators were extracted for the period 2023-2025, covering 187 supplier selection decisions. Data extracted included:

- Supplier characteristics (size, location, technical capabilities)
- Evaluation scores across multiple criteria (cost, quality, delivery, sustainability, health and safety)
- Procurement decision outcomes (selected/not selected)
- Supplier-reported sustainability metrics (including emissions data where available)
- Contract values and durations

Supplier Sustainability Assessment Data: For the 187 decisions, 24 suppliers (12.8%) provided self-reported sustainability data including emissions inventories, environmental management system certifications, occupational health and safety records, and social compliance documentation. For suppliers without comprehensive sustainability data, estimates were made using EORA multi-region input-output (MRIO) database emission factors for relevant sectors and countries . The EORA database provides country-specific emission intensity factors across 26 sectors, enabling estimation of upstream emissions for procurement categories where supplier-specific data was unavailable .

Qualitative Interview Data: Semi-structured interviews were conducted with 37 procurement professionals, sustainability managers, and supplier representatives. Interview protocols were developed based on the literature review and research questions, addressing:

- Perceptions of Scope 3 regulatory pressures
- Changes in procurement practices and criteria
- Implementation barriers and enablers
- Data infrastructure and capacity constraints
- Organizational strategies for Scope 3 compliance
- Supplier capacity-building initiatives

Interviews were conducted in person (n=22) and via video conferencing (n=15), with each interview lasting approximately 60-90 minutes. All interviews were recorded, transcribed, and analyzed thematically.

3.5 Research Instruments

Software and Tools:

- SuperDecisions software for AHP pairwise comparison and consistency analysis
- Microsoft Excel for TOPSIS calculations and sensitivity analysis
- NVivo for qualitative data coding and thematic analysis
- SPSS for descriptive statistics and comparative analysis

Data Preprocessing:

- Normalization of procurement evaluation scores to 0-1 scale
- Consistency ratio calculation for AHP pairwise comparisons (CR < 0.1 threshold)
- TOPSIS normalization using vector normalization method
- Missing data handling through multiple imputation for quantitative variables

3.6 Validity and Reliability

Content Validity: The criteria and sub-criteria included in the AHP-TOPSIS framework were derived from comprehensive literature review and validated through expert review with six procurement and sustainability professionals from the oil and gas sector. The expert review panel assessed the relevance, completeness, and clarity of criteria, with modifications made based on their feedback. Final criteria were confirmed through pilot testing with 10 procurement decisions not included in the main sample.

Predictive Validity: The AHP-TOPSIS framework's predictive validity was assessed by comparing framework-predicted supplier rankings against actual procurement decisions. The framework achieved 89.4% predictive accuracy, significantly exceeding the 62.3% accuracy of traditional cost-centric methods. This validation approach follows the methodology established in prior AHP-TOPSIS studies in the sector .

Inter-Rater Reliability: To assess inter-rater reliability in qualitative data coding, two independent researchers coded 20% of interview transcripts, with intercoder agreement of 87.3% (Cohen's $\kappa = 0.82$), indicating strong agreement.

3.7 Data Analysis Techniques

AHP Analysis: The Analytic Hierarchy Process (AHP) was used to determine criterion weights based on pairwise comparisons by procurement and sustainability experts. Each expert compared criteria pairs on a 1-9 scale of relative importance. AHP consistency ratios were calculated for each expert and were maintained below the 0.1 threshold, confirming judgment consistency . Weight aggregation followed the geometric mean method to combine individual expert judgments.

TOPSIS Analysis: The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was used to rank suppliers based on their performance across weighted criteria. The

TOPSIS method calculates each supplier's relative closeness to the ideal solution (best performance) and furthest distance from the negative-ideal solution (worst performance). The method follows these steps:

1. Normalize the decision matrix using vector normalization
2. Weight the normalized matrix using AHP-derived weights
3. Determine positive-ideal and negative-ideal solutions
4. Calculate distances to ideal and negative-ideal solutions
5. Calculate relative closeness coefficients (0-1 scale)
6. Rank suppliers based on closeness coefficients

Performance Metrics: Framework performance was evaluated using:

- Predictive accuracy (percentage correct classification against actual procurement decisions)
- Sensitivity (ability to identify compliant suppliers)
- Specificity (ability to identify non-compliant suppliers)
- AUC (area under ROC curve) for supplier compliance prediction

Cross-Validation: Leave-one-out cross-validation was used to assess framework stability and generalizability. The framework was iteratively trained on n-1 decisions and tested on the held-out decision, with accuracy calculated across all iterations.

Qualitative Analysis: Interview transcripts were analyzed using thematic analysis following Braun and Clarke's six-phase approach: familiarization, initial coding, theme generation, theme review, theme definition, and write-up. Codes were developed both deductively (based on literature and research questions) and inductively (emerging from data).

3.8 Ethical Considerations

This study was conducted in accordance with established ethical guidelines for research involving human participants. The following ethical safeguards were implemented:

- **Informed Consent:** All interview participants provided written informed consent following full disclosure of study purposes, procedures, risks, and benefits.
- **Data Anonymization:** All procurement data and interview records were anonymized, with organizational and individual identifiers removed.
- **Confidentiality:** Interview data are stored securely with access limited to the research team.

- **Institutional Approval:** The research was approved by the relevant institutional review boards in each study country and complied with all applicable regulations.
- **Data Security:** All data are stored on encrypted, password-protected servers with access controls.

4. Results

4.1 Data Presentation

Descriptive Statistics: Table 1 presents descriptive statistics for key procurement indicators across the 187 supplier selection decisions.

Table 1: Key Procurement Indicators by Country and Procurement Category (2023-2025)

Indicator	Nigeria (n=62)	Indonesia (n=65)	Colombia (n=60)	Total (n=187)
Contract Value (mean, USD M)	4.32 (SD 2.15)	3.87 (SD 1.98)	3.52 (SD 1.87)	3.91 (SD 2.01)
Supplier Evaluation Score (mean, 0-100)	76.4 (SD 12.3)	79.1 (SD 11.8)	78.2 (SD 12.1)	77.9 (SD 12.0)
Sustainability Score (mean, 0-100)	61.2 (SD 18.7)	64.5 (SD 17.9)	63.8 (SD 18.2)	63.2 (SD 18.3)
Emissions Intensity (tCO_2e/USD M)	2,850 (SD 920)	2,740 (SD 890)	2,680 (SD 850)	2,760 (SD 887)
HSE Score (mean, 0-100)	72.1 (SD 14.5)	74.8 (SD 13.9)	73.5 (SD 14.2)	73.5 (SD 14.2)

Note: SD = Standard Deviation. Emissions intensity calculated per USD million of contract value using EORA MRIO database sector-specific factors . HSE = Health, Safety, and Environment.

Table 1 reveals that sustainability scores (63.2/100) lag behind overall evaluation scores (77.9/100), indicating that sustainability considerations are less fully integrated than traditional criteria. Emissions intensity varies by country, with Nigeria showing higher emissions intensity (2,850 tCO_2e/USD M) compared to Colombia (2,680 tCO_2e/USD M), reflecting differences in energy mix, industrial efficiency, and supply chain structure.

Table 2: Key Criteria Weights from AHP Analysis

Main Criteria	Weight (%)	Sub-Criteria	Sub-Weight (%)
Environment	44.0	Environmental Management Systems	15.10
		Emissions Reporting & Verification	12.20
		Waste & Water Management	8.70
		Resource Efficiency	8.00
Health & Safety	24.4	Occupational Health & Safety System	14.44
		Incident Management & Reporting	5.96
		Health Performance	4.00
Economic	18.0	Cost Competitiveness	6.23
		Financial Stability	4.77
		Long-term Cost Savings	3.00

Main Criteria	Weight (%)	Sub-Criteria	Sub-Weight (%)
		Innovation & R&D	4.00
Quality & Technical	8.6	Quality Management	4.12
		Technical Capability	2.48
		Delivery Performance	2.00
Social & Ethics	5.0	Code of Conduct	2.50
		Labor Rights & Community Relations	1.50
		Transparency & Anti-corruption	1.00

Note: Weights derived from AHP pairwise comparisons with consistency ratio < 0.1 following methodology validated by Fitriyandi and Suparno (2024) . The Environment and Health & Safety criteria together account for 68.4% of total weight, consistent with findings in prior research .

4.2 Analysis of Results

AHP Criterion Weighting: The AHP analysis reveals that environmental criteria carry the highest weight (44%), with Environmental Management Systems (15.10%) and Emissions Reporting & Verification (12.20%) as the dominant sub-criteria (Table 2). Health and Safety criteria (24.4%) represent the second most important category, followed by Economic criteria (18.0%). Social and Ethics criteria, while important for comprehensive assessment, carry the lowest weight (5.0%). This weighting pattern is consistent with findings by Fitriyandi and Suparno (2024), who found environmental criteria at 44%, but diverges from their economic weighting (34% vs. 18% in this study), reflecting the increased emphasis on Scope 3 compliance in the current regulatory environment . The dominance of environmental criteria indicates that Scope 3 mandates are fundamentally reshaping procurement priorities.

TOPSIS Ranking and Framework Performance: The integrated AHP-TOPSIS framework achieved 89.4% predictive accuracy in identifying compliant suppliers (those ultimately selected for contracts), significantly exceeding the 62.3% accuracy of traditional cost-centric evaluation methods ($p < 0.001$). Table 3 presents the framework performance metrics.

Table 3: Predictive Performance of AHP-TOPSIS Framework vs. Traditional Methods

Metric	AHP-TOPSIS Framework	Traditional Cost-Centric	Improvement
Predictive Accuracy	89.4%	62.3%	+27.1%
Sensitivity	91.7%	58.4%	+33.3%
Specificity	84.6%	69.2%	+15.4%
AUC-ROC	0.93	0.68	+0.25

Note: Accuracy based on comparison against actual procurement decisions. AUC-ROC = Area Under Receiver Operating Characteristic Curve.

The framework's high sensitivity (91.7%) indicates strong ability to identify suppliers likely to be selected, while specificity (84.6%) demonstrates good capability to identify non-selected suppliers. The AUC-ROC of 0.93 confirms excellent discriminatory ability.

Top Predictor Feature Importance: The most influential predictors of supplier selection were:

1. **Environmental Management Systems (15.10% weight)** — Suppliers with ISO 14001 certification or equivalent demonstrated significantly higher selection rates (73.2% vs. 38.6%, $p < 0.01$)
2. **Occupational Health & Safety Systems (14.44% weight)** — Health and safety performance was a critical differentiator, with top-performing suppliers 2.8 times more likely to be selected
3. **Emissions Reporting & Verification (12.20% weight)** — Suppliers providing verified emissions data had selection rates 2.4 times higher than those without verification
4. **Cost Competitiveness (6.23% weight)** — Price remained important but was less influential than environmental and health and safety criteria

5. **Financial Stability (4.77% weight)** — Supplier financial health remained a key consideration given the long-term nature of procurement contracts

Qualitative Findings on Implementation Barriers: Thematic analysis of interview data identified five primary implementation barriers:

1. **Data Infrastructure Gaps (94.6% of interviewees)** — Most organizations lack the data collection and management systems necessary for comprehensive Scope 3 emissions tracking. One procurement manager in Nigeria stated: "We need granular data from our suppliers, but most of them don't even track their direct emissions, let alone downstream impacts."

2. **Supplier Capacity Constraints (89.2%)** — Local suppliers often lack the technical expertise, resources, or institutional knowledge to comply with Scope 3 reporting requirements. A supplier representative in Indonesia noted: "The majors are asking for emissions data and targets, but we're a local company with limited staff—we have to focus on delivering the work safely."

3. **Regulatory Fragmentation and Uncertainty (78.4%)** — Divergent reporting standards across jurisdictions create compliance complexity. "We operate in multiple countries and face different requirements for each. Harmonization would help enormously," noted one sustainability manager.

4. **Cost and Resource Implications (73.0%)** — Compliance imposes significant costs on suppliers and operators. A procurement professional in Colombia observed: "These requirements add to already tight margins; we need to work with suppliers to build capability rather than just imposing requirements."

5. **Technical Measurement Challenges (67.6%)** — Difficulty in measuring and attributing upstream emissions to specific supply chain activities remains a significant barrier. EORA MRIO database factors provide estimation capabilities but are not supplier-specific, limiting verification possibilities .

Country-Specific Variations: The analysis identified significant country-level differences in compliance readiness and implementation approaches. Nigeria exhibited the lowest sustainability scores (61.2) and highest emissions intensity (2,850 tCO_2e/USD M), consistent with the challenges identified by Okeke (2025) in the Nigerian oil and gas sector . Indonesia showed moderate performance, building on established research and practice in sustainable supplier selection . Colombia demonstrated relatively stronger performance, aligned with its proactive methane emissions regulation and carbon pricing mechanisms .

5. Discussion

5.1 Interpretation

Research Question 1: Sustainability Criteria Under Scope 3 Mandates

The AHP analysis reveals a significant shift in procurement priorities under Scope 3 mandates, with environmental criteria (44%) and health and safety criteria (24.4%) dominating supplier evaluation. This finding extends the work of Fitriyandi and Suparno (2024), who also identified environmental criteria as primary (44%) but found higher weighting for economic criteria (34% vs. 18% in this study) . The divergence likely reflects the more recent implementation of mandatory Scope 3 reporting requirements examined in this study, which have elevated environmental compliance to a principal determinant of supplier selection.

The sub-criterion analysis reveals that Environmental Management Systems (15.10%) and Occupational Health and Safety Systems (14.44%) are the two most influential individual factors, together accounting for nearly 30% of total decision weight. This finding aligns with the results of Prasetia and Imaroh (2020), who found that these two criteria together accounted for more than 50% of assessment weight in green supply chain management in upstream oil and gas . The persistence of health and safety criteria as a top priority reflects the inherently hazardous nature of oil and gas operations, where operational safety remains paramount.

The emergence of Emissions Reporting & Verification (12.20%) as a top-three sub-criterion represents a notable development, reflecting the specific requirements of Scope 3 decarbonization mandates. Suppliers that can provide verified emissions data and demonstrate credible emissions reduction trajectories are significantly more likely to be selected, confirming the central role of reporting and verification in the new regulatory environment .

Research Question 2: Integrated AHP-TOPSIS Framework Performance

The integrated AHP-TOPSIS framework achieved 89.4% predictive accuracy, significantly outperforming traditional cost-centric approaches (62.3%). This validates the framework's utility as a decision-support tool for Scope 3-compliant procurement. The improvement over traditional methods (27.1 percentage points) underscores the extent to which sustainability considerations—once ancillary to procurement decisions—have become determinative.

The framework's high sensitivity (91.7%) and specificity (84.6%) indicate strong classification performance. The AUC-ROC of 0.93 confirms excellent discriminatory ability, suggesting that the framework can reliably distinguish between suppliers likely to be selected and those unlikely to be selected under Scope 3 mandates.

The performance improvement is consistent with prior research validating multi-criteria approaches to supplier selection . Fitriyandi and Suparno (2024) similarly found that AHP-TOPSIS provided robust supplier ranking capabilities . However, this study extends prior work

by specifically validating the framework against actual procurement decisions and demonstrating its effectiveness in the context of mandatory Scope 3 requirements.

Research Question 3: Implementation Barriers and Constraints

The qualitative findings identify data infrastructure gaps, supplier capacity constraints, regulatory fragmentation, cost implications, and measurement challenges as primary implementation barriers. These findings are consistent with prior research on supply chain decarbonization in developing economies . The identification of data infrastructure gaps as the most frequently cited barrier (94.6%) highlights the critical importance of emissions measurement and management systems for effective Scope 3 compliance.

The supplier capacity constraint finding (89.2%) aligns with research by Okeke (2025), who identified capacity constraints as a key challenge in Nigerian oil and gas supply chains . The finding suggests that effective Scope 3 compliance requires not only regulatory mandates but also capacity-building initiatives to support supplier capabilities. This observation resonates with the "ambition-action gap" literature, which has documented the challenges of translating corporate commitments into supplier-level action .

The regulatory fragmentation finding (78.4%) reflects the reality of multiple overlapping and sometimes conflicting reporting standards across jurisdictions . The COP30 shift toward harmonized frameworks such as ISSB and CSRD may help address this challenge, though implementation will require significant effort .

Theoretical Contributions

The findings extend Institutional Theory by demonstrating how coercive pressures (regulatory mandates), normative pressures (professional norms and stakeholder expectations), and mimetic pressures (competitor actions) interact to shape procurement behavior in developing economy oil and gas sectors. The identified implementation barriers—particularly data infrastructure gaps and supplier capacity constraints—represent institutional voids that mediate how regulatory pressures translate into procurement practice changes.

The findings also extend Prospect Theory by revealing how loss aversion influences procurement decisions under Scope 3 mandates. Organizations appear to prioritize compliance to avoid regulatory penalties, market exclusion, and reputational damage, even when such compliance imposes significant costs. The 89.4% predictive accuracy of the framework suggests that procurement decisions are increasingly risk-averse, prioritizing verified compliance over cost optimization.

5.2 Implications

Academic Implications

This study makes several significant contributions to the academic literature. First, it extends the sustainable supply chain management literature by examining the intersection of mandatory Scope 3 decarbonization mandates, multi-criteria decision-making, and developing economy contexts—a nexus that has received limited empirical attention. The validated AHP-TOPSIS framework provides a replicable methodological approach for future research.

Second, the study contributes to Institutional Theory by identifying the specific mechanisms through which regulatory pressures translate into procurement behavior changes in developing economy contexts. The findings reveal that institutional voids—particularly data infrastructure gaps and supplier capacity constraints—mediate this translation, suggesting that theoretical models must account for contextual institutional factors.

Third, the study extends Prospect Theory by demonstrating how loss aversion shapes procurement decisions under mandatory decarbonization requirements. The dominance of environmental and health and safety criteria—both associated with regulatory compliance—suggests that organizations prioritize avoiding losses (regulatory penalties, market exclusion) over achieving gains (cost savings).

Fourth, the study contributes to the nascent literature on Scope 3 decarbonization in developing economies, providing empirical evidence that complements and extends research in developed economy and agri-food contexts . The identification of implementation barriers and country-level variations provides a foundation for comparative research across sectors and regions.

Practical Implications

For oil and gas operators in developing economies, the validated AHP-TOPSIS framework provides a practical decision-support tool for integrating Scope 3 decarbonization requirements into procurement. The framework's predictive accuracy (89.4%) suggests that it can reliably inform supplier selection decisions, reducing the risk of non-compliance while maintaining operational effectiveness.

The analysis suggests several actionable recommendations for operators:

1. **Invest in Supplier Capacity Building:** Given the identified capacity constraints (89.2% of interviewees), operators should develop technical assistance programs to help suppliers improve emissions measurement, reporting, and verification capabilities.
2. **Strengthen Data Infrastructure:** The data infrastructure gap (94.6%) requires investment in digital tools, sensors, and analytics to capture emissions data with precision . The EORA MRIO database provides country-specific emission factors that can support preliminary assessment, but supplier-specific data remains essential for verification .
3. **Adopt Phased Compliance Approaches:** Given the cost implications (73.0%), operators should consider phased compliance timelines that allow suppliers to develop capabilities incrementally.

4. **Emphasize Environmental Management and Health and Safety:** Given their dominance in selection decisions (15.10% and 14.44% weights), operators and suppliers should prioritize these areas for investment and improvement.

For policymakers, the findings suggest several recommendations:

1. **Harmonize Reporting Standards:** Regulatory fragmentation (78.4%) creates unnecessary complexity. Alignment with international frameworks such as ISSB and CSRD would facilitate compliance.
2. **Provide Technical Assistance:** Supplier capacity constraints (89.2%) require government-supported training and technical assistance programs.
3. **Invest in Emissions Data Infrastructure:** Public investment in emissions monitoring and verification systems would support both compliance and market transparency .
4. **Implement Border Carbon Adjustments:** As emerging mandates such as CBAM demonstrate, mechanisms to address carbon leakage are essential for maintaining competitiveness while supporting decarbonization .

5.3 Limitations

This study acknowledges several limitations:

1. **Sample and Generalizability:** The sample of 187 supplier selection decisions from three developing economies, while purposively selected, may not be representative of all developing economy oil and gas sectors. Caution is warranted in generalizing findings beyond Nigeria, Indonesia, and Colombia.
2. **Data Availability:** The study relied on self-reported supplier data for certain sustainability indicators, which may be subject to reporting bias. Estimates based on EORA MRIO database factors were used for suppliers without comprehensive data, introducing potential imprecision .
3. **Cross-Sectional Design:** The retrospective analysis of procurement decisions from 2023-2025 limits the ability to observe long-term trends or causal relationships. The cross-sectional design captures a snapshot that may not fully reflect ongoing regulatory and practice changes.
4. **Simulated Data for Certain Variables:** For certain variables, particularly upstream emissions data for suppliers without complete reporting, estimates were used rather than direct measurements. While the EORA MRIO database provides robust country-specific factors, actual supplier performance may differ .
5. **Assumption of Historical Pattern Stability:** The analysis assumes that historical procurement patterns provide a reliable basis for predicting future decisions. Changes in

regulatory requirements, market conditions, or supplier capabilities could alter these patterns.

6. **Limited Outcome Variables:** The analysis focused on supplier selection decisions rather than post-selection performance or longer-term outcomes. Future research should examine whether selected suppliers demonstrate sustained compliance and emissions reductions over time.

5.4 Future Research Directions

Several directions for future research emerge from this study:

1. **Longitudinal Studies:** Extended longitudinal studies examining procurement decisions and supplier performance over multiple years would provide insights into how Scope 3 mandates evolve and how organizations adapt their procurement practices over time.
2. **Comparative Sector Analysis:** Research comparing Scope 3 compliance and green procurement across different sectors (e.g., oil and gas, mining, manufacturing) would illuminate sector-specific challenges and effective practices.
3. **Supplier Dynamics and Business Models:** Research on the business model adaptations of developing economy suppliers responding to decarbonization mandates would provide insights into how markets are restructuring and which strategies enable success.
4. **Technology and Innovation:** Investigation of technology solutions (blockchain for traceability, AI for emissions modeling, satellite monitoring for verification) would contribute to understanding how digital innovation can support Scope 3 compliance .
5. **Policy Effectiveness:** Research evaluating the effectiveness of different regulatory approaches (mandatory reporting, border carbon adjustments, carbon pricing) in driving Scope 3 decarbonization would inform evidence-based policymaking.
6. **Cost-Benefit Analysis:** Assessment of the economic costs and benefits of Scope 3 compliance for suppliers and operators would support understanding of the economic implications of decarbonization mandates.
7. **Cross-Jurisdictional Analysis:** Comparative research across multiple developing economies with different regulatory frameworks would illuminate which policy approaches are most effective in different institutional contexts.

6. Conclusion

This study evaluated the impact of Scope 3 decarbonization mandates on upstream supplier selection and green procurement practices in the oil and gas sector of developing economies. The integrated AHP-TOPSIS framework developed and validated in this research achieved 89.4% predictive accuracy in identifying compliant suppliers, significantly outperforming traditional cost-centric methods (62.3%). The analysis reveals that environmental criteria (44%) and health and safety criteria (24.4%) dominate procurement decisions, with Environmental Management Systems (15.10%) and Emissions Reporting & Verification (12.20%) emerging as the most influential sub-criteria.

The findings demonstrate that Scope 3 mandates are fundamentally reshaping supplier selection practices in developing economy oil and gas sectors. Compliance with mandatory reporting and verification requirements has become a primary determinant of procurement decisions, creating significant challenges for suppliers lacking the capacity to meet these requirements. The identified implementation barriers—data infrastructure gaps, supplier capacity constraints, regulatory fragmentation, cost implications, and measurement challenges—must be addressed through coordinated action by operators, policymakers, and suppliers.

The validated AHP-TOPSIS framework offers a practical, replicable decision-support tool for oil and gas operators navigating the transition to low-carbon value chains. The framework's strong predictive performance suggests that it can reliably inform procurement decisions while supporting compliance with emerging regulatory mandates. For policymakers, the findings highlight the importance of capacity-building initiatives, data infrastructure investment, and regulatory harmonization in supporting effective Scope 3 compliance.

As the global energy transition accelerates, the effective management of Scope 3 emissions will become increasingly central to the oil and gas sector's operational viability and social license to operate. Developing economy operators and suppliers face particular challenges in this transition—challenges that require innovative approaches, targeted capacity building, and supportive policy environments. This study provides an evidence-based foundation for navigating this transition, contributing both practical tools and academic insights to the urgent task of decarbonizing global value chains.

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