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RISK MANAGEMENT AND MITIGATION IN OFFSHORE ENGINEERING PROJECTS: A CASE STUDY OF FIXED OFFSHORE PLATFORMS IN MALAYSIA

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ABSTRACT

The offshore oil and gas sector faces complex technical, operational, and environmental risks that require robust and context-specific management strategies. Although international standards such as ISO 31000, API RP 75, and DNV recommended practices offer comprehensive guidance, their direct adoption in Malaysia often overlooks local regulatory, environmental, and organizational realities. This study develops and conceptually validates a Risk Management and Mitigation Framework tailored to Malaysian offshore engineering projects, focusing on fixed offshore platforms. Using a quantitative survey of management and operational personnel, supported by thematic analysis, six framework layers were identified: Risk Identification, Risk Analysis, Risk Control, Monitoring, Review and Improvement, and Training and Culture. The framework was refined through expert review and aligned with international standards to ensure contextual relevance and feasibility. The results highlight perception gaps between management and operational groups, limitations in framework review frequency, and underutilisation of digital tools. The proposed framework integrates feedback loops and human-centred safety culture to bridge policy and practice. This research contributes both practical guidance for industry practitioners and a scholarly foundation for strengthening offshore risk governance in Malaysia.

Keywords: *Risk management, offshore engineering, framework development, Malaysia, ISO 31000, API RP 75, DNV*

INTRODUCTION

Offshore oil and gas operations are among the most hazardous industrial activities, where the consequences of failure extend beyond economic losses to human lives and environmental damage. Malaysia, as one of the leading producers in Southeast Asia, relies heavily on offshore production to sustain its energy needs and economic growth [1]. With over 200 offshore platforms, including numerous fixed installations, ensuring structural integrity and operational safety remains a national and industry priority [2].

Although Malaysia has aligned its safety and risk management systems with international frameworks such as ISO 31000 [3], API RP 75 [4], and DNV recommended practices [5], local studies show persistent challenges in implementation. These include outdated tools, competency gaps, regulatory misalignment, and limited feedback mechanisms for continuous improvement [6–8]. Abdullah et al. [6] and Sulaiman and Rahman [7] observed that many operators rely on static hazard registers and manual assessments rather than predictive or data- driven models, reducing responsiveness to real-time conditions. Similar concerns were noted by Lee et al. [9] and Ajmal et al. [10], who highlighted weak safety culture and inconsistent application of safety management systems, especially in contractor operations.

From a technical perspective, corrosion, fatigue, and structural degradation remain key issues for Malaysia's aging fixed platforms. Studies by Ma et al. [11], Mohd Zaki et al. [12], and Mat Soom et al. [13] confirm that localized corrosion and stress-strength interference are major contributors to asset deterioration. These challenges are compounded by environmental factors such as high chloride exposure and monsoonal

conditions unique to Malaysian waters [14]. Human-factor risks also play a critical role: Maternová et al. [15] and Chowdhury et al. [16] found that inadequate training, communication breakdowns, and procedural lapses continue to influence incident frequency in offshore and maritime settings.

At the same time, research on digitalisation and predictive maintenance has gained momentum. Ismail and Hassan [17] emphasised that the adoption of Industry 4.0 technologies in Malaysia's offshore sector remains limited, with integration barriers between digital systems and existing safety processes. Kaur and Paul [18] demonstrated how predictive maintenance and real-time data analytics can improve reliability, while Nguyen and Lim [19] identified the need to align digital transformation with regulatory and human-resource readiness.

Collectively, these findings indicate that while Malaysia's offshore sector has adopted international standards, their translation into practice is uneven. Existing frameworks often operate as compliance exercises rather than integrated management systems that adapt to local operational and regulatory realities. This study therefore develops and validates a Risk Management and Mitigation Framework specifically tailored for fixed offshore platforms in Malaysia. The framework integrates global best practices with local operational, cultural, and regulatory contexts to enhance resilience, safety performance, and continuous learning across offshore operations.

METHOD

The framework was developed through a mixed-methods approach combining quantitative survey data with qualitative thematic insights. Structured questionnaires were designed for two respondent groups: management personnel, focusing on strategy, governance, and compliance; and operational personnel, focusing on field-level risk identification and mitigation practices. This dual design allowed the study to capture both strategic and implementation perspectives of risk management within Malaysian offshore operations.

Target Population and Sampling

The target population comprised personnel involved in offshore engineering projects in Malaysia, including management and operational staff from operating companies, contractors, and service providers. Respondents were selected using purposive sampling to ensure participation from individuals directly engaged in project risk management and safety-related decision-making.

A total of 76 valid responses were collected, consisting of 40 management personnel and 36 operational personnel**.** This distribution provided balanced insights into both strategic and field-level perspectives on offshore risk management. The chosen sample size was considered sufficient to reflect key stakeholder views across Malaysia's offshore sector and to support meaningful comparative analysis between the two groups.

Questionnaire Design and Validation

The survey instrument was developed based on established risk management frameworks [3-5, 20, 21] and adapted from previous studies relevant to offshore engineering projects [6-10]. It included both closed-ended questions using five-point Likert scales and open-ended items to capture qualitative perspectives. Content validity was ensured through expert and supervisory review, where academic advisors and industry professionals evaluated the questionnaire's clarity, structure, and relevance to Malaysian offshore operations. Feedback from this process guided several wording adjustments and ensured that each item aligned with the study's objectives.

In addition, a preliminary expert review of the proposed framework was conducted to enhance its clarity and contextual relevance. Selected researchers and practicing offshore engineers assessed the framework's practicality and consistency with current industry practices. Their feedback informed minor refinements to improve presentation and conceptual soundness prior to validation.

Data Analysis

Quantitative data were analysed using SPSS to generate descriptive statistics illustrating trends in risk perception, framework review practices, and operational confidence in existing safety protocols.

The results were summarised through frequency distributions, comparative tables, and visual graphs to highlight differences between management and operational perspectives.

For the qualitative component, open-ended responses were coded and grouped into recurring themes to identify major challenges and recommendations related to offshore risk management. This process allowed integration of both quantitative and qualitative insights, providing a more comprehensive understanding of how risks are perceived and managed across organizational levels.

Framework Development Process

The framework development followed four structured stages:

1. Risk identification across technical, operational, and environmental domains.
2. Framework structuring based on empirical data collected from both management and operational respondent groups.
3. Integration of international and national standards**,** including *ISO 31000*, *API RP 75*, and *PETRONAS Technical Standards (PTS)*, in alignment with Malaysian regulatory expectations under the *Occupational Safety and Health Act (1994)* and the oversight of the *Department of Occupational Safety and Health (DOSH)*.
4. Expert validation, assessing the framework's clarity, contextual relevance, andconceptual soundness.

In addition, the study recommends that future validation of the proposed framework be conducted using measurable indicators such as incident-rate reduction, compliance improvement, and cost efficiency from mitigation initiatives.

RESULT AND DISCUSSION

Perception Gaps and Risk Prioritisation

The analysis revealed a 23.3% difference in the perception of "full compliance" with international standards between management and operational groups, as illustrated in Figure 1. Management respondents associated compliance with the presence of documentation and training programmes, whereas operational personnel evaluated it through daily enforcement and adherence. This gap suggests that standards adopted at policy level are not consistently applied in practice.

The implications are significant: when field staff do not fully recognise or apply the standards assumed by management, the credibility and effectiveness of the entire risk management process are compromised. This reinforces the need for improved communication, cross-level training, and stronger monitoring mechanisms to align policy with practice.

Divergent Risk Perceptions Between Management and Operational Personnel

Distinct differences were observed in how each group prioritised risks. Management respondents focused primarily on equipment failure (31.4%), corrosion (26.4%), and human error (19.4%), reflecting their concern with operational continuity and regulatory exposure. Conversely, operational personnel identified equipment malfunction (33.3%) and corrosion (25%) as the most dominant risks, emphasizing the daily challenges associated with aging assets.

Procedural issues such as emergency shutdowns and human error were less frequently reported (8.3%) but were consistently rated as severe when they occurred, indicating low- frequency but high-impact events. Environmental risks such as strong currents

Are your operations governed by international risk management standards (e.g., ISO 31000, API RP 75, etc.)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	26	65.0	65.0	65.0
	Partially	13	32.5	32.5	97.5
	No	1	2.5	2.5	100.0
	Total	40	100.0	100.0	

(a) Management Personnel

Are your operations governed by international risk management standards (e.g., ISO 31000, API RP 75, etc.)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	15	41.7	41.7	41.7
	Partially	15	41.7	41.7	83.3
	No	6	16.7	16.7	100.0
	Total	36	100.0	100.0	

(b) Operational Personnel

Figure 1 Comparative perception of compliance with international risk management standards

and lightning accounted for approximately 20% of reported concerns, reflecting Malaysia's tropical offshore conditions.

The comparison suggests that management's risk priorities are often strategic, while operational priorities are immediate and experience-based. Bridging these viewpoints requires integrated reporting systems, shared hazard registers, and a stronger feedback loop between the two levels of operation.

Although numerous specific risks were assessed, the overarching trend shows that management prioritises strategic and compliance-oriented risks, while operational teams prioritise immediate technical and environmental threats. This difference highlights the need for shared hazard registers and cross-level discussions to ensure a unified understanding of risk significance. Detailed risk-by-risk tabulations are provided in the supplementary data and full thesis for reference.

Framework Review Practices and Confidence in Protocols

The survey indicated that framework reviews are conducted inconsistently across organizations. Management personnel reported performing reviews periodically, typically aligned with project milestones or annual audits. In contrast, operational staff noted that most reviews occurred reactively—triggered by incidents, equipment failures, or inspection findings. This discrepancy suggests that many organizations still adopt a reactive rather than proactive approach to framework management.

Confidence levels in existing safety and mitigation protocols were moderate. While most respondents expressed confidence in the systems, nearly one-fifth reported uncertainty or low confidence, mainly due to limited supervisory presence, infrequent safety drills, and outdated equipment. Improving consistency in review schedules and strengthening leadership involvement during safety exercises could enhance both confidence and practical implementation. Detailed confidence levels are available in the full thesis dataset.

Organisational Challenges, Framework Priorities, and Technology Gaps

Respondents identified several organisational challenges that affect the effectiveness of offshore risk management. Management participants emphasised issues such as competency gaps, weak interdepartmental communication, and resistance to procedural change. They also prioritised short-term measures—emergency planning, workforce readiness, and regulatory compliance—over long-term investments in technology and data-driven systems.

Operational personnel highlighted limited use of digital monitoring, inconsistent data sharing, and lack of integration between onshore and offshore teams. Together, these findings point to an implementation gap between strategic planning and field execution. To bridge this, organisations should prioritise integrated communication systems, consistent digital adoption, and structured training that aligns technology with human capability. Supporting data for each challenge category are presented in the main thesis.

Qualitative Insights: Stakeholders Perspective

Open-ended responses provided deeper context to the quantitative findings. Management respondents frequently pointed to outdated tools and paper-based systems (21.9%), weak risk modelling (14.6%), and persistent competency gaps (12.2%). These shortcomings reflect a disconnect between formal compliance and practical application, resulting in fragmented data, reactive decision-making, and inconsistent training outcomes. Other challenges, such as regulatory misalignment, asset integrity concerns, and cultural barriers, further illustrated the systemic obstacles to effective framework implementation.

At the same time, management also proposed a set of strategic improvements. The most frequently cited recommendation was the modernization of training and workforce development (19.5%), supported by calls for stronger leadership engagement (14.6%) and more integrated digital systems (12.2%). Additional themes included regulatory alignment, resource constraints, vendor limitations, and communication gaps. These recommendations highlight that managers recognize not only the technical but also the cultural and structural reforms needed to move from compliance-driven practices toward proactive risk governance.

Operational personnel echoed many of these themes but framed them in more immediate terms. Their concerns cantered on training and competency gaps (14.6%), asset integrity and predictive maintenance (14.6%), and persistent communication breakdowns (12.2%). Respondents described how inadequate training, aging equipment, and poor shift handovers directly undermine safety on offshore platforms. Other issues—such as documentation gaps, inconsistent learning from incidents, and limited digital adoption—further revealed an implementation gap between formal frameworks and field-level realities. These perspectives are summarized in the following tables, which consolidate the frequency of themes and illustrative insights from both groups.

Table 1 Perceived gaps in risk management practices – theme frequency by management respondents

Theme	% of Respondents	Illustrative Insight
Outdated tools & processes	21.9%	Reliance on legacy systems and siloed data platforms.
Weak risk modelling	14.6%	Overuse of static, historical data with limited predictive analytics.
Competency & training gaps	12.2%	Inconsistent preparedness among contractors and field staff.
Regulatory misalignment	12.2%	Difficulty aligning DOSH and international standards.
Asset integrity & life extension gaps	12.2%	Challenges in extending platform lifespan safely.
Communication & cultural barriers	9.8%	Inconsistent reporting and fragmented coordination.

This table illustrates that while formal frameworks exist, their effectiveness is undermined by outdated systems, weak modelling practices, and workforce competency issues. Compliance is often procedural rather than experiential, with limited capacity for real-time responsiveness.

As shown, managers placed priority on training modernization, leadership accountability, and system integration, while also acknowledging resource and regulatory barriers. These recommendations highlight that structural reform must extend beyond

Table 2 Distribution of strategic improvement themes identified by management respondents (%)

Theme	% of Respondents	Illustrative Insight
Training & workforce development	19.5%	Need for modernized, scenario-based training and mentorship.
Leadership & cultural reform	14.6%	Embed accountability and safety KPIs across management levels.
Technology & system upgrades	12.2%	Improve integration of monitoring, analytics, and digital platforms.
Regulatory & governance alignment	12.2%	Harmonise national and international compliance requirements.
Budget & resource constraints	7.3%	Limited funding for training and digitalization.
Supply chain/ vendor limitations	7.3%	Inconsistent standards among local contractors.
Communication gaps	4.9%	Weak cross-functional coordination.

Table 3 Operational realities and recommendations (operational/technical group)

Theme	% of Respondents	Illustrative Insight
Training & competency gaps	14.6%	Lack of immersive, scenario-based training; reliance on generic content.
Asset integrity & predictive maintenance	14.6%	Aging assets with limited predictive maintenance or monitoring systems.
Communication & coordination issues	12.2%	Breakdowns during handovers and between offshore/onshore teams.
Digitalization & documentation gaps	7.3%	Inconsistent application of reporting systems and documentation tools.
Knowledge transfer & learning	7.3%	Weak mechanisms for knowledge retention and cross-generational transfer.
Risk management practices	7.3%	Procedures not consistently followed, creating implementation gaps.
Incident learning & reporting	2.4%	Limited institutionalization of lessons from past incidents.

technical upgrades to include cultural and governance improvements.

Operational personnel emphasised immediate and practical challenges: gaps in training, maintenance, and communication. Their perspective highlights the vulnerabilities that arise when risk frameworks do not translate into consistent frontline practice, underscoring the importance of embedding local realities into any proposed framework.

Thematic Summary of Results

To consolidate the quantitative and qualitative findings, Table 4 summarises the key results and their implications for framework development.

To consolidate the quantitative and qualitative findings, Table 4 summarises the key results and their implications for framework development. While this study did not include post- implementation testing, the proposed framework was conceptually validated through preliminary expert review and alignment with international standards. Future validation is recommended through measurable performance indicators in operational settings.

Table 4 Summary of survey findings and framework implications

Result Area	Key Findings	Framework Implications
Perception Gap in Standards Compliance	23.3% gap between management and operational staff in perceiving "full compliance." Management equated compliance with documentation and training, while operational staff judged by enforcement and daily practice.	Need for clearer enforcement mechanisms, stronger training integration, and monitoring systems that align strategic intent with frontline execution.
Risk Prioritisation	Management prioritised equipment failure, corrosion, and human error; operational staff highlighted equipment malfunction (33.3%) and corrosion (25%), with rare but severe risks like emergency shutdowns also stressed.	Risk ranking must account for both frequency and severity, ensuring low-frequency/high-impact risks are adequately addressed.
Framework Review Practices	Management conducted scheduled reviews; operational staff relied on incident-driven reviews. Disconnect weakened institutional learning and feedback loops.	Framework should include incident-triggered reviews and formal upward communication channels to capture frontline insights.
Confidence in Mitigation Protocols	19.4% of operational staff reported low confidence, majority were neutral. Compliance often lacked trust in reliability, due to outdated systems and infrequent drills.	Requires regular scenario-based drills, refresher training, and leadership visibility to strengthen trust and operational confidence.
Management Challenges	Identified barriers were largely cultural/structural: competency gaps, regulatory misalignment, communication complexity, and change resistance.	Highlights the need for human capital investment, regulatory alignment, streamlined communication, and leadership-driven change.
Framework Components	Management prioritised safety protocols, emergency planning, and workforce readiness, but gave limited weight to digitalisation and long-term asset strategies.	Emphasises need to embed predictive tools, lifecycle planning, and digital integration into framework layers.
Technology Adoption Gap	Misalignment between management's reported digital strategies and operational staff's field-level practices; tools underutilised.	Requires cross-functional technology reviews, joint audits, and clearer communication of digital transformation goals.
Qualitative Insights (Management)	Reported outdated tools (21.9%), weak modelling (14.6%), and competency gaps (12.2%) as key issues. Recommended training modernisation (19.5%), stronger leadership (14.6%), and digital integration (12.2%).	Framework must address both technical weaknesses and cultural reforms, embedding accountability and updated systems.
Qualitative Insights (Operational)	Emphasised training and competency gaps (14.6%), asset integrity issues (14.6%), and communication breakdowns (12.2%). Highlighted documentations gaps and weak incident learning.	Reinforces need for site- specific training, predictive maintenance, improved shift handovers, and stronger knowledge retention systems.

PROPOSED OFFSHORE RISK MANAGEMENT AND MITIGATION FRAMEWORK

Based on the findings presented in Section 3, a comprehensive Risk Management and Mitigation Framework was developed for fixed offshore platforms in Malaysia, as illustrated in Figure 2. The framework integrates global standards—ISO 31000 [3], API RP 75 [4], and DNV Recommended Practices [5]—with locally derived empirical evidence to create a context-specific, adaptive model for offshore operations.

The framework comprises six interrelated layers representing the full risk management cycle:

1. Risk Identification – focuses on early recognition of technical, operational, and environmental risks identified in this study, including equipment malfunction, corrosion, and human error.
2. Risk Analysis – evaluates the likelihood and severity of identified risks through structured assessment tools and inspection data, encouraging a shift from paper-based to digital methods.
3. Risk Control and Mitigation – outlines preventive and corrective measures such as enhanced maintenance, emergency planning, and competency improvement.
4. Monitoring – ensures the continuous tracking of control effectiveness through inspections, audits, and performance dashboards.
5. Review and Improvement – institutionalises regular reviews, promoting learning from incidents and near misses to strengthen resilience.
6. Training and Culture – fosters safety awareness, technical competency, and leadership engagement across all operational levels.

The six layers form a closed-loop system, allowing information from monitoring and review to feed back into earlier stages. This design promotes continuous improvement and adaptability in risk management processes, addressing gaps identified between management and operational practices.

Following development, the framework underwent expert review by researchers and practicing engineers with offshore experience. Their feedback confirmed its practicality, clarity, and relevance to Malaysian offshore operations. While the framework has yet to undergo empirical performance validation, it provides a structured basis for improving risk communication, consistency, and operational safety across the sector.

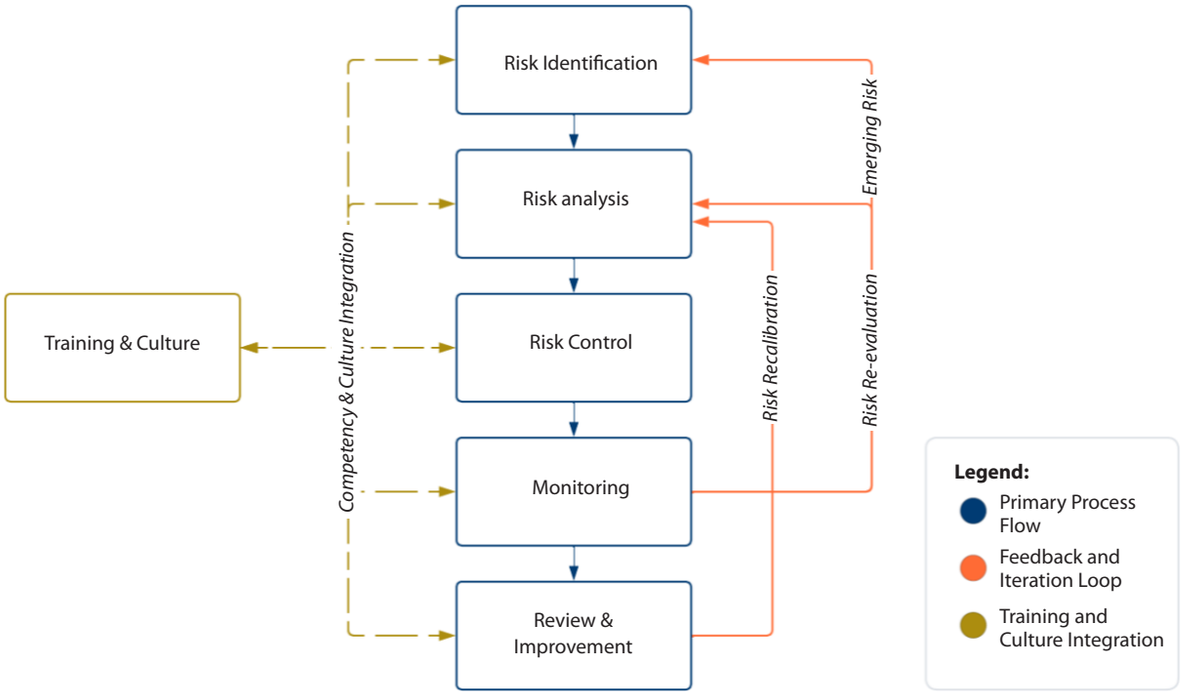

Figure 2 Proposed risk management and mitigation framework for fixed offshore platforms in Malaysia

CONCLUSION

In conclusion, this study examined risk management practices in Malaysia's offshore engineering sector and developed a comprehensive framework to enhance safety, resilience, and operational consistency. While many organisations have adopted international standards like ISO 31000 and API RP 75, gaps persist in implementation due to differing risk perceptions between management and operational staff, competency issues, weak communication, and limited digital integration—resulting in reactive management. The proposed six-layer Risk Management and Mitigation Framework integrates identification, analysis, control, monitoring, review, and training to promote continuous improvement. Expert validation confirmed its clarity, practicality, and alignment with industry standards, offering a structured approach to strengthening offshore safety management and governance in Malaysia.

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