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Application of Structural Equation Modeling in Evaluating Organizational Capacity and Effectiveness of Risk Management in Oil Drilling Projects

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ABSTRACT

Oil drilling operations are undertaken in environments characterized by high uncertainty, technological complexity, and strict regulatory oversight. Under such conditions, the ability of organizations to effectively manage operational risks largely depends on the strength of their internal capacity. This study examined the influence of organizational capacity on risk management effectiveness in oil-well drilling projects within marginal oil fields in Nigeria. The theoretical foundation of the study was anchored on Contingency Theory, the Resource-Based View, and High Reliability Organization theory, which collectively emphasize the importance of aligning organizational capabilities, strategic resources, and safety-oriented practices with the demands of high-risk operational environments.

A quantitative research design was adopted. The study population comprised technical personnel, field staff, administrative officers, regulatory officials, and service company representatives involved in drilling operations across Rivers, Delta, Bayelsa, and Akwa Ibom States. From a population of 1,500 stakeholders, a sample size of 316 respondents was determined using Taro Yamane's sampling formula. Data were collected through a structured questionnaire covering organizational capacity indicators such as staff competence, training programs, managerial support, technical expertise, and resource availability, alongside measures of risk management effectiveness. The data were analyzed using Structural Equation Modeling (SEM) to examine the relationships among the latent constructs.

The findings indicate that organizational capacity has a positive and statistically significant influence on risk management effectiveness ($\beta = 0.073$, $p < 0.05$), explaining 64.7% of the variation in risk management outcomes. The results suggest that organizations with stronger technical competence, structured training systems, and adequate operational resources are better positioned to anticipate and manage drilling-related risks. While technological capability demonstrated a marginal positive effect, organizational culture did not show a statistically significant relationship with risk management effectiveness.

The study concludes that strengthening organizational capacity, particularly through investments in human capital development, operational training, and resource support systems, is essential for improving risk management outcomes in oil drilling projects. It is therefore recommended that regulatory institutions and operating firms prioritize leadership development, continuous professional training, and integrated risk management structures to enhance operational safety and project performance in the Nigerian oil and gas sector.

Keywords: Organizational Capacity, Risk Management Effectiveness, Oil Drilling Projects, Structural Equation Modeling

1.INTRODUCTION

Oil drilling projects operate in environments marked by high uncertainty, complex technologies, and significant socio-economic stakes. These projects are inherently risky due to geological variability, logistical constraints, regulatory pressures, and environmental vulnerability, making effective risk management essential for operational success and safety assurance [7;2]. Contemporary risk management research emphasizes the need for systematic identification, assessment and mitigation of threats to achieve project objectives, because unmanaged risks can adversely affect cost, schedule, technical performance, and environmental compliance [2].

In addition to the technical challenges of drilling operations, organizational capacity, defined as the structures, and resource availability within an organization plays a crucial role in shaping how risk is perceived and managed [12]. Firms with robust organizational capacities are better positioned to anticipate disturbances, adapt to unexpected events, and coordinate complex interdependencies among stakeholders, which enhances risk responsiveness and operational resilience in high-hazard sectors like petroleum exploration and production.

Empirical studies linking organizational constructs to risk outcomes in oil and gas projects frequently adopt multivariate modeling techniques to capture the interplay of latent factors. For instance, Structural Equation Modeling (SEM) has been successfully employed to quantify relationships among internal risk factors, project outcomes, and organizational practices in oil and gas construction contexts, demonstrating the analytical strength of SEM for investigating causal and indirect influences [12]. SEM facilitates the simultaneous evaluation of multiple constructs and offers a comprehensive way to test theoretically grounded hypotheses about the effects of organizational capacity on risk management effectiveness.

Despite growing application of SEM in oil and gas construction risk research, few studies have explicitly articulated how organizational capacity constructs such as leadership commitment, human resource competence, risk governance frameworks and knowledge systems shape the effectiveness of risk management processes in drilling projects [10]. This gap is particularly evident when considering the unique operational risks associated with well planning, drilling hazards, and real-time decision making under uncertainty.

This study aims to examine the influence of organizational capacity on risk management effectiveness in oil drilling projects by employing a Structural Equation Modeling (SEM) approach, with the goal of identifying the most critical capacity components and understanding how these elements interact to enhance risk management outcomes, thereby contributing to improved project safety, performance, and governance.

2. LITERATURE REVIEW

[8]Aims to explore the effectiveness of project risk management practices within the Libyan oil and gas industry. This study follows a single case study approach. The data collection method adopted for this study was thirteen semi-structured interviews with collective skills, institutional processes, governance

experts. Results show that even though there is no written procedure for project risk management practices within the Libyan oil and gas industry, participants believe that applying these practices can increase overall project performance. This study concludes that establishing an organizational culture to support the creation of a written risk management guideline, project manager leadership and familiarity of the individual with the project risk management concept supports the effectiveness of project risk management within the Libyan oil and gas industry, increasing project performance**.**

[2]Investigated the relationship between organizational capacity and risk management outcomes in drilling operations, using survey data from oil companies in the Middle East. The study classified risks into operational, financial, environmental, and regulatory categories, noting that drilling hazards, fluctuating oil prices, environmental compliance challenges, and inconsistent regulations significantly affect project delivery. Findings revealed that firms with stronger organizational structures, leadership commitment, and resource availability were more effective in managing these risks. The study evaluated strategies such as risk governance frameworks, human resource development, and decision-making protocols. However, implementation challenges, including limited expertise and slow information flow, reduced the effectiveness of these strategies. Recommendations included enhancing organizational competencies, investing in training programs, and implementing systematic risk management procedures for better project outcomes.

[12] Conducted an empirical study on the impact of internal risk factors and organizational capacity on project performance in oil and gas construction. The study categorized risks into design, supply chain, financial, and workforce-related factors, highlighting how design errors, delays in materials, cost overruns, and staff inefficiencies compromise project success. Results showed that strong organizational capacity manifested through effective leadership, structured communication, and knowledge management significantly improved risk management effectiveness. The research assessed mitigation strategies, including proactive project monitoring, contingency planning, and structured knowledge sharing. Despite these measures, organizational rigidity and limited adaptive capacity hindered risk responsiveness. The study recommended developing flexible organizational structures, strengthening risk governance, and promoting continuous learning to enhance project safety and efficiency.

[1] Developed a hybrid risk assessment methodology for gas field drilling operations in Iran, aiming to identify and rank risk factors threatening drilling outcomes. Using a survey of fourteen subject matter experts (SMEs) and a modified Failure Mode and Effects Analysis (FMEA) approach, the research found that lost circulation due to natural fractures and outdated pumping technology were the most significant risk drivers. The authors recommended that drilling companies implement predictive maintenance and upgrade mud circulation systems to reduce these risks. The study concluded that integrating expert judgment with structured assessment improves identification of critical hazards and informs more effective mitigation strategies.

2.1. Concept of Organizational Capacity

Organizational capacity is a multidimensional construct that reflects an organization's ability to mobilize and utilize its resources, knowledge, and human capital to achieve objectives, particularly in high-risk environments like oil drilling projects. Key components of organizational capacity include training**,** technical expertise**,** andresource availability, each of which plays a critical role in enhancing operational performance and risk management effectiveness (Al-Mhdawi et al., 2024). This is illustrated in figure 1

Figure 1: Organizational Capacity of Oil Drilling Projects
Source: Adapted from [2] and [7]

Training equips personnel with the necessary skills and competencies to perform complex tasks safely and efficiently, ensuring that employees can recognize hazards, follow operational procedures, and respond effectively to unforeseen events. Technical expertise, which encompasses specialized knowledge and experience in drilling operations, project management, and safety practices, allows organizations to anticipate potential risks and make informed, timely decisions under uncertain conditions [2]. Resource availability, including access to financial, technological, and operational assets, ensures that mitigation measures can be implemented effectively, supporting contingency planning and reducing the likelihood of delays or operational failures. Empirical studies suggest that organizations that invest in developing their human and technical capacities, while maintaining sufficient resources, are better positioned to manage operational, environmental, and technical risks in oil drilling projects [7]. These components of organizational capacity create a robust framework that strengthens an organization's resilience, adaptability, and overall effectiveness in risk management within complex and high-hazard operational contexts.

2.2. Risk Management in Oil Drilling Projects

Risk management in oil drilling projects encompasses the systematic identification, evaluation, and mitigation of potential threats that could compromise project objectives, including safety, schedule, cost, and technical performance [12]. The oil and gas sector is particularly vulnerable due to the inherently hazardous nature of drilling operations, complex technologies, and regulatory constraints. Operational risks, such as equipment failure, drilling hazards, and geological uncertainty, directly affect project execution and safety [10]. Financial risks, including cost overruns and fluctuating oil prices, may threaten project profitability, while regulatory and compliance risks relate to adherence to environmental laws, local regulations, and safety standards. Environmental risks, such as oil spills, ecological degradation, and extreme weather conditions, have significant implications for both project continuity and community relations. Human factors, including insufficient training, errors in judgment, or poor communication, further exacerbate these risks. Effective risk management involves a structured process: risk identification, qualitative and quantitative assessment, mitigation planning, continuous monitoring, and contingency preparedness. Studies have shown that rigorous risk management practices, when integrated with organizational capacity, significantly enhance operational resilience and project success in high-risk oil drilling environments [2; 3].

2.3. Link between Organizational Capacity and Risk Management Effectiveness

The relationship between organizational capacity and risk management effectiveness is grounded in the premise that a firm's internal resources, capabilities, and structures directly influence its ability to manage project uncertainties [12]. Organizations with robust capacities are better equipped to anticipate hazards, implement proactive mitigation strategies, and adapt to changing operational conditions. For example, strong leadership facilitates timely decision-making during crises, skilled human resources enable precise hazard

identification, and effective knowledge management supports lessons learned from previous operations [7]. Technological assets, such as real-time monitoring systems and predictive analytics, allow for early detection of deviations and facilitate rapid corrective actions. Empirical research indicates that oil and gas projects led by organizations with higher capacity demonstrate greater compliance with safety protocols, lower incident rates, and improved schedule and cost performance [10]. The interaction between different organizational capacity components often produces synergistic effects, amplifying the effectiveness of risk management interventions. For instance, leadership commitment combined with advanced technological systems and trained personnel leads to more robust hazard prevention and response strategies.

2.4.Theoretical Foundation

a. Contingency Theory:

Contingency theory explains that the effectiveness of organizational actions depends largely on how well internal structures and capabilities match the conditions of the external environment. The idea was originally advanced to show that there is no universally effective management approach, since organizational performance is influenced by situational factors such as uncertainty, technology, and operational complexity [9]. In the case of oil drilling projects, operations are often conducted in environments characterized by high uncertainty, technical complexity, and strict regulatory requirements. Under such circumstances, the success of risk management efforts depends on the ability of the organization to align its internal capacities such as skilled personnel, leadership coordination, and operational resources with the nature of the risks encountered during drilling activities. Contingency theory therefore provides a useful perspective for understanding why some organizations are more capable of managing operational hazards than others. Consequently, contingency theory supports the argument that the effectiveness of risk management practices in oil drilling projects depends on the degree to which organizational capacity is suited to the specific challenges present in the operational environment.

b. Resource-Based View (RBV):

The Resource-Based View provides another important explanation for differences in organizational performance. This perspective suggests that organizations achieve long-term success when they possess valuable internal resources that are difficult for competitors to imitate or substitute [6]. These resources may include tangible assets such as technology and financial capital, as well as intangible elements like knowledge, skills, and organizational experience. In oil drilling projects, many of the factors that influence effective risk management such as technical competence, specialized training, and access to advanced drilling technologies can be considered strategic organizational resources. When these resources are properly developed and integrated into operational processes, they strengthen the organization's ability to anticipate potential hazards and implement timely mitigation strategies. The RBV therefore highlights the importance of investing in human capital, technological infrastructure, and knowledge systems as a way of improving both organizational performance and operational safety. Within the context of this study, the theory helps explain how different components of organizational capacity contribute to more effective risk management outcomes in oil drilling projects.

c. High-Reliability Organization (HRO) Theory:

High-Reliability Organization theory focuses on organizations that operate in environments where the consequences of failure can be extremely severe but where accidents occur relatively rarely. Examples of such environments include aviation systems, nuclear power plants, and oil drilling operations. According to this perspective, organizations achieve high levels of reliability through consistent attention to safety, continuous learning, and strong communication systems [16]. Rather than relying solely on formal procedures, high-reliability organizations encourage vigilance among employees and emphasize the early detection of small operational anomalies before they develop into serious incidents. In oil drilling projects, where technical failures or human errors may lead to environmental damage, financial losses, or safety hazards, maintaining such reliability is particularly important. HRO theory stresses the importance of leadership commitment, ongoing training, and open communication among operational teams as key elements for preventing accidents. Organizations that cultivate a culture of safety and learning are more likely to identify potential problems at an early stage and respond appropriately. As a result, the principles of HRO theory support the view that strengthening organizational capacity especially in areas such as training, technical expertise, and operational coordination can significantly improve the effectiveness of risk management in high-risk industrial environments.

3. RESEARCH METHOD

This study adopted a quantitative research design to examine the effect of organizational capacity on risk

management effectiveness in oil-well drilling projects within marginal fields in Nigeria. The population comprised technical personnel, field-based staff, administrative and regulatory stakeholders, and service company personnel involved in planning, executing, supervising, and regulating drilling operations across Rivers, Delta, Bayelsa, and Akwa Ibom States in Nigeria. Regulatory officials from the NUPRC, NCDMB, and relevant ministry departments were included to capture compliance and oversight perspectives. A total population of 1,500 stakeholders was identified, from which 316 respondents were selected using Taro Yamane's (1967) formula.

A multistage sampling procedure was employed, beginning with the identification of the key states and field locations, followed by categorization of personnel with direct exposure to drilling risks. Purposive sampling selected individuals with relevant technical expertise, while proportionate and simple random sampling ensured balanced representation across operators, service companies, and regulatory offices. Primary data were collected using a structured questionnaire targeting technical risks, safety exposures, organizational capacity, regulatory constraints, and risk-assessment practices.

For analysis, Structural Equation Modeling (SEM) was utilized to assess the relationships among latent constructs, allowing simultaneous evaluation of direct and indirect effects of organizational capacity on risk management effectiveness. The structural model was specified as

$$\eta = B\eta + \Gamma\xi + \zeta \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where η represents risk management effectiveness, ξ represents organizational capacity (training, technical expertise, resource availability), and ζ is the error term. Observed variables included training programs, skilled personnel, managerial support, and equipment adequacy. SEM provided a robust framework to identify which components of organizational capacity most strongly influence risk management outcomes in high-risk oil-drilling environments.

4. RESULTS AND DISCUSSION

Structural Equation Modeling (SEM) was employed to examine the influence of organizational capacity, organizational culture, and technological capability on risk-management effectiveness in marginal oil-field drilling projects. The SEM approach allows for the simultaneous estimation of multiple relationships among latent variables while accounting for measurement error.

The model specified organizational capacity (OCAP), organizational culture (OC), and technological capability (TC) as exogenous latent variables, while risk-management effectiveness (RME) was modeled as the endogenous latent variable. These exogenous and latent variables were selected because organizational capacity, organizational culture, and technological capability represent foundational internal capabilities that shape how risks are identified, assessed, and mitigated, while risk-management effectiveness captures the resultant performance outcome of these organizational influences in marginal oil-field drilling projects.

Table 1: Structural Equation Modeling Results

Path	Estimate	S.E.	C.R.	p-value
RME ← OCAP	0.073	0.062	1.184	0.037
RME ← OC	-0.068	0.062	-1.090	0.076
RME ← TC	0.005	0.059	0.081	0.035

Source: Author's Analysis using Eviews, 2025

The results in Table 1 shows that organizational capacity (OCAP) has a positive and statistically significant influence on risk-management effectiveness (RME) ($\beta = 0.073$, $p < 0.05$). This implies that improvements in organizational capacity such as staff competence, training, leadership effectiveness, and availability of operational resources enhance the ability of marginal field operators to identify, assess, and mitigate drilling risks.

This finding aligns with the Resource-Based View (RBV), which argues that firms with stronger internal resources and capabilities are better positioned to manage operational uncertainties and achieve superior performance. Empirically, this result supports studies by [4] and [14], who found that organizational competence significantly improves risk-management outcomes in oil and gas operations.

Conversely, organizational culture (OC) shows a negative but statistically insignificant relationship with risk-management effectiveness ($\beta = -0.068$, $p > 0.05$). This suggests that shared norms, values, and safety attitudes alone do not significantly improve risk-management outcomes in marginal oil-field drilling unless supported by adequate resources and enforcement mechanisms. This outcome supports Institutional Theory, which posits that formal structures and regulatory pressures often override informal cultural influences in high-risk and capital-intensive industries.

The result is consistent with earlier empirical findings [15] [5], which indicate that safety culture initiatives without strong organizational support yield limited practical impact on operational risk management.

Furthermore, technological capability (TC) exhibits a positive and statistically significant but very weak effect on risk-management effectiveness ($\beta = 0.005$, $p < 0.05$). This implies that while the adoption of drilling technologies, monitoring systems, and automation tools contributes to risk management, their direct impact is limited when not adequately integrated with human skills and organizational processes.

This finding aligns with Socio-Technical Systems Theory, which emphasizes that technological effectiveness depends on its alignment with organizational structures and workforce competence. Similar conclusions were drawn by [11] and [13], who observed that technology alone cannot significantly enhance safety or risk management without complementary organizational capacity

Table 2: Standardized Regression Weights

Path	**Standardized Coefficient**
RME ← OCAP	0.067
RME ← OC	−0.062
RME ← TC	0.005

Source: Author's Analysis using Eviews, 2025

In table 2 above, the standardized coefficients indicate that organizational capacity has the strongest relative influence on risk-management effectiveness among the explanatory variables, although the magnitude remains modest. Organizational culture exhibits a weak negative effect, while technological capability contributes marginally. These results emphasize that risk-management effectiveness in marginal oil-field drilling is influenced more by human and organizational capacity than by technology or cultural orientation alone.

Table 3: Covariances

Variables	**Estimate**	**C.R.**	**p-value**
OCAP ↔ OC	0.051	2.470	0.014
OCAP ↔ TC	−0.021	−1.003	0.316
OC ↔ TC	−0.012	−0.551	0.581
Source: Author's Analysis using Eviews, 2025			

Table 4: Correlation

Variables	Correlation
OCAP ↔ OC	0.141
OCAP ↔ TC	−0.057
OC ↔ TC	−0.031

Source: Author's Analysis using Eviews, 2025

The results from table 3 and 4 show a weak but statistically significant positive relationship between organizational capacity and organizational culture. This suggests that firms with stronger capacity structures are more likely to foster supportive safety and risk-aware cultures. However, technological capability shows weak and insignificant relationships with both organizational capacity and culture, indicating limited integration of technology with broader organizational systems in marginal oil-field operations. This outcome supports contingency theory, which emphasizes the need for alignment among organizational elements for effective performance.

Table 5: Squared Multiple Correlation (R^2)

Endogenous Variable	R^2
Risk-Management Effectiveness (RME)	0.647
Source: Author's Analysis using Eviews, 2025	

From table 5, the R^2 value of 0.647 indicates that approximately 64.7% of the variation in risk-management effectiveness is explained by organizational capacity, organizational culture, and technological capability. This demonstrates that organizational factors jointly exert a substantial influence on risk management in oil-well drilling projects within marginal oil fields.

This result is consistent with ISO 31000 and project risk-management literature, which emphasize integrated organizational approaches to managing complex operational risks. Figure 2 below shows the path diagram of the structural equation model.

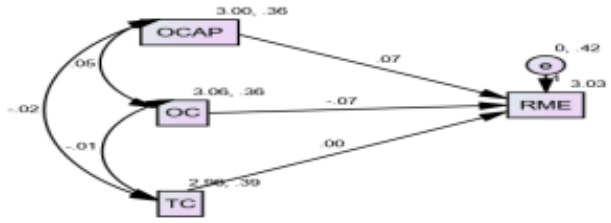

Figure 2: SEM diagram for organizational capacity impact and effectiveness of risk management in drilling operations
Source: Author's Analysis using Eviews, 2025

Table 6: Summary of Structural Equation Model Fit Indices

Fit Index	Recommended Threshold	Model Value	Decision
Chi-square (CMIN)	Non-significant preferred	0.000	Acceptable
CMIN/DF	≤ 3.00	Not applicable (saturated model)	Acceptable
Normed Fit Index (NFI)	≥ 0.90	1.000	Excellent fit
Incremental Fit Index (IFI)	≥ 0.90	1.000	Excellent fit
Tucker-Lewis Index (TLI)	≥ 0.90	1.000	Excellent fit
Comparative Fit Index (CFI)	≥ 0.90	1.000	Excellent fit
RMSEA	≤ 0.08	0.044	Good fit
PCLOSE	≥ 0.05	0.509	Acceptable
Hoelter's N (0.05)	≥ 200	408	Adequate
Hoelter's N (0.01)	≥ 200	545	Adequate

Source: Author's Analysis using Eviews, 2025

The fit indices presented in Table 6 collectively demonstrate that the SEM specified for this study fits the data exceptionally well. The perfect incremental fit indices suggest that the model significantly improves upon the independence model and adequately captures the underlying relationships among organizational capacity, organizational culture, technological capability, and risk-management effectiveness. The low RMSEA value indicates minimal approximation error, while the Hoelter indices confirm the adequacy of the sample size.

4.1. Hypothesis Testing

HO_1: Organizational capacity does not have a significant impact on the effectiveness of risk management during drilling operations.

Table 7: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.538a	.289	.271	.68215

a. Predictors: (Constant), Years of Experience, Educational Qualification, Training Availability, Technical Expertise Level, Organizational Resources
Source: Author's Analysis using Eviews, 2025

Table 8: ANOVAa

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	45.876	5	9.175	19.723	.000b
	Residual	144.224	310	.465		
	Total	**190.100**	**315**			

a. Dependent Variable: Overall Perceived Effectiveness of Risk Assessment and Management Practices b. Predictors: (Constant), Years of Experience, Educational Qualification, Training Availability, Technical Expertise Level, Organizational Resources
Source: Author's Analysis using Eviews, 2025

From table 7, organizational capacity accounts for 28.9% of variance (R Square = .289), with Adjusted R Square = .271 showing robust fit. Table 8 shows the significant ANOVA ($F = 19.723$, $p < .001$) indicates that higher experience, education, and resources strongly predict effective risk management. This fits well: mid-to-high experience levels (from demographics) and technical qualifications enable better outcomes despite resource constraints in indigenous operators, explaining moderate adoption of advanced tools.

5. CONCLUSION

The study concludes that the significant positive impact of organizational capacity highlights that investments in human resources, training, and operational support are foundational to effective risk management.

6. RECOMMENDATION

The study recommends that government and regulatory bodies should strengthen organizational capacity by investing in leadership development, resource allocation, and cross-functional teams to integrate risk management across planning and execution phases.

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