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Highly Reliable Organisations and Sustainability Risk Management: Safety Cultures in the Nigerian Oil and Gas Supply Chain Sector

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ABSTRACT

This study investigates the environmental consequences of pursuing profits in the oil and gas industry, focusing on Nigeria. It examines the role of top management commitment, safety culture and stakeholder risk prioritisation in the industry. By surveying 441 stakeholders, this study highlights the importance of extensive stakeholder engagement and a systemic supply chain approach in building resilience and shaping sustainable practices. The findings reveal that stakeholder risk perception influences sustainability risk management; however, variations in risk prioritisation between internal and external stakeholders remain a challenge. The study advocates for a paradigm shift and emphasises the crucial role of high-reliability management in guiding organisations towards effective risk mitigation strategies for the industry's immediate health, communities, environment and future.

1 | Introduction

The landscape of risk management is rapidly evolving and driven by increasingly complex and interconnected global challenges (Horvey and Odei-Mensah 2023). Recent research has highlighted the need for organisations to adopt more sophisticated and holistic approaches to risk management, particularly in high-reliability sectors (Hartzel and Spangler 2021). Research on highly reliable organisations (HROs) has predominantly focused on single organisations operating in safety-critical environments, implementing robust, reliable and resilient operational management system designs (Agwu, Labib, and Hadleigh-Dunn 2019; Harvey, Waterson, and Dainty 2019). Recent advancements have highlighted the incorporation of comprehensive risk management tools, such as data envelopment analysis (DEA), to prioritise risk factors, including criminality, terrorist attacks and environmental hazards, thus providing a more strategic response framework for HROs (Hatami-Marbini et al. 2024). These organisations maintain high levels of performance despite operating in environments characterised by high levels of latent failures and potentially catastrophic consequences (e.g., nuclear and transportation systems, emergency services and healthcare settings). Recently, researchers have addressed reliability in terms of production assets in single organisations but have ignored wider supply chains (Kumar et al. 2023). This research aims to explore the common mental models of managing risks to enhance reliability and prevent accidents that lead to environmental deterioration at both the organisational and supply network/supply chain levels. The literature also overlooks the severe negative impact of production system failures on the ecological environment, their generational impact on residents and national UN commitments to better stewardship. A lack of supply chain resilience, as exemplified by the blocking of the Suez Canal, has heightened operations management (OM) sensitivities to reliability as a countermeasure to the acceptance of failure as inevitable, which was the basis of the 'normal accident theory' school of thought that has dominated safety thinking (Gephart 2004).

Engineering and OM literature traditionally acknowledges the inevitability of system failure and the futility of controlling complex systems. Heinrich's (1931) safety triangle outlines a linear relationship between workplace behaviours, near-miss events and catastrophic failure. Recent academic perspectives emphasise a shift towards a control approach, distinguishing between human-caused and system-induced failures, focusing on understanding successful safety maintenance. Moreover, fostering psychological safety in the workplace, allowing all staff to voice concerns, is emphasised (Plouffe et al. 2023). Companies may prioritise efficiency and commercial pressures over safety, leading to poor safety management and trade-offs between safety and commercial performance (known as the efficiency–thoroughness trade-off [ETTO]) (Hollnagel 2009). We appreciate the shared commitment of the researchers to promote safety measures that can detect potential safety breaches in a timely manner to prevent catastrophic outcomes. The researchers aim to establish standards to avoid system failure due to both imminent and latent threats, as well as the negative impact of commercial pressures on organisations and their surrounding environments, such as the Deepwater Horizon Disaster in 2010. While considered rare in the Global North due to prevalent technical advancements, these catastrophes occur more frequently and with greater severity in the Global South, often overlooked by the international community.

The historical development of modern control approaches uses a generalised time-sequence model (GTSM) or the flow of events to understand the process that leads to failure. A 'bow tie' model is used to identify many latent threats in the working environment that funnel into an event, which then leads to varying forms of negative consequences. The Swiss Cheese Model accepts that each stage of the production process or supply chain has latent risks, which can be triggered by poor control (Reason 1990). These risks can lead to failures, if not corrected or prevented, and the magnitude of the failure increases as it moves through the process. To prevent this, defences and checks are introduced to prevent holes in the process/system from aligning and causing catastrophic failure. Commercial pressures, psychological safety and poor situational awareness all contribute to errors and are used to create organisational and supply chain countermeasures such as checklists, failure modes and effects analysis (FMEA) and audits of known risks in the workplace.

These models are useful in conceptualising safety failures, but none has addressed the impact of wider operational management issues behind human harm and the cessation of production. The aerospace sector has generated the most safety models (Reason 1990), and these models have led to greater reliability of aircraft design and operation and demonstrated HRO performance relative to other sectors such as healthcare and primary supply chain producers. Pressures for 'profit over planet' have resulted in significant loss of life (e.g., Bhopal disaster in India, Union Carbide, 1984; the Piper Alpha Oil Rig Disaster OPCAL, 1988; the Exxon Valdez Sinking, Exxon, 1989; and the Deepwater Horizon Oil Rig Disaster Transocean and BP, 2010). These catastrophic events mask many unreported incidents despite major damage to the environment, especially in poorly regulated areas in developing countries. Crucial for developing countries' O&G producers, framing policies is vital to optimise resource production for economic development (Stevens 2018).

In sustainability-driven markets, companies must strategically develop portfolios that balance proactive sustainability initiatives with operational demands, ensuring that they can mitigate risks and seize opportunities (Villamil, Schulte, and Hallstedt 2022). This dual approach is critical for organisations operating in sectors as vulnerable as oil and gas, where sustainability risks and opportunities must be equally weighted to achieve long-term resilience. The importance of HROs and sustainability risk management (SRM) in the Nigerian oil and gas sector is multifaceted. It encompasses safeguarding human lives, protecting the environment, ensuring regulatory compliance, maintaining financial stability, fostering operational efficiency, upholding social responsibility and aligning global industrial trends and standards. By prioritising safety cultures and sustainability initiatives, organisations can mitigate risks, enhance resilience and contribute to the long-term viability and reputation of the industry. In the oil and gas sector, safety is of utmost importance owing to the inherently high-risk nature of operations. Establishing a robust safety culture is crucial for protecting human lives and preserving the workforce, which is the lifeblood of industry. This sector operates in sensitive ecosystems where any mishap can result in significant environmental damage. SRM aims to mitigate environmental risks, protect biodiversity and ensure the responsible extraction of resources.

The Deepwater Horizon (DWH) oil spill was a pivotal moment in the expression and reporting of stakeholder risk perceptions (SRPs) about oil spills, response options and safety (Walker et al. 2015). Risk management strategies are highly dependent on stakeholder perceptions and attitudes, which play a critical role in how individuals and institutions act to mitigate risks (Santoro and Zanin 2021; Santoro et al. 2019). Cultural theory claims that risk perception within social groups and structures is predictable according to group and individual worldviews (Tsohou et al. 2006) and that robust corporate governance, in conjunction with sustainability reporting and stakeholder engagement, plays a crucial role in ensuring accountability for environmental outcomes. Organisations adopting transparent governance practices are better positioned to meet environmental, social and governance (ESG) criteria, which are essential for maintaining investor confidence and regulatory compliance (Jagoda and Wojcik 2019). As we navigate an era of hyperdisruption characterised by compounding and interconnected risks, organisations and their risk leadership must elevate their risk management strategies. This study explores the current state of SRM practices, identifies key challenges and proposes innovative approaches to enhance organisational resilience in the face of unprecedented volatility and uncertainty.

2 | Theoretical Background Development

2.1 | Highly Reliable Organisational Theory

Achieving high reliability as an organisation, with a formalised strategy for effective problem management and prevention, contrasts with normal accident theory. It signifies a commitment to resilience engineering and robust organisational management systems. This requires not only highly situationally aware staff but also a range of engineering skills to detect potential signs of failure, including a focus on learning and improvement and the creation of organisational resilience through system redundancy (Hollnagel 2009, 2014). The nuclear power generation sector, exemplifying investment in safety measures, employs multiple control systems to prevent meltdowns. However, incidents like Chernobyl and Fukushima highlight vulnerabilities to human error or design flaws.

HROs and supply chain networks are distinct branches of safety thinking that originated from organisational psychology and decision-making research in the 1980s (Weick and Sutcliffe 2007). The proposed definition of an HRO (Roberts and Gargano 1989) posits that it is an organisation that uses hazardous technology but operates with a long history of no such catastrophic events (Pillay, Tuck, and Klockner 2020). Successful HROs continually 'reinvent' themselves and operate with a 'collective mindfulness' among all staff, which represents a safety culture that is sensitive to the potential for failure and prioritises areas of known risk and high consequence of failure. A culture of reliability, which works synergistically with foundational organisational characteristics, allows mindfulness—a key hallmark of HROs—to flourish. This distinction between 'reliable' and 'highly reliable' operations is what ensures sustainable performance in complex and high-risk industries like oil and gas (Cantu et al. 2020).

The work of HRO researchers highlights the importance of top management commitment (TMC), psychological safety, heightened employee skills and senses, risk prioritisation and willingness to intervene quickly to halt the OM system before major negative consequences ensue, which creates accidents. Most HROs operate in high-risk environments that present significant environmental hazards that have not been thoroughly studied at the network level. Five key principles characterise an HRO and its network: *preoccupation with failure*, *reluctance to simplify*, *sensitivity to operations*, *commitment to resilience* and *deference to expertise*. These principles emphasise the importance of engaging frontline staff, anticipating and rehearsing potential events and prioritising knowledge and expertise in decision-making processes (Agwu, Labib, and Hadleigh-Dunn 2019).

According to Pariès et al. (2019), the primary goal of an HRO is to address safety-critical technology/context constraints while achieving high efficiency. To achieve this heightened awareness, top leadership must engage behaviours that create organisational safety cultures (OSCs) and climate and result in management strategies/prioritisation of risks to mitigate their effects while satisfying both the commercial and ethical requirements of internal and external stakeholders (Hartzel and Spangler 2021). For tightly coupled supply chains, the inclusion of upstream/downstream supply chain partners is also required so that all risks to the environment and material flow are less vulnerable to disruption which could trigger economic collapse and environmental devastation (Wagner and Neshat 2012). In recent years, supply chains have undergone significant transformations due to globalisation, technological advancements and recent global disruptions such as the COVID-19 pandemic. These developments have increased supply chain complexity, particularly concerning sustainability (Minh Ngo et al. 2023). Effective supply chain integration is now critical as it helps organisations manage environmental hazards and deliver positive outcomes for both business performance and environmental protection. Consequently, HROs extend risk controls to customers and suppliers to enhance reliability and dependable material flow performance (Anderson et al. 2015). The most significant gap in the literature is the omission of environmental factors in safety management, particularly for supply networks. A study on commitment and risk management in impoverished industries facing stress would help fill this literature void.

In high-risk industries such as oil and gas, comprehensive risk assessments and audits are essential for identifying hazards that can result in environmental spills, equipment damage or operational disruptions. By preventing such incidents, firms can mitigate their environmental impacts and ensure safer operations (Schneider et al. 2013). Proper control of hazardous substances reduces occupational diseases and environmental damage, benefiting both human health and the planet. Minimising workplace accidents not only enhances worker safety but also reduces costs related to resource wastage, pollution and operational inefficiencies. Effective hazardous material management helps companies avoid expenses associated with environmental damage, regulatory penalties and remediation efforts. These measures align with SRM strategies that aim to balance economic, environmental and social performance (Manab and Aziz 2019).

2.2 | SRM

Integrating sustainability risks into enterprise risk management (ERM) frameworks has become crucial for businesses to enhance organisational resilience and support long-term success as environmental and social risks are increasingly viewed as existential threats (Schulte and Hallstedt 2017). SRM extends traditional ERM by encompassing risks associated with sustainability, such as climate change, resource depletion and natural catastrophes, with the aim of balancing environmental, social and economic performance, which are key components of a company's survival in today's complex and dynamic business environment (Manab and Aziz 2019). Effective integration of SRM into ERM frameworks requires several critical factors, and active stakeholder engagement is essential for incorporating diverse perspectives into the risk management process (Cort and Gudernatch 2014). Sustainability risks often extend over longer timelines than traditional financial risks do, necessitating ERM criteria to consider both the magnitude and likelihood of these risks over extended periods (Cort and Gudernatch 2014). Effective SRM programmes rely on robust leadership, a supportive risk culture, adherence to sustainability regulations, comprehensive risk management tools and business continuity planning (Aziz and Manab 2020). Sustainability risks should align with an organisation's strategic objectives, ensuring the prioritisation of value creation for both internal and external stakeholders (Schulte and Hallstedt 2018). While traditional risk management frameworks often rely on static assessments, emerging methodologies, such as scenario planning and real-time risk monitoring, offer more dynamic and adaptive approaches. These tools enable organisations to better navigate the volatile and uncertain environmental conditions characteristic of the oil and gas industry (Hossain et al. 2023).

The United Nations' Sustainable Development Goals (SDGs) are increasingly becoming benchmarks for sustainability in business strategies. Recent empirical research has demonstrated a significant correlation between corporate social responsibility (CSR), SRM and organisational performance. Entities that actively engage in CSR initiatives tend to more effectively integrate sustainability risks into their risk management frameworks, resulting in enhanced resilience and performance (Singh et al. 2023). This proactive approach not only augments risk management practices but also enables firms to maintain competitiveness in sustainability-oriented markets. SRM is described as an organisation's risks resulting from social, environmental and economic concerns (Wijethilake and Lama 2019). Few studies on the identification and management of operational risks using SRM exist in the O&G supply chain. This extends the ERM concept, employed for handling emerging and nonquantifiable risks (Manab, Othman, and Jadi 2017). Hence, the structured integration of antecedent variables into current risk management processes holds significance (Schulte and Hallstedt 2018). Extant research studies have acknowledged that sustainability risk measurement analysts face significant obstacles owing to the scarcity of reliable data, unpredictability of sustainability risks, measurement process issues and the complexity and context sensitivity of risk assessment. These difficulties cast doubt on rating agencies' optimistic rhetoric (Boiral, Heras-Saizarbitoria, and Brotherton 2020). It also plays a vital role in firm performance, and it is critical to understand the underlying mechanisms that drive better firm performance with sustainability adoption (Gopalakrishna-Remani, Byun, and Doty 2022).

The assessment of environmental risks, social and economic mitigation strategies and SRM requires organisational governance and interorganisational cooperation, especially in post-pandemic austerity and volatile market conditions (Linton, Klassen, and Jayaraman 2007). The systematic OM optimisation approach using increased process performance and optimised materials yields low energy consumption, but SRM requires significant sensitivity to emerging hazards and their assessment when assets perform at levels close to the design thresholds offered by the equipment manufacturer (Manab, Aziz, and Jadi 2020). SRM, at the network scale, requires the assessment of resource depletion, by-product capture or utilisation, pollutants and waste on a network scale. Various regulations and legal compliance also reinforce the need for formal risk assessments including internal and independent auditing. When combined, these risk measurements create the SRM and offer insights into the effectiveness of risk mitigation practices.

2.3 | Risk Mitigation Strategy (RMS)

Effective risk management strategies are critical to achieving sustainability goals, as they help ensure business continuity, maintain production schedules and reduce environmental impact (Jum'a, Qamardin, and Muhammad 2024). By integrating sustainability into supply chain risk management, organisations can better protect their operations and contribute to long-term environmental sustainability. Formalised risk mitigation methodologies lower the impact/occurrence of known and likely failure sources by pre-empting solutions (Koutsandreas et al. 2022) but remain reliant on the skills of employees to recognise weak signs of failure and enact preventative action to protect the environment and economic sustainability (Zhang et al. 2020). Furthermore, organisations may not realise the benefits of their investments unless they establish robust plans to mitigate climate change risks (Hossain et al. 2023). Although risk-reduction strategies exist, few businesses focus on issues beyond the technology employed, ignoring their wider dependencies on stakeholders, especially the supply chain (Hajmohammad and Vachon 2016; Gouda and Saranga 2018).

This gap is reflected in the current focus on supply network resilience, which implies a heightened sensitivity to failure throughout the supply chain as a community of good practice. Network-scale practice improvements enable greater proactivity, effective real-time monitoring, timely interventions to protect the production system and environment and a common mental model for all supply chain partners (Hsu et al. 2021). A limiting factor in this process is the subjective interpretation and opinions of risks rather than objective and quantifiable assessments (e.g., regulatory requirements, potential costs and revenue) and the quality of the devised countermeasures. Under networks and high interorganisational dependency, supply chains engage stakeholders, and their feedback is necessary for an effective SRM framework and risk mitigation to occur (Cort and Gudernatch 2014). Furthermore, the incorporation of sustainable finance mechanisms such as green bonds and climate insurance has become critical in mitigating environmental risks and supporting sustainability goals in the oil and gas sector (Olagunju, Ajasa, and Laguda 2022). These strategies, integrated into SRM frameworks, can help offset the potential environmental hazards posed by oil exploration and production activities.

2.4 | Stakeholder Risk Perception (SRP)

SRP involves subjective beliefs, attitudes, judgements and feelings about hazards, danger and the acceptance of managerial/employee risk-taking within the broader social and cultural context of the firm (Flin et al. 1996). Research suggests that diverse stakeholder perceptions exist, but common cultural denominators and similarities in risk are found (Al Nahyan, Hawas, and Raza 2021; Karimi 2021). Advocates highlight the importance of stakeholder engagement in developing mutual sustainability values and language, clarity and transparency in supply chain activities and continuity and equity in long-term partnerships (Pederneiras et al. 2023). Research indicates that shareholders, investors and the community exert the most significant influence on a company's decision to disclose greenhouse gas emissions, followed by government regulators, employees, customers, suppliers, competitors, non-governmental organisations (NGOs) and the media (Chithambo et al. 2022). Effective stakeholder engagement not only mitigates risks but also generates shared value by aligning the interests of local communities, investors and companies. Collaboration with stakeholders on environmental and social issues, including public participation in environmental impact assessments, enhances resilience and facilitates more efficacious SRM (Santoro et al. 2019). Effective sustainability management requires a multistakeholder approach that addresses not only environmental risks but also the conflicting expectations of diverse stakeholders, including NGOs, local communities and companies (Dias et al. 2024). This approach fosters a more collaborative and inclusive framework for managing risks in vulnerable environments, leading to co-created sustainability-based value across networks.

Perceiving natural hazards is often seen as an 'act of God' and is intricately influenced by cultural dimensions. Such determinants may differ from those shaping the perception of technological or man-made disasters (Han, Liu, and Wu 2022). On the other hand, this implies that national culture may influence risk perceptions, with societies that are thrifty, uncertainty avoidant and hierarchical having higher risk perceptions and governance structures for businesses (Karimi and Komendantova 2017). Perceived risk affects stakeholders' decisions and actions, and differences in risk perception can lead to conflicts or opportunities to develop innovative operational management (Santoro and Zanin 2021). However, most stakeholders are still dislocated from risk management systems (Bampasidou, Kaller, and Tanger 2021). Under conditions of high market volatility, supply network partners require greater communication on risk management issues for network viability (Sato, Tse, and Tan 2020).

Previous research has utilised the 'Johari window' method to identify known business risks (Sato, Tse, and Tan 2020) and eco-sustainability risk indicators (Abdel-Basset and Mohamed 2020). However, limited exploration exists on how SRPs influence organisations and their networks in protecting against environmental failures in production process management. Reinerth, Busse, and Wagner (2019) recommend sector-specific studies, especially in austere conditions. Adekola et al. (2017) call for studies in developing countries, offering valuable insights into strained organisational management systems and a supply network perspective. This context sheds light on risk perception in developing countries and the O&G industries, revealing gaps in understanding and interactions between companies, stakeholders, TMC and OSC (Busse 2016).

2.5 | TMC

The TMC concept portrays practical, goal-oriented activities aimed at implementing a business vision that ensures the viability and sustainability of the organisation in the future (Aletaiby, Rathnasinghe, and Kulatunga 2021). Research on TMC has addressed challenges related to sustainability risk practices and found that TMC positively moderates these relationships (Wijethilake and Lama 2019) while facilitating positive practices that promote ecological sustainability (Praharsi et al. 2020). However, these studies did not address the safety commitment required to translate this positive perception into effective environmental risk management and protection within a single company or supply network (Wijethilake and Lama 2019). Concurrently, TMC has been shown to significantly influence organisational safety culture (O'Dea and Flin 2001) through behaviours and discipline enacted to address staff violations. Even a focus on total quality management or CSR has been insufficient for designing effective safety systems (Pagell and Wu 2009). Top management active participation has a critical moderating effect on sustainability adoption. Their engagement not only influences corporate strategies but also positively impacts the relationship between perceived top management beliefs and sustainability adoption levels (Gopalakrishna-Remani, Byun, and Doty 2022). By fostering active participation, firms are better positioned to integrate sustainability into their core operations, improving overall firm performance.

While TMC plays a crucial role in the level of sustainability adoption by organisations, resulting in better environmental and financial performance (Gopalakrishna-Remani, Byun, and Doty 2022), other studies demonstrate that TMC has a significant mediating influence (as an antecedent) on sustainability (Kitsis and Chen 2021). Wan Ahmad et al. (2016) found that TMC increased the transparency of sustainability-related initiatives, but this was not always sufficient to improve the organisation or its networks. To understand the rationale behind an organisation's actions or performance, it is essential to examine the characteristics of its top management, such as their experience, abilities, values, social connections and aspirations (Cannella, Finkestein, and Hambrick 2009). Recent research indicates that TMC significantly influences energy management, with the three dimensions of top management participation, support and beliefs predicting energy management positively and significantly (Arinaitwe et al. 2023). Interestingly, coercive pressure positively affects top management participation without mediating top management beliefs (Liang et al. 2007).

2.6 | OSC

A crucial aspect of ensuring a safe working environment and preventing accidents is the establishment of a robust safety culture. According to a recent study, employee perceptions of safety leadership and safety culture were found to be at a standard level. However, certain areas, such as off-the-job safety, effective communication about safety, empowering employees, setting safety standards and expectations and promoting safety improvements and sharing, necessitate enhanced management commitment and awareness development to elevate the organisation's safety culture to a foundational level (Jaroenroy et al. 2024). Strengthening the relationship between safety management systems (SMSs) and worker safety compliance is crucial for enhancing safety performance in the oil and gas sector. Recent findings indicate that effective SMS implementation fosters a more robust safety culture, thereby improving both safety behaviour and operational outcomes (Ehiaguina et al. 2024).

Conversely, Pidgeon and O'Leary (2000) argued that an organisation's safety culture comprises collective assumptions, beliefs and practices concerning risks and their management and protection processes. Norms, beliefs and values underpin this aspect of high-reliability organisations. However, the extent to which safety culture influences a sustainable risk strategy remains questionable (Manab, Aziz, and Jadi 2020). Understanding risk perceptions and workforce attitudes towards safety is crucial for cultivating a culture of high personal responsibility for operational safety and human factors engineering (Hollnagel 2014). As culture dictates what is deemed 'acceptable' workforce behaviour and shapes attitudes towards organisational learning, memory and safety prioritisation, the development and dissemination of best practices across the supply chain become crucial responsibilities for any organisation reliant on external partnerships (Clarke 1998).

Developing countries often face significant pressures to generate revenue, leading to reliance on comparatively 'dirty' industries that are at high risk of catastrophic failures and environmental damage. These industries frequently experience elevated rates of failure (Wan Ahmad et al. 2016). The root cause of such underperformance is often attributed to insufficient investment in essential areas such as equipment, maintenance, training and management competence. This insufficient investment impedes the capacity to address complex stakeholder expectations and establish the requisite psychological safety culture for effective sustainability management (Hassandoust and Johnston 2023). Consequently, the incorporation of circular economy principles into oil and gas operations, including waste reduction, recycling and resource use optimisation, represents an emerging trend towards enhancing both safety and environmental sustainability. The circular economy of safety (CES) framework mitigates operational risks and improves efficiency by minimising waste and maximising resource reuse (Tayab et al. 2024).

3 | Research Hypothesis and Conceptual Model Development

Previous research has partially explored sustainability risk assessment from a stakeholder perspective but has provided limited clarity on the antecedent variables influencing safety decisions at both the organisational and network levels, particularly in the context of 'dirty industries' in developing countries. The existing literature reveals significant opportunities to hypothesise relationships concerning stakeholder risk perception (SRP) in the implementation of sustainable and responsible practices. This includes investigating the impact of safety cultures on environmental impact assessments and exploring the role of top leadership in maintaining safety culture. Additionally, it involves advocating for stakeholder perspectives while addressing latent risks within the OM and supply network processes of firms. The authors propose a conceptual framework (Figure 1) to depict these literature-derived hypothetical relationships and developed the following set of hypotheses:

Hypothesis H1a posits that stakeholder risk perception (SRP) have a direct and positive impact on sustainability risk management (SRM) practices. This hypothesis is grounded in existing literature that underscores the importance of stakeholder perspectives in shaping risk perceptions, which in turn influence risk management practices (Al Nahyan, Hawas, and Raza 2021). Fleming et al. (1998) highlight the need for a more thorough examination of the causal relationships between risk factors and perceived risk, stressing the significance of understanding stakeholders' subjective perceptions. Additionally, Amin et al. (2017) emphasise that perceived benefits shape stakeholder attitudes, reflecting the complex interplay of factors affecting risk perception. As such, stakeholders are currently the most influential drivers of sustainability efforts (Mehregan, Chaghooshi, and Hashemi 2014).

H1a. *SRP directly and positively impacts SRM practices.*

Given the crucial importance of TMC in decision-making (Aletaiby, Rathnasinghe, and Kulatunga 2021), it is reasonable to infer that managers' risk perceptions may vary not only among different companies but also between different divisions within a single company. This variation in risk perception can necessitate adjustments to supply chain strategies in response to environmental uncertainty (Sato, Tse, and Tan 2020). As a result, the findings offer managers valuable insights into how to

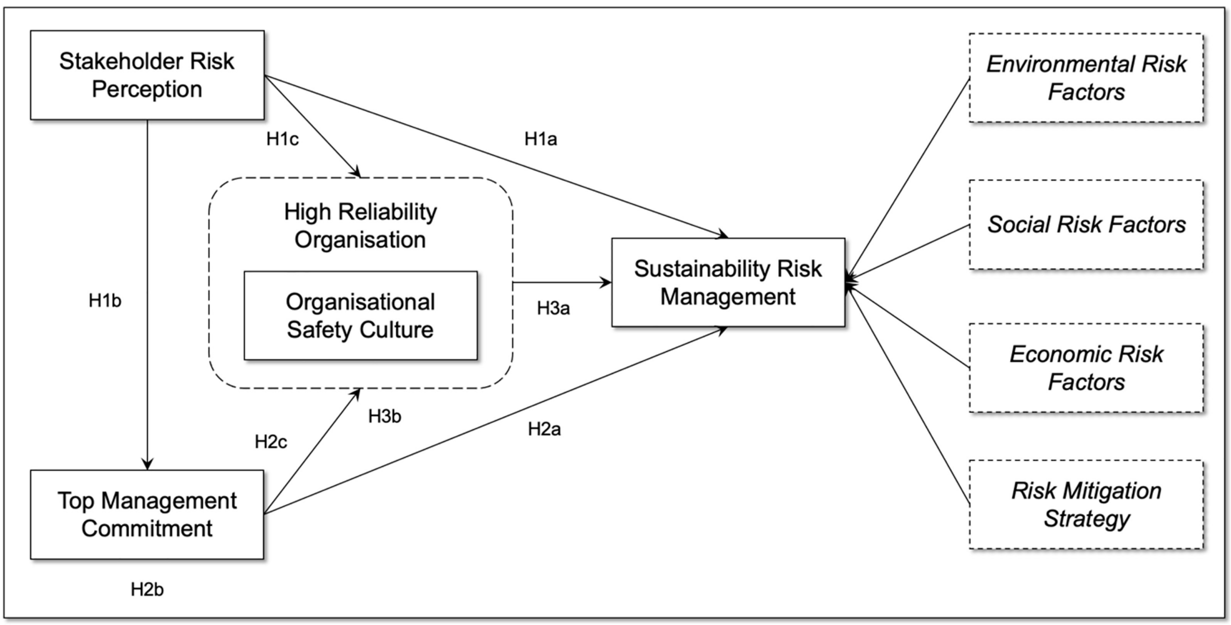

FIGURE 1 | Conceptualising sustainability risk management.

develop supply chain strategies that align with their risk perceptions. Strategic decision-making, which is influenced by these perceptions, plays a critical role in the sustainability and growth of enterprises (Wu et al. 2017). Therefore, the collective risk perception of stakeholders significantly impacts top management's commitment to addressing safety and sustainability risks.

H1b. *SRP directly and positively impacts TMC.*

It is crucial to recognise that perceptions of risk and stakeholders' concerns vary across different countries. These variations in experts' risk perceptions can be influenced by factors such as cultural orientation; stakeholders' attitudes and views; and the social, political and technical contexts of technology deployment in each country (Karimi 2021). Previous studies have underscored the impact of globalisation on the attitudes, beliefs and behaviours of diverse national workforce within the same multinational company (Mearns and Yule 2009). Additionally, research has shown that risk perception can serve as a mediator, with safety culture also mediating the relationship between safety leadership and safety performance (Wei and Kuo 2023). Consequently, it can be concluded that an organisation's safety culture may be associated with negative perceptions of management's commitment to safety.

H1c. *SRP directly and positively impacts OSC.*

TMC positively influences SRM practices (Wijethilake and Lama 2019). Previous studies have highlighted the importance of adopting a proactive approach to environmental concerns (Bhatia and Jakhar 2021), which significantly enhances sustainability efforts, particularly in terms of environmental impact (Jang 2022). Direct or proxy stakeholder engagement is reported as a key determinant in the development and operation of corporate SRM systems and represents a potential causal link to HRO performance. Top management engagement and commitment are essential for developing HRO competencies, aligning corporate strategies with the prevailing culture, and formal control processes. This leads to the following hypothesis:

H2a. *TMC directly and positively impacts SRM.*

H2b. *TMC mediates the relationship between SRP and impact on SRM.*

Umeokafor, Evangelinos, and Windapo (2022) underscored the role of leadership in promoting a positive safety culture that actively involves employees, which is critical for reducing accidents and improving operational efficiency and has been identified as a crucial determinant of a positive safety culture within an organisation. Emphasis is placed on managers demonstrating their commitment to safety and maintaining visibility in a project-based workforce (Biggs et al. 2013). Top management's commitment to safety is widely recognised as a fundamental component of an organisation's safety culture (O'Dea and Flin 2001).

H2c. *TMC directly and positively impacts OSC.*

The concept of HROs, although not explicitly highlighted in the literature, is crucial for enhancing the safety and sustainability of Nigeria's oil and gas sectors. This sector faces substantial challenges in cultivating effective safety cultures and implementing sustainable risk management practices. Otitolaiye et al. (2021) confirmed a positive correlation between safety culture and safety performance in organisations. The rise of HRO concepts in safety management has shifted focus away from bureaucracy, providing a means to manage safety without compromising performance. However, the application of these concepts outside the ultrasafe sectors in which they were initially developed has been limited (Harvey, Waterson, and Dainty 2019). OSC and the normalisation of beliefs and attitudes lead to the following hypotheses:

H3a. *OSC directly and positively impacts SRM.*

H3b. *OSC mediates the relationship between SRP and impact on SRM.*

From an economic perspective, fostering a strong safety culture can reduce the frequency of costly accidents, thereby lowering operational risk and enhancing productivity. However, despite the significant contribution of the oil and gas sector to Nigeria's gross domestic product (GDP), the industry continues to be plagued by frequent accidents (Olaniran and Akinbile 2023). These accidents not only disrupt economic activities, but also result in environmental degradation, which threatens long-term sustainability. Furthermore, significant disparities exist in how global oil and gas companies emphasise sustainability in their supply chains. Okeke (2021) notes that firms in Asia and America lag behind in addressing all three dimensions of sustainability—economic, environmental and social—in their supply chain management. This imbalance creates risks that could translate into increased costs, reduced competitiveness and long-term reputational damage in the long run.

In conclusion, enhancing safety and sustainability in Nigeria's oil and gas sector requires a multifaceted approach. Developing strong safety cultures, implementing robust risk management frameworks and adopting HRO principles are key strategies for reducing operational risks and improving economic performance and sustainability in the sector. In this study, a SRM model was developed that incorporates seven primary constructs: stakeholders' risk perception, OSC, TMC, environmental risk factors, social risk factors, economic risk factors and risk mitigation strategies. Additionally, a secondary construct, the risk management system, was developed to identify SRM practices and examine the effects of TMC and OSC on the adoption of these practices. This model is illustrated in Figure 1.

4 | Research Methodology and Data Analysis

4.1 | Descriptive Analysis

A comprehensive survey questionnaire was developed based on an extensive literature review and expert consultation. The questionnaire included Likert-scale items designed to evaluate stakeholders' perceptions of economic, environmental and social risks. The initial version of the survey was pilot tested with a small group of expert stakeholders to assess its clarity, comprehensiveness and reliability. Feedback from these pilot participants was used to refine the instrument. Following pilot testing, the final survey was distributed to the selected stakeholders via online Qualtrics surveys shared on LinkedIn. This approach aimed to ensure a representative sample while maintaining diversity across stakeholder groups. A broad, non-discriminatory snowball sampling technique was employed to capture a wide range of internal and external stakeholders across oil and gas supply chains. This includes participants from various companies within the value chain. LinkedIn was used strategically to access hard-to-reach professionals with specialised knowledge of Nigeria's oil and gas sector. Respondents were encouraged to forward the survey to their colleagues, further broadening the participant pool through a snowball effect. While the survey targeted specific industry demographics, efforts were made to maintain a representative sample that reflected the wider population.

In line with previous studies on the oil and gas industry (e.g., Giannakis and Papadopoulos 2016; Wan Ahmad et al. 2016; Gardas et al. 2019), the final sample size of 441 fully completed responses was statistically robust to address the objectives of the study. Of the 732 responses collected between December 2021 and March 2022, 39.8% were excluded due to incompleteness, duplication or anomalies. To ensure data integrity, only fully completed surveys were analysed. In addition, the response patterns were thoroughly examined to identify and remove biased or inconsistent responses. A randomisation technique embedded in the questionnaire design further mitigated response bias by varying the order of questions for each participant. These measures enhance the validity and reliability of the data and provide a robust foundation for subsequent analysis.

Quantitative data analysis techniques, including descriptive statistics, frequency distribution and correlation analysis, were employed to analyse stakeholder responses. This analysis revealed patterns, trends and disparities in risk perception among different stakeholder groups and project contexts. The quantitative assessment of stakeholder risk perception offers valuable insights into identifying key risk factors. This study collected perceptions from 441 businesses within the O&G sector, including O&G marketers, independent petroleum marketers and O&G government organisations. Participants were selected based on verified accounts from relevant platforms (see Table 1). The analysis specifically focuses on internal and external stakeholders within the Nigerian O&G supply chain. A research questionnaire was developed, validated and administered to professionals in Nigeria's O&G supply chain. The O&G sector was chosen as the operational context, and Nigeria was selected as the developing-country context because of the accessibility of the data. A pilot survey confirmed the presence of critical risk factors for sustainability. The questionnaire covered stakeholder demographics, antecedent variables of stakeholder risk perception, sustainability risk factors and risk mitigation strategies.

Table 1 provides a comprehensive overview of the demographics, educational backgrounds, professional experiences and stakeholder roles of individuals in Nigeria's oil and gas sector. The majority of the respondents (74.8%) were male, while 25.2% were female. This gender imbalance is expected in a male-dominated oil and gas industry. The age distribution of respondents was as follows: the largest group, comprising 34.7% of respondents, was between 35 and 44 years. Age groups 25–34 and 45–54 years also had substantial representation, accounting for 25.5% and 21.2% of respondents, respectively. The youngest age group, 18–24 years, accounted for 16.3% of the sample, while older age groups had lower representation. A significant number of respondents (50.6%) had attained at least a university degree or higher, with 40.6% having a postgraduate education. Only 4.1% obtained a doctoral-level qualification. The majority (39.7%) had less than 5 years of professional experience. The other experience categories were evenly distributed.

The stakeholders included oil and gas employees, government regulators, private business shareholders/owners/managers, NGOs/civil society organisations, suppliers/contractors/distributors, media/academic researchers and professional organisations. The largest group was oil and gas employees, accounting for 46.7% of respondents, followed by medium-sized companies (42.4%) and wholesale oil and gas customers (11.3%). The survey was mostly completed by employees of medium (42.4%) and large (23.8%) companies, with a smaller representation from very large international firms (16.1%). Government-owned and other designated companies were also included, although to a lesser extent. This table provides valuable insights into the demographics, education, experience, roles and size of Nigerian oil and gas companies. These insights can inform discussions and strategies related to safety culture and SRM in the industry.

An initial risk assessment exercise was conducted using a failure mode effect analysis (FMEA) process, which involved consulting experts to assess the perceived sustainability risks in the O&G supply chain. The FMEA process entails evaluating the severity, frequency and detectability of potential failure modes, in addition to devising preventive measures that can be implemented by managers to minimise or eliminate risk effects. This highly systematic and structured approach is well suited for engaging multiple stakeholders in risk management. Scores were allocated by informants to depict the severity and frequency of an identified source of failure, which were then compared among the different tiers of stakeholders to determine whether there were any significant differences in the patterns. This study found that stakeholders perceived economic risk factors (SRM6 and SRM8) to be more severe than other factors, whereas SRM2, SRM9 and SRM4 were perceived to be the least sustainable risk factors (Table 2).

Table 2 provides a comprehensive overview of several crucial constructs pertaining to safety culture and SRM in Nigeria's oil and gas sector. OSC1–OSC8 represent various items or dimensions that assess different aspects of OSC. Table 2 features factor loadings, variance inflation factors (VIFs), Cronbach's alpha, composite reliability and average variance extracted (AVE) for each item. SRM1–SRM3, SRM4–SRM6 and SRM7–SRM9 represent distinct items or dimensions that assess environmental, social and economic risks within the sector, respectively. SRP1, SRP4 and SRP5 represent various items or dimensions that assess stakeholder risk perception. TMC1–TMC5 represent different items or dimensions that assess the commitment of top management. In aggregate, Table 2 presents a structured and detailed analysis of multiple constructs related to safety culture and SRM in Nigeria's oil and gas sector. The incorporation of reliability and validity measures adds rigour to the assessment, making it valuable for comprehending the complexities and

TABLE 1 | Distribution of survey respondents in O&G.

Demographics		Frequency	Percent
Gender	Male	330	74.8
	Female	111	25.2
Age range	18–24 years	72	16.3
	25–34 years	127	28.8
	35–44 years	153	34.7
	45–54 years	65	14.7
	55–64 years	16	3.6
	Above 65 years	8	1.8
Education level	Not more than secondary/technical education	21	4.8
	University graduate/higher national diploma	223	50.6
	Post graduate education MSc, MBA	179	40.6
	Doctoral level and above, PhD	18	4.1
Experience	Less than 5 years	175	39.7
	5–10 years	101	22.9
	11–15 years	101	22.9
	16–20 years	33	7.5
	More than 20 years	31	7
Stakeholder	Oil and gas wholesale customer	50	11.3
	Oil and gas employee	206	46.7
	Private business shareholder/owner/manager	59	13.4
	Government regulator	21	4.8
	Non-governmental organisation/civil society organisation	23	5.2
	Supplier/contractors/distributor	28	6.3
	Media/academic research, professional organisations	54	12.2
	Medium size (50–249)	187	42.4
	Large company (250–1000)	105	23.8
Company size	Very large (international above 1000)	71	16.1
	Government owned	58	13.2
	Others specific	20	4.5

nuances of these constructs within the industry. These insights can support organisations in developing effective strategies to enhance safety cultures and effectively manage sustainability risks.

Bivariate correlation analysis was conducted to assess sustainability risks and identify potential mitigation strategies (see Table S1). Positive correlations between the two risks indicate that they can be reduced simultaneously, whereas negative correlations suggest that one risk may have an opposite impact on the other. The results show statistically significant correlations between weak and medium risks across all factors examined in the Table S1. Factor and principal component analyses followed by varimax rotation were conducted on the data. The Kaiser–Meyer–Olkin measure of sample adequacy was 0.846, and the test reduced all variables into seven independent and parsimonious factors with eigenvalues greater than 1.0, explaining 62.52% of the total variance. The first latent variable explained nearly 20.4% of the total variance and ensured that a common method bias was not present. All factors contained interpretable variables.

Subsequently, structural equation modelling (SEM) using partial least square SEM (PLS-SEM) software v3 was employed because it permits the unrestricted computation of cause-effect relationship models of reflective and formative measurement approaches (Ringle and Sarstedt 2016). These quantitative methods ascertained the psychological factors influencing sustainability

TABLE 2 | Sustainability risk indicator (severity and frequency).

Sustainability risk factors	Overall (S*F)	1	2	3	4	5	6
Man-made disaster (SRM1)	10.81	11.43	10.85	10.31	12.82	13.80	11.38
Natural disasters (SRM1)	8.30	9.57	8.28	7.17	8.34	9.40	8.18
Waste management, energy consumption (SRM3)	9.64	11.37	9.49	8.83	10.27	11.10	9.78
Discrimination and unethical activities (SRM4)	8.10	9.77	7.90	8.51	8.87	9.00	8.56
Unhealthy and unsafe work (SRM5)	10.91	11.40	11.41	10.56	11.60	12.30	11.26
Unfair wages, excessive working hours and work–life balance (SRM6)	11.52	12.33	11.90	12.13	11.58	13.40	11.98
Volatility of product prices, exchange rates, inflation, subsidies and taxes (SRM7)	10.81	11.60	10.53	9.78	11.39	12.70	10.75
Bribery, false claims and corruption (SRM8)	10.40	11.03	10.85	9.76	10.34	13.30	10.54
Industrial action, strikes and boycotts (SRM9)	9.67	11.73	9.34	8.71	10.15	12.70	9.77

Note: S = severity, F = frequency, D = detection ease, SRM = risk priority number: 1 = top management, 2 = middle management, 3 = Supervisor, 4 = operator, 5 = others, 6 = overall.

risk attitudes and the mediating effect of TMC and OSC among companies operating in the O&G sector. The data collection phase spanned 3 months, and a snowballing technique was employed to encourage informants to introduce other professionals. This sampling method was effective in generating a critical mass of participants within a given period. The Harman single-factor statistical method was used to detect any potential common method bias, along with variables with eigenvalues greater than 1. By subjecting all scale items to exploratory factorial analysis and analysing the unrotated factor solution, the study was able to explain the total variance of the study, with no evidence of common method bias. Of the 45 items, the sum of the squared variance was 13.7%, confirming the absence of a common method bias.

4.2 | Confirmatory Factor Analysis

PLS-SEM was selected because when dealing with a complex structural model involving numerous constructs, indicators or model relationships, including formatively measured constructs, distribution issues, such as lack of normality, are of concern (Shiau, Sarstedt, and Hair 2019). This study used PLS-SEM to derive both reflective and formative constructs (Hair, Ringle, and Sarstedt 2013). The lower order construct of SRM includes economic, social and environmental risk factors and risk mitigation strategies for each factor. This study combined lower order components using a disjoint two-stage approach and used latent variable scores as indicators for the higher order construct. The measurement model was validated, with factor loadings below 0.6, VIF values below 3.3, Cronbach's alpha greater than 0.6 and AVE and composite reliability figures within the expected ranges. However, the formative constructs were reviewed separately, and the reliability of the variables was tested using Cronbach's alpha and composite reliability. Items with low factor loadings were eliminated to improve the model (Table 3).

Discriminate validity was conducted to test the uniqueness and independence of the measurement and the differences between them using the Fornell and Larcker and the heterotrait–monotrait method (HTMT) criteria (Table 4). The discriminant values were measured using the AVE square root of each measurement factor and factor and were greater than the latent variable correlations between that factor and other factors, indicating the discrimination and reliability of the factors.

4.3 | Check for Robustness

Robustness checks were performed to address issues such as non-normality, endogeneity, unobserved heterogeneity, nonlinearity and heteroscedasticity (Vaithilingam et al. 2024). To address endogeneity and enhance awareness of how to manage this issue, this study introduced a systematic procedure that incorporates control variables, instrumental variables and Gaussian copulas into a PLS-SEM framework (Thomas et al. 2018). This procedure aims to identify and mitigate endogeneity issues within SEM frameworks with a specific focus on PLS-SEM (Sarstedt et al. 2020). By translating these variables into the PLS-SEM framework, the study contributes to a deeper understanding of how to address this methodological challenge.

Initially, we examined the quadratic effect to verify the assumptions regarding linearity, as detailed in Table 4. The results indicate a generally linear relationship, except for the impact of TMC on SRM, which did not follow a linear pattern. This suggests that a nonlinear model may explain this

TABLE 3 | Reflective measurement model using confirmatory compositive analysis.

First-order construct	Items	Factor	VIF	Cronbach's alpha	Composite reliability	AVE
Organisational safety culture	OSC1	1.67	1.64	0.861	0.892	0.509
	OSC2	1.63	1.61			
	OSC3	1.42	1.41			
	OSC4	1.67	1.7			
	OSC5	1.66	1.81			
	OSC6	1.95	1.9			
	OSC7	2.1	2.06			
	OSC8	1.84	1.92			
Environmental risk	SRM1	1.66	1.61	0.779	0.87	0.69
	SRM2	1.65	1.69			
	SRM3	1.54	1.53			
Social risk	SRM4	1.49	1.46	0.753	0.842	0.644
	SRM5	1.8	1.68			
	SRM6	1.47	1.37			
Economic risk	SRM7	1.65	1.72	0.806	0.884	0.718
	SRM8	1.88	1.91			
	SRM9	1.76	1.84			
Stakeholder risk perception	SRP1	1.34	1.29	0.687	0.827	0.615
	SRP4	1.41	1.36			
	SRP5	1.29	1.25			
Top management commitment	TMC1	1.54	1.61	0.841	0.887	0.612
	TMC2	1.77	1.76			
	TMC3	2	1.97			
	TMC4	1.98	1.98			
	TMC5	1.75	1.76			

relationship better. Potential issues contributing to this could include omitted variable bias, simultaneity, measurement error or common method bias. In contrast, the nonsignificant interaction term supports the robustness of the linear effect. Regarding the quadratic effect, bootstrapping with 5000 samples and no sign changes revealed that none of the nonlinear effects were significant (see Table 5). Therefore, we conclude that the linear effects model is robust.

Subsequently, an endogeneity test was performed to assess whether the predictor construct not only explains the dependent construct but also its error term, utilising the Gaussian copula approach. This test focused on latent variables identified as sources of endogeneity within the original model (Sarstedt et al. 2020). To address potential endogeneity issues, we employed instrumental variable techniques and SEM approaches. This involved identifying and controlling for confounding variables that could bias our estimates and introducing instrumental variables to mitigate endogeneity concerns. We assessed single relationships within the model up to a maximum of seven. The results indicate that none of the *p* values fell below 0.05; instead, they ranged from 0.05 to 0.916. Consequently, we can conclude that the linear effect is robust.

Additionally, we conducted a check for unobserved heterogeneity to ensure that unobserved heterogeneity does not occur when subgroups within the data exhibit significantly different model estimates. If unobserved heterogeneity is present, estimating the model using the entire dataset could produce misleading results because substantial differences between subgroups could lead to incorrect conclusions (Sarstedt, Ringle, and Hair 2017). To address this, we used Fimix-PLS, a systematic approach for identifying and addressing unobserved heterogeneity within PLS models (Sarstedt, Ringle, and Hair 2017). We began by assuming a one-segment solution with the following default settings: stop criterion (1.0E10), maximum number of iterations (5000) and

TABLE 4 | Fornell and Larcker and the heterotrait–monotrait method (HTMT).

	1	2	3	4	5	6
1. OSC	0.713					
2. ENV	0.266	0.831				
3. SCO	0.192	0.648	0.802			
4. ECO	0.141	0.644	0.684	0.848		
5. SRP	0.470	0.226	0.218	0.159	0.784	
6. TMC	0.541	0.215	0.171	0.135	0.496	0.782
1. OSC						
2. ENV	0.322					
3. SCO	0.208	0.890				
4. ECO	0.164	0.817	0.890			
5. SRP	0.610	0.302	0.261	0.212		
6. TMC	0.627	0.256	0.181	0.162	0.646	

TABLE 5 | Quadratic effect.

	Original sample (O)	Standard deviation	*T* statistics	*p*
QE (SRP) t OSC	0.046	0.03	1.538	0.124
QE (SRP) ⟶ SRM	0.036	0.035	1.038	0.299
QE (SRP) ⟶ TMC	0.032	0.043	0.738	0.46
QE (TMC) ⟶ OSC	−0.009	0.034	0.269	0.788
QE (TMC) ⟶ SRM	0.076	0.037	2.063	0.039*
QE (OSC) ⟶ SRM	0.004	0.036	0.102	0.919

number of repetitions (10). First, we computed the minimum sample size required for each segment to determine the maximum number of segments to be extracted. With a sample size exceeding 400, which meets the common recommendations for social and business science research, we created five segments, each with a minimum sample size of 85.

The results of the post hoc power analysis, assuming an effect size of 0.15 and a power level of 80%, suggest that the fit indices for solutions ranging from one to five segments present an ambiguous picture. Both AIC3 and CAIC indicate similar findings, while MDL5 suggests a one-segment solution, and AIC and EN point towards a four-segment solution. Consequently, we were unable to produce any form of segmentation based on our results because the metrics point to more than one-segment solution produce divergent results, researchers can conclude that unobserved heterogeneity does not significantly affect the data.

4.4 | Reflective Formative Model

The selection of the measurement perspective has implications for the derived coordination measure as it affects content, parsimony and criterion validity, as stated by Diamantopoulos and Siguaw (2006). In this study, the path model incorporates the SRM construct as a formative scale, which necessitates the evaluation of the VIF values and the significance of all items before proceeding to the structural model assessment. Therefore, validating the higher order construct involved a significant outer weight, which resulted in only one insignificant result for RSM1, with a *p* value that was insignificant for both outer weight and loading. Further examination of the outer loading revealed that it remained insignificant despite being theoretically relevant and not impacting the formative construct. Additionally, the VIF values were assessed to check for collinearity; however, all VIFs values were less than 5.

The structural model displayed the relationships between the constructs in the model developed for this study. All hypotheses from the construct are supported through the data analysis of stakeholders in oil and gas corporations with *t* values greater than 1.96 at a 5% level of significance (see Table 6). The table presented in the text displays the regression coefficients (β), standard deviations (STD), *t* values (T), *p* values (p) and confidence intervals (2.5th and 97.5th percentiles) for each hypothesis (H), labelled as H1a, H1b, H1c, H2a, H2c and H3a. These hypotheses examine the associations between various constructs in the model, such as OSC, stakeholder risk perception (SRP), TMC and SRM. The results demonstrate that each hypothesis is supported based on statistical significance.

TABLE 6 | Fit indices for one- to four-segment solutions.

Criteria	1	2	3	4
AIC (Akaike's information criterion)	3351.539	3296.715	3300.055	**3280.188**
AIC3 (modified AIC with Factor 3)	3360.539	**3315.715**	3329.055	3319.188
AIC4 (modified AIC with Factor 4)	3369.539	**3334.715**	3358.055	3358.188
BIC (Bayesian information criterion)	3388.34	**3374.407**	3418.638	3439.661
CAIC (consistent AIC)	3397.34	**3393.407**	3447.638	3478.661
MDL5 (minimum description length with Factor 5)	**3607.546**	3837.174	4124.967	4389.552
EN (normed entropy statistic)	0	0.358	0.292	**0.588**

Note: The table compares fit indices for one to four segments. Lower AIC-family values favor the four-segment solution, while stricter BIC and CAIC penalties suggest two segments as optimal. Normed entropy (EN) improves with more segments, peaking at 4 (0.588), indicating clearer separation.

TABLE 7 | Structural model result.

		β	STD	T	p	2.5	97.5	
H3a	OSC ⟶ SRM	0.192	0.064	2.979	0.003	0.072	0.324	Supported
H1a	SRP ⟶ SRM	0.127	0.059	2.145	0.032	0.023	0.255	Supported
H1c	SRP ⟶ OSC	0.265	0.047	5.589		0.179	0.365	Supported
H1b	SRP ⟶ TMC	0.498	0.047	10.690		0.408	0.589	Supported
H2a	TMC ⟶ SRM	0.240	0.062	3.863		0.123	0.367	Supported
H2c	TMC ⟶ OSC	0.412	0.049	8.426		0.311	0.502	Supported

	R^2 value	Q^2 value	SRMR	NFI
OSC	0.347	0.165	0.053	0.827
SRM	0.214	0.021		
TMC	0.247	0.144		

For example, H3a examines the connection between OSC and SRM. A coefficient (β) of 0.192 suggests a positive relationship between OSC and SRM. A t value of 2.979, with a p value of 0.003, indicates that this relationship is statistically significant, thereby supporting H3a. Similar interpretations can be made for the remaining hypotheses. The table also includes model fit statistics, including R-squared (R^2) values, Q^2 values, standardised root mean square residual (SRMR) and normed fit index (NFI). The R^2 values for OSC, SRM and TMC indicate the proportion of variance explained by the predictors in each construct. The Q^2 values offer insight into the predictive performance of the model. SRMR values close to zero indicate a good fit between the model and data, whereas NFI values close to 1 suggest a good fit between the model and data.

Overall, Table 7 provides a comprehensive analysis of the relationships between different constructs in the context of safety cultures and SRM in the Nigerian oil and gas sector, along with the model fit statistics. These results can inform further research and guide organisational strategies for enhancing safety cultures and effectively managing sustainability risks in the industry.

PLS-SEM does not assume normally distributed data, and the parametric significance tests used in regression analysis cannot be applied to test whether loadings are significant. Instead, nonparametric bootstrap procedures were used. This study used a 5000 subsample to estimate the statistically significant relationship of the model and generated 97.5 confidence intervals. The results indicate the significance of all relationships in the model. Prior literature examining sustainability risk does not offer links to antecedent variables (Abdel-Basset and Mohamed 2020). The hypotheses were tested, and the size and significance of the path coefficient, R^2 (0.214), for the endogenous variables, predictive relevance Q^2 and model fit were determined using a structural model.

H1a evaluated whether SRP has a significant impact on SRM and revealed that SRP significantly affects SRM ($\beta = 0.127$, $T = 2.145$, $p = 0.032$), and the hypothesis was duly accepted. H1b and H1c evaluated whether SRP significantly impacts OSC and TMC. The results indicated that SRP had a significant impact on OSC ($\beta = 0.265$, $T = 5.59$, $p < 0.001$) and TMC ($\beta = 0.498$, $T = 10.690$, $p < 0.001$). The study concludes that SRP directly and positively impacts TMC and OSC. Furthermore, H2a and H2c evaluated whether TMC had a significant positive impact on SRM ($\beta = 0.240$, $T = 3.863$, $p < 0.001$) and OSC ($\beta = 0.412$, $T = 8.426$, $p > 0.001$), and this hypothesis was supported. However, H3a evaluated whether OSC had a significant impact on SRM and found that it also had a significant impact on SRM ($\beta = 0.192$, $T = 2.979$, $p = 0.003$). All the values of these measurements were within the criteria suitable for the model. Subsequently, complementary PLS-SEM analyses were used to understand any mediators, multigroup analysis and importance-performance analyses from the original PLS path model (Figure 2).

4.5 | Mediation Analysis

H2b and H3b proposed a crucial mediation relationship of TMC and OSC respectively between SRP and SRM to be investigated using primary data. Mediation analysis involves a two-step process: investigating the specific indirect effect of the independent variable on the dependent variable through the mediator (if significant), followed by a direct effect assessment between the dependent and independent variables (Jha et al. 2023). The mediating role must meet four requirements: (1) The independent variable and dependent variable must be significantly correlated, (2) the independent variable and hypothesised mediator must also be significantly correlated, (3) the mediator and dependent variable must be significantly correlated when the effects of the independent variable are controlled and (4) the mediated effect must be statistically significant (Yang, Adams, and Yapa 2013).

Mediation and conditional process analyses have become popular approaches for examining the mechanisms by which effects operate and the factors influencing those. Mediation analysis was conducted to assess the mediating role of TMC and OSC, revealing a significant ($p < 0.001$) mediating role of TMC ($\beta = 0.205$, $T = 8.239$, $p < 0.001$) and OSC ($\beta = 0.210$, $T = 6.484$, $p < 0.001$) between SRP but only a partial account for SRM (Table 8). The mediating effect through the indirect path of TMC-SRM ($\beta = 0.079$, $T = 2.762$, $p = 0.006$) showed no mediation effect. Table 8 shows that the relationship between SRP and SRM is partially mediated by the TMC and OSC in the model. There is a relationship between SRP and SRM in the absence of TMC and OSC, but as soon as they are introduced in the research model (in the Nigerian context only), the relationship between SRP and SRM vanishes.

4.6 | Multigroup Analysis

To gain deeper insight into industry-wide stakeholder studies, a multigroup analysis was performed as a final analytical stage which explored any significant differences between internal and external SRP and its influence on SRM. The parametric test findings (Table 9) reveal major differences when comparing the critical hypotheses except the SRP ⟶ SRM ($p = 0.577$, $T = 0.559$, $\beta = 0.068$). Examining the result path coefficient shows a high difference in the safety culture for internal and external stakeholders (OSC ⟶ SRM). Table 9 shows that there is a significant difference between TMC and OSC between these groups. The difference between major stakeholder groups (internal and external) using the parametric test revealed further details regarding the significant differences in the impact of perceived TMC on OSC in terms of sustainability risk, which was significant at 0.002 (Table 9).

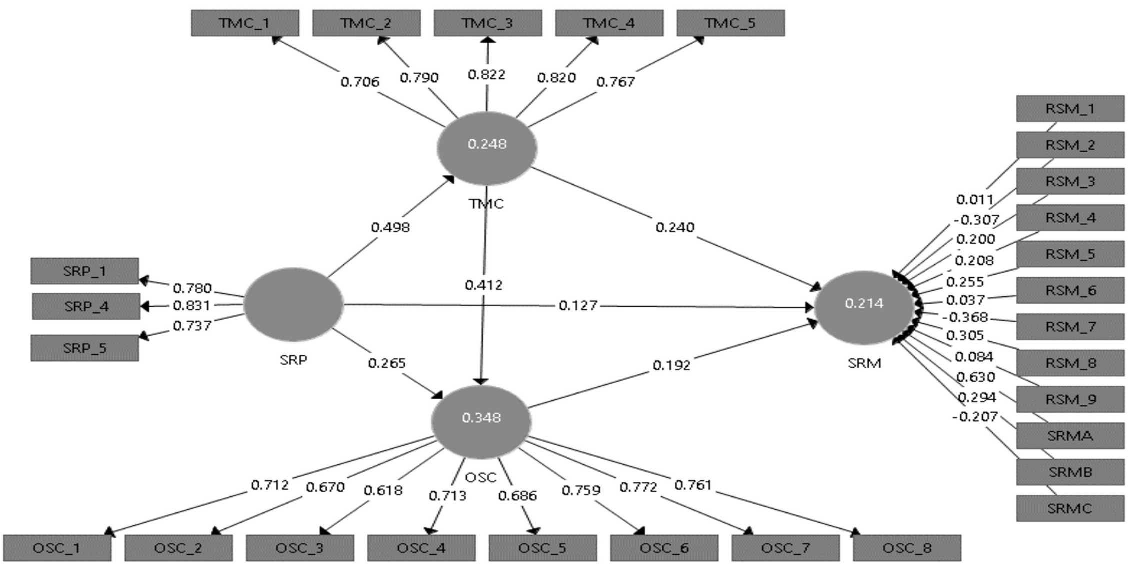

FIGURE 2 | PLS analysis.

TABLE 8 | Mediation effect.

	β	T	Sig		Effect	T	Sig
SRP ⟶ OSC	0.470	10.953		SRP ⟶ OSC	0.205	8.239	
SRP ⟶ SRM	0.337	7.191		SRP ⟶ SRM	0.210	6.484	
TMC ⟶ SRM	0.319	5.960		TMC ⟶ SRM	0.079	2.762	0.006

TABLE 9 | Path coefficients for structural model for difference stakeholder groups and parametric testing.

	Internal stakeholder			External stakeholder			Parametric testing		
	β	T	p	β	T	p	β	T	p
OSC ⟶ SRM	0.16	1.85	0.07	0.24	2.08	0.04	0.08	0.59	0.56
SRP ⟶ OSC	0.22	3.84	0.00	0.36	4.02	0.00	0.14	1.33	0.19
SRP ⟶ SRM	0.15	2.06	0.04	0.07	0.56	0.58	0.08	0.60	0.55
SRP ⟶ TMC	0.42	6.80	0.00	0.58	8.36	0.00	0.16	1.66	0.10
TMC ⟶ OSC	0.52	9.87	0.00	0.21	2.17	0.03	0.31	3.06	0.00
TMC ⟶ SRM	0.27	3.10	0.00	0.28	2.60	0.01	0.01	0.05	0.96

TABLE 10 | Importance-performance results.

	Index values	Performances
OSC	3.71	67.80
SRM	1.42	48.77
SRP	3.50	62.37
TMC	3.42	60.48

4.7 | Importance-Performance Map Analysis (IPMA)

IPMA values (Table 8) combine PLS-SEM estimates to indicate the importance of an exogenous construction influencing another endogenous construction (thus improving decision-making). The analysis revealed that OSC has high performance and importance compared to SRP and TMC. From the analysis, OSC had the highest performance and importance, compared to SRP and TMC, at 67.8%. Table 10 presents the importance-performance results for different factors, including OSC, SRM, SRP and TMC. The 'Index values' column indicates the importance of each factor based on certain criteria, while the 'Performances' column indicates the performance level of each factor. OSC has the highest importance index value of 3.71 and a performance level of 67.80. SRM has a lower importance index value of 1.42 but a performance level of 48.77. SRP and TMC also show varying importance index values and performance levels. Overall, these tables provide detailed insights into the mediation effects, path coefficients and importance-performance results of various factors within the research model, contributing to a deeper understanding of the dynamics within the Nigerian oil and gas sector regarding safety culture and SRM.

5 | Discussion

The O&G sector, a key player in the global energy system, faces critical sustainability challenges (Tamala et al. 2022). Catastrophic industry incidents have caused severe financial losses, environmental degradation and health risks (Lai, Shad, and Shah 2021), underscoring the need for robust SRM frameworks in high-risk industries, such as O&G. However, many companies, particularly in sub-Saharan Africa, struggle to identify and manage these risks effectively (Schulte and Hallstedt 2017). This highlights the urgent need for improved SRM practices, particularly given the limited academic focus on petroleum-related incidents and their economic and environmental consequences in these regions (Carlson et al. 2015). This study investigates stakeholder perceptions of sustainability-related risks within the O&G supply chain, addressing a critical research gap, especially in developing countries. A deeper understanding of these perceptions can enhance environmental performance and improve organisational disclosure practices. The research is grounded in HRO theory, which advocates for adaptive, multilayered and holistic approaches to managing complex organisations (Peters et al. 2023). By evaluating TMC and safety culture, this study seeks to expand our understanding of how environmental management tools can effectively mitigate sustainability risks in the O&G sector.

Understanding stakeholder perceptions and management commitment is crucial for informing governance structures and green finance initiatives within organisations. This understanding facilitates effective integration of sustainability into business strategies. The findings of this research provide guidance for businesses on how to respond effectively to climate change risks within the oil and gas industry, aligning with broader objectives of addressing contemporary environmental challenges. Overall, this research offers valuable insights into how organisations can strategically manage sustainability risks within the oil and gas supply chain.

Organisational resilience and risk management are critical areas of focus in the academic literature on high-performance and HROs, particularly in sectors such as the oligopolistic oil and gas industry, which is characterised by tight coupling and high interdependence. An effective SRM assessment model is essential for examining risks within the supply network, including those arising from market dynamism, environmental uncertainty, reputational and commercial damage due to catastrophic operational failures and potential environmental harm. TMC and the development of a robust OSC face significant challenges under these conditions. To mitigate trade-offs between profit and sustainability, it is crucial to maintain a strong commitment to environmental protection. Organisations that foster a strong safety culture and engage in proactive risk identification are better equipped to address potential failures and maintain resilience. Previous research indicates that supply network priorities may differ, suggesting that risk assessment models are not uniformly applied across all staff and organisations. This inconsistency can undermine the development of a cohesive safety culture that encourages proactive risk management.

A review of the findings through the lens of Reason's Swiss Cheese Model indicates that variations in risk perception are to be expected, reflecting differences across organisations and their hierarchical and structural levels. The model highlights how prioritisation of gaps, or 'holes', at various organisational strata demonstrates contingent prioritisation. These findings align with Reason's advocacy for localised analysis of risks at each operational management stage, across different levels of management and between organisations within the supply network. Specifically, the prioritisation of social and natural factors by the operator class may be influenced by their proximity to events, underscoring the importance of addressing risk perceptions at multiple levels within the organisation.

The utility of the FMEA method for risk assessment in SRM has been well-established through research, demonstrating its effectiveness in developing practical approaches to mitigate risks within the operational management subsystem. This conclusion is supported by experts who suggest that managers and industry professionals can adapt FMEA to various industries to ensure long-term sustainability of supply chain performance (Valinejad and Rahmani 2018). The criteria proposed for the research model are not tied to a specific method. Instead, the study's findings reveal that antecedent variables such as organisational safety culture and TMC significantly influence SRM within the oil and gas supply chain. The primary focus of the research model is on extracting key performance indicators from systematic literature.

This study seeks to enhance understanding of how stakeholders in the oil and gas sector perceive risks related to long-term sustainability. This research identified TMC and OSC as crucial mediators of SRM. Effective risk management relies on accurately perceiving risks, measuring identified risk factors and implementing a well-designed RMS. While stakeholders' risk perceptions can improve SRM and TMC, top management's commitment is essential for translating both external and internal pressures into innovative and effective risk mitigation practices. Despite this commitment, the impact of the organisation's safety culture on managing sustainability risks remains limited. This suggests that substantial progress can be achieved only if risk assessment and stakeholder participation are more deeply integrated throughout the organisation. Additionally, the FMEA process is suboptimised due to insufficient internal stakeholder engagement. The lack of enabling forces and practices undermines nearly all five principles of a high-reliability organisation (Wijethilake and Lama 2019; Kitsis and Chen 2021).

The R^2 value accounts for 21.4% of the SRM, and the model results of SRMR = 0.053 and NFI = 0.827 indicate that the model fits well with the observed reality. However, the mediating effect of top management and OSC is only partially effective for SRM. This finding is noteworthy given the high incidence of O&G catastrophic events, which are a cause of concern for stakeholders. Our study reveals that TMC significantly affects an organisation's safety culture. However, it has no effect on the management of the risks associated with long-term sustainability. This finding contradicts the dominant view and supports the findings of recent studies by Kitsis and Chen (2021) and Wijethilake and Lama (2019). The comparative analysis of multiple groups of internal and external stakeholders revealed some significant differences in the networks' OSCs. The findings show no significant differences except for the relationship between SRP and SRM for O&G stakeholder perceptions. More specifically, the results of our analyses indicate that the impact of SRP on the sector's OSC is significant. This may be because more organisations are engaged in internationalisation activities that may indicate disregard for activities further down the value chain.

The current academic focus on upstream network partners (Sueyoshi and Wang 2014) represents a significant shortcoming, as it overlooks the downstream organisations that are most vulnerable to economic failure. This narrow focus neglects the engagement needed for effective risk perception management in downstream operations, which are closer to the consumer and heavily impacted by disruptions in the supply network, including potential brand damage. Enhancing collaboration and prioritisation across the supply chain, particularly through initiatives led by the purchasing departments of downstream organisations, could drive meaningful improvements throughout the entire supply chain. Adopting a systems approach for supply chain network resilience and enhancement is crucial for achieving these improvements.

The PLS model reveals that an organisation's safety culture has a minimal direct impact on the SRM. This finding underscores the pivotal role of top management's commitment to successfully implement SRM practices. For O&G supply chain firms, the SRM's effectiveness is closely tied to the dedication of top leadership. In light of this, it is crucial for top management to reconsider how safety culture is designed by increasing employee awareness and knowledge of sustainability practices. This conclusion is consistent with prior research emphasising the importance of sustainability management (Wijethilake and Lama 2019; Kitsis and Chen 2021). A cultural shift within the organisation is required to implement effective safety and sustainability practices. Training programmes focused on sustainable practices enhance employees' understanding of these initiatives, promoting greater engagement and alignment with the organisation's sustainability goals. This engagement not only boosts morale but also fosters a sustainability-oriented work culture that prioritises health and safety. Over time, such cultural transformation strengthens operational success and resilience, as employees internalise sustainability objectives and contribute to continuous improvement.

Amidst global sustainability challenges, organisations must integrate socially responsible practices to mitigate adverse economic and societal impacts (Nobanee et al. 2021). Incorporating SRM into broader risk management frameworks enhances organisational resilience, improves performance and ensures long-term viability. By prioritising sustainability, companies contribute to a more sustainable future while solidifying their strategic and operational foundations.

6 | Conclusions

The integration of HRO principles and safety culture into the SRM offers substantial strategic advantages for high-risk industries such as oil and gas. These approaches not only improve safety and sustainability but also contribute to long-term operational and competitive success. The proposed framework provides managers with practical guidance while enriching academic discourse on sustainable business strategies with relevance across various high-risk sectors. Grounded in the high-reliability organisational theory, stakeholder theory and risk perception literature, our research emphasises the critical role of SRP in shaping sustainable business models. The findings reveal intricate relationships between SRP, OSC and TMC, highlighting the necessity of incorporating diverse stakeholder perspectives into risk management strategies. This study critiques traditional risk assessment methods and advocates for a more holistic approach that incorporates comprehensive supply chain policies. Furthermore, this research addresses the impact of bounded rationality on stakeholder decision-making, underscoring the essential role of top management in refining risk assessment models. By acknowledging the limitations of conventional methods, this study calls for a broader and more inclusive risk management framework that enhances both strategic resilience and sustainability.

Our insights contribute to the ongoing discourse on sustainable supply chain management, providing practical implications for businesses, policymakers and researchers aiming to navigate the complexities of sustainability risks in modern industrial landscapes (Thistlethwaite and Wood 2018; Bouguerra et al. 2023). This study empirically examined the influence of SRPs and the potential mediating effects of TMC to the environment and the prevailing OSC for businesses operating in the Nigerian O&G supply chain. The Nigerian O&G industry is crucial to the performance of the economy in the short term, as well as in the long-term stewardship of the environment and local communities. These findings confirm significant SRP–SRM relationships (Hajmohammad and Vachon 2016).

This finding agrees with stakeholder theory and the risk perception literature on stakeholders driving sustainability risk prioritisation. Modern cognitive psychology focuses on intuitive, rapid and instinctive responses to risk, given the research environment (Slovic et al. 2004). SRP affects top management's commitment and safety culture. This study used FMEA and SEM-PLS to evaluate stakeholder experts' risk perception, which is influenced by experience and risk management knowledge. This technique provides a holistic overview of risk management. It is adaptable to fresh information and easy to implement in a computerised risk analysis tool. The link between stakeholder and HRO theory perspectives helps explain the relationship between SRP, OSC and TMC in the O&G industry.

To understand how stakeholder perceptions of various variables affect SRM, interdisciplinary, multiscale and multifunctional research is essential. This study enhances our understanding of sustainability risk within the O&G sector, highlighting the critical role of SRP in assessing supply chain sustainability risk. By examining the factors influencing stakeholders' perceptions of sustainability risk at multiple levels, this research clarifies how SRP impacts sustainability risk and contributes to the body of knowledge on SRM, particularly in developing nations. These findings underscore the significance of TMC and OSC as key determinants of effective risk management within the O&G supply chain.

It is crucial for businesses to understand the risk perceptions of stakeholders and the commitment of top management to sustainability goals to align their strategies with sustainability. This alignment ensures that sustainability is integrated into core operations and is not just a peripheral concern, thereby enhancing long-term viability and resilience. Effective SRM is crucial for mitigating the risks associated with environmental, social and economic factors in the oil and gas supply chain. By assessing stakeholders' perceptions of risks and evaluating the organisation's safety culture, companies can identify potential threats and implement proactive measures, minimising the likelihood of environmental incidents, social unrest, regulatory noncompliance and reputational damage.

This research makes a significant contribution to corporate sustainability by fostering a culture of responsibility and accountability within organisations. By rigorously evaluating TMC and OSC, this study underscores the importance of integrating these elements into a comprehensive sustainability strategy. Such an approach not only enhances environmental stewardship and social welfare but also reinforces ethical business practices. Adopting a holistic perspective on sustainability enables companies to strengthen their corporate reputation, attract sustainability-minded investors and customers and build robust, long-term relationships with stakeholders. The insights gained from examining SRP, TMC and OSC provide valuable guidance for shaping business strategies, advancing sustainability initiatives, mitigating risks and bolstering supply chain resilience, particularly in the oil and gas industry. By addressing these critical factors, companies can not only achieve enduring success but also fulfil their environmental and social responsibilities, thereby positioning themselves as leaders in sustainable development.

This study theoretically develops a customised framework for evaluating and mitigating sustainability risks in oil and gas supply chains, with a particular focus on stakeholders' risk appetites. It also explores the role of antecedent variables, such as safety culture, in influencing decision makers' SRM practices. This framework assists managers in understanding sustainability-related risks within a multistakeholder environment and equips them with strategies for mitigation and risk management. Empirical evidence underscores the difficulty of extending sustainability-related SRM beyond internal operations, particularly when engaging with external stakeholders. The proposed framework, while tailored to the oil and gas sector, can be adapted to other high-risk industries. Managers can apply it to sustain long-term supply chain performance while managing sustainability risk.

6.1 | Theoretical and Practical Implications

This study bridges the gap between academic theory and business practice by offering practical guidance for integrating HRO principles into the SRM frameworks. This demonstrates that these theoretical concepts can enhance sustainability and operational efficiency. The findings illustrate how HRO principles can be embedded in organisational processes to improve safety and sustainability. This complements traditional strategic tools, such as Porter's Five Forces and PESTEL analysis, offering a sustainability-oriented lens for decision-making. Moreover, this study underscores the need for improved sustainability metrics and reporting standards (Athanasios et al. 2021), laying a foundation for more accurate, industry-specific performance indicators.

This study has both theoretical and practical implications, shedding light on the complex relationship between stakeholder perceptions, OSC and TMC within the O&G supply chain SRM framework. Theoretically, the study supports HRO and stakeholder theories by demonstrating the interconnection between individual attitudes and organisational dynamics (Hörisch, Freeman, and Schaltegger 2014; Giannakis and Papadopoulos 2016; Schulte and Hallstedt 2018). Practically, this study reveals that safety culture alone does not directly influence SRM, urging O&G companies to adopt a more comprehensive approach that integrates stakeholder perspectives (Jia et al. 2020; Kitsis and Chen 2021).

Developing holistic supply chain policies requires addressing diverse stakeholder goals and risk perceptions within the O&G supply chain. These policies should consider individual, sectoral and national perspectives to devise more effective risk mitigation strategies (Abdul Aziz and Abdul Manab 2020; Sato, Tse, and Tan 2020). Importantly, top management must engage with stakeholders, set high safety targets and foster a supportive environment. Employees who perceive their employers as indifferent may shift their risk attitudes, highlighting the need for a positive organisational culture to encourage effective risk management (Aletaiby, Rathnasinghe, and Kulatunga 2021; Wijethilake and Lama 2019).

This is particularly important in developing countries, where bounded rationality challenges stakeholder decision-making during risk evaluation. Improved protocols within O&G supply chains can help stakeholders make better risk assessments and decisions (Roehrich, Grosvold, and Hoejmose 2014). Recent research emphasises the importance of both direct and indirect collaboration with multi-tier suppliers, not only focusing on first-tier suppliers but also involving lower-tier suppliers in risk-monitoring practices (Kähkönen et al. 2023). This ensures that sustainability risks are managed comprehensively across the entire supply chain, thereby reducing the vulnerability to environmental and economic pressures from the global energy transition (Oruwari et al. 2024). This study emphasises the need for increased awareness and adoption of sustainable practices in regions where extreme environmental risks are often overlooked. Strategic environmental risk management, supported by robust policies, can reduce negative environmental impacts (Giannakis and Papadopoulos 2016). Findings from the Nigerian O&G supply chain are applicable to other developing countries with similar economic structures, underscoring the critical role of top management in SRM. In rentier economies and low-income regions, actively involving top management in sustainability-focused risk management can help bridge the power distance gap and promote better long-term outcomes.

In summary, this study advances theoretical understanding by supporting HRO and stakeholder theories while offering actionable insights for practitioners. It calls for re-evaluating organisational behaviour, adopting holistic supply chain policies, engaging employees and addressing bounded rationality and environmental risks. By following these recommendations, O&G supply chain organisations can enhance their SRM practices. The study's implications extend beyond the O&G sector, offering guidance to other high-risk industries that face similar sustainability pressures. Like other high-risk industries, the oil and gas sector faces growing pressure to balance sustainability with profitability and operational efficiency. Previous studies have highlighted gaps in management systems that hinder sustainable production (Schneider et al. 2013) and have emphasised the need for improved sustainability reporting (Aljanadi and Alazzani 2023). Integrating HRO principles into safety culture reduces operational and environmental risks, aligning with the broader SRM goals of optimising social, environmental and economic performance (Manab and Aziz 2019). Firms that prioritise early risk identification and a safety-first approach gain a sustainable competitive advantage. This strategy aligns with Porter's Five Forces framework, as firms that lead proactive risk management influence industry standards and strengthen stakeholder trust. Moreover, integrating sustainability into core business strategies supports CSR initiatives, unlocks new markets, enhances investor confidence and aligns with the triple bottom line (TBL) approach of balancing economic, environmental and social outcomes.

6.2 | Research Limitations and Recommendations

The limitations of this study are related to its survey-based design. Although we employed empirical techniques to mitigate common method bias in the current study, the dependent variable was nonetheless a self-report measure. Another limitation is the cultural context specificity of the Nigerian context, and new research will be designed to enable greater generalisation based on similar problems posed by similar O&G technology in other developing countries. Model testing will also be conducted in mature O&G settings to determine whether these findings are general. Future research may also address issues in equivalent technologies such as chemical processing, steel production and HRO settings such as power generation. They are highly dependent and tightly coupled supply networks.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data supporting the findings of this study are available from the corresponding author (upon reasonable request).

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.