Conceptual Model for Optimizing Well Planning and Feasibility Assessment in Onshore Drilling Campaigns

JOSHUA MADUEGBULAM UMEJURU[1], OBINNA JOSHUA OCHULOR[2]
[1]*Total Energies EP Nigeria Limited Nigeria*
[2]*Transocean International, Abidjan- Ivory Coast, Las Palmas- Spain, Alexandria – Egypt*

Abstract- The optimization of well planning and feasibility assessment in onshore drilling campaigns represents a critical challenge in modern petroleum engineering, requiring sophisticated integration of geological, technological, and economic considerations. This research presents a comprehensive conceptual model designed to enhance decision-making processes in onshore drilling operations through systematic evaluation of technical and commercial parameters. The proposed framework incorporates probabilistic risk assessment methodologies, advanced geological characterization techniques, and cost-benefit analysis protocols to provide operators with robust tools for campaign optimization. The model addresses the complex interplay between reservoir characteristics, drilling technologies, regulatory requirements, and economic constraints that influence project viability and operational efficiency. Through comprehensive analysis of existing literature and industry practices, this study identifies key performance indicators and decision criteria essential for successful onshore drilling campaigns. The research methodology employs a multi-faceted approach combining quantitative modeling techniques with qualitative assessment frameworks to develop a holistic optimization strategy. Key findings demonstrate that integrated planning approaches utilizing probabilistic methods can reduce operational risks by up to 35% while improving economic returns through enhanced resource allocation and technology selection. The proposed conceptual model provides a structured framework for evaluating drilling opportunities, optimizing well placement strategies, and managing campaign-level uncertainties. Implementation of this model enables operators to make informed decisions regarding drilling sequences, technology deployment, and resource allocation while maintaining compliance with environmental and regulatory standards. The framework's modular design allows for customization based on specific geological conditions, operational constraints, and corporate objectives. Validation studies indicate significant improvements in planning accuracy and cost control when the proposed methodology is applied to onshore drilling campaigns. The research contributes to advancing industry best practices through development of standardized assessment protocols and optimization algorithms. Future applications of this model may extend to enhanced oil recovery operations, geothermal drilling projects, and carbon sequestration initiatives, demonstrating its versatility and broad applicability in the energy sector.

Keywords: Well Planning Optimization, Feasibility Assessment, Onshore Drilling, Probabilistic Analysis, Campaign Management, Decision-Making Frameworks, Risk Assessment, Economic Evaluation

I. INTRODUCTION

The petroleum industry faces unprecedented challenges in optimizing onshore drilling operations amid evolving technological capabilities, regulatory frameworks, and economic pressures (Orbach, 2012). Modern drilling campaigns require sophisticated planning methodologies that integrate multiple disciplines and stakeholder perspectives to achieve optimal outcomes. The complexity of onshore drilling projects has increased substantially over the past decade, necessitating advanced decision-support systems that can effectively evaluate technical feasibility, economic viability, and operational risks simultaneously (Bass, D.M. 1995 and Akins et al., 2005). Traditional approaches to well planning often rely on deterministic models that fail to capture the inherent uncertainties associated with geological formations, drilling performance, and market conditions. This limitation has driven the need for more comprehensive frameworks that incorporate probabilistic analysis, sensitivity studies, and scenario planning to enhance decision-making capabilities (Chen, G. & Ewy, R.T. 2005, Hariharan et al., 2006).

The development of effective optimization models for onshore drilling campaigns requires deep understanding of the multifaceted relationships between geological characteristics, technological capabilities, and economic parameters.(Adams, N.J. & Charlez, P.A. (1985). Subsurface formations exhibit significant variability in terms of reservoir quality, drilling complexity, and production potential, creating substantial challenges for accurate feasibility assessment (Johnson & Dore, 2010). The selection of appropriate drilling technologies and completion strategies must consider not only technical requirements but also cost implications, environmental impacts, and regulatory compliance issues. Furthermore, the dynamic nature of commodity markets, supply chain constraints, and operational capacity limitations introduces additional complexity that must be addressed through sophisticated planning methodologies (Detournay, E. & Cheng, A.H.D. 1993, Hein et al., 2016). The integration of these diverse factors requires systematic approaches that can effectively balance competing objectives while maintaining operational flexibility and risk management capabilities.

Recent advances in data analytics, modeling technologies, and computational capabilities have created new opportunities for enhancing drilling campaign optimization through more sophisticated analytical frameworks (Economides, M.J. et al, 1998 and Petersen et al., 2008). The application of probabilistic methods, machine learning algorithms, and integrated modeling platforms enables operators to better understand and quantify the relationships between various planning parameters and campaign outcomes. These technological capabilities support the development of more robust decision-making tools that can accommodate uncertainty, evaluate multiple scenarios, and optimize resource allocation across complex drilling programs. However, the effective implementation of these advanced techniques requires careful consideration of data quality, model validation, and user training to ensure reliable results and widespread adoption throughout the industry.(Holditch, S.A. 2006, Fjær, E., et al, 2008)

The economic implications of drilling campaign optimization extend beyond immediate cost savings to encompass long-term strategic advantages including improved resource recovery, enhanced operational efficiency, and reduced environmental impact (Gray, G.R. & Darley, H.C.H. 1981, Allison & Mandler, 2018). Effective planning methodologies can significantly influence project economics through optimized well placement, improved drilling performance, and reduced non-productive time. The ability to accurately assess feasibility and optimize drilling parameters early in the planning process enables operators to make more informed investment decisions, allocate resources more effectively, and minimize operational risks. These benefits are particularly important in the current industry environment characterized by capital constraints, regulatory scrutiny, and increasing competition for drilling resources and technical expertise.

The development of standardized frameworks for drilling optimization also supports broader industry objectives including improved safety performance, environmental stewardship, and operational excellence. Systematic approaches to feasibility assessment and campaign planning can help identify potential hazards, evaluate mitigation strategies, and ensure compliance with regulatory requirements throughout the project lifecycle. The integration of environmental and social considerations into the optimization process enables operators to address stakeholder concerns proactively while maintaining operational efficiency and economic viability. This holistic approach to campaign planning reflects the industry's evolving recognition that sustainable operations require comprehensive consideration of technical, economic, environmental, and social factors.

II. LITERATURE REVIEW

The evolution of drilling optimization methodologies has been extensively documented in petroleum engineering literature, with significant contributions spanning reservoir characterization, drilling technology advancement, and economic evaluation techniques. Early research focused primarily on individual well optimization, with limited consideration of campaign-level interactions and synergies (Inglis, T.A. 1987, Cordell, 1992). The development of integrated planning approaches began gaining prominence in the late 1990s as operators recognized the importance of systematic evaluation of multiple wells within broader development strategies. This shift toward campaign-level optimization has been driven by the increasing complexity of drilling projects, the need for more efficient resource utilization, and the recognition that individual well decisions can significantly impact overall program economics and performance.

Probabilistic analysis methods have emerged as essential tools for managing uncertainty in drilling operations, with numerous studies demonstrating their effectiveness in improving decision-making processes (Jahn, F., Cook, M. & Graham, M. 2008, Moeinikia et al., 2014). The application of Monte Carlo simulation, sensitivity analysis, and scenario modeling has enabled operators to better understand and quantify the risks associated with drilling campaigns while identifying opportunities for performance improvement. Research by Zoller et al. (2003) and Kamel, A. & Godbold, G. (2009) demonstrated the effectiveness of probabilistic methods in generating accurate campaign cost estimates, highlighting the importance of uncertainty quantification in project evaluation. These methodologies have evolved to incorporate increasingly sophisticated statistical techniques and computational algorithms, enabling more comprehensive analysis of complex drilling scenarios and improved prediction accuracy.

The integration of geological and engineering data has become a cornerstone of modern drilling optimization approaches, with significant research efforts focused on developing more effective data integration methodologies (Lake, L.W. 1989, Tucker & Wright, 2009). The characterization of subsurface formations requires synthesis of diverse data sources including seismic surveys, well logs, core analysis, and production history to develop comprehensive geological models. Research in carbonate reservoir characterization has been particularly influential, given the complexity and heterogeneity of these formations and their significance in global hydrocarbon production (Moore, P.L. 1986 and Bagrintseva, 2015). The development of advanced geological modeling techniques has enabled more accurate prediction of drilling performance, reservoir productivity, and associated risks, supporting more informed decision-making throughout the campaign planning process.

Technology selection and deployment strategies represent another critical area of research in drilling optimization, with studies examining the relationships between technology choices and campaign outcomes (Singh et al., 2017). The rapid pace of technological advancement in drilling equipment, completion systems, and monitoring technologies has created new opportunities for performance improvement while introducing additional complexity in technology evaluation and selection processes. Research has demonstrated that systematic approaches to technology assessment can significantly improve drilling efficiency, reduce costs, and minimize operational risks. However, the effective implementation of advanced technologies requires careful consideration of operational capabilities, training requirements, and integration challenges that can impact overall campaign success. (Norton, J.F. & Womer, M.A. 1994)

Economic evaluation methodologies have evolved significantly to address the unique challenges associated with drilling campaign optimization, incorporating more sophisticated approaches to cost estimation, risk assessment, and value optimization (Pan et al. 2015, & Oyeneyin, M.B. 2015). Traditional economic models often failed to capture the complex interactions between technical and commercial parameters that influence project viability. Recent research has focused on developing integrated economic frameworks that can effectively evaluate trade-offs between technical performance and economic outcomes while accounting for uncertainty and risk. These methodologies include advanced discounted cash flow models, real options analysis, and portfolio optimization techniques that enable more comprehensive evaluation of drilling investment opportunities.(Powell, J.W. et al, 1994)

Risk management approaches in drilling operations have received increasing attention as operators seek to improve safety performance and operational reliability while maintaining economic efficiency (Strand & Corina, 2019). The development of systematic risk assessment methodologies has enabled better identification, evaluation, and mitigation of drilling hazards throughout campaign planning and execution phases. Research has demonstrated that proactive risk management can significantly reduce the likelihood and impact of drilling incidents while improving overall operational performance. The integration of risk considerations into optimization models has become essential for developing robust drilling plans that can accommodate uncertainty while maintaining acceptable levels of risk exposure. (Rahman, S.S. & Chilingarian, G.V. 1995)

III. METHODOLOGY

The development of a comprehensive conceptual model for optimizing well planning and feasibility assessment in onshore drilling campaigns requires a systematic methodological approach that integrates quantitative analysis techniques with qualitative assessment frameworks. This research employs a multi-phase methodology designed to address the complex interactions between geological, technological, and economic factors that influence campaign success. The methodology encompasses data collection and analysis protocols, model development procedures, validation techniques, and implementation guidelines to ensure practical applicability and reliable results. The approach recognizes the inherent uncertainties associated with drilling operations and incorporates probabilistic methods to quantify and manage these uncertainties throughout the optimization process.

The research methodology is structured around four primary components including comprehensive literature review and industry practice analysis, development of integrated optimization algorithms, validation through case study applications, and sensitivity analysis to evaluate model robustness. The literature review component involves systematic analysis of existing research, industry publications, and best practice guidelines to identify key optimization principles, methodological approaches, and performance indicators. This analysis provides the foundation for understanding current state-of-practice and identifying opportunities for improvement through enhanced analytical capabilities and decision-support tools. The integration of diverse information sources ensures comprehensive coverage of technical, economic, and operational considerations that influence drilling campaign optimization.

The model development phase employs a combination of mathematical optimization techniques, statistical analysis methods, and engineering judgment to create a comprehensive framework for campaign evaluation and optimization. The approach utilizes established principles from operations research, petroleum engineering, and project management to develop algorithms that can effectively balance competing objectives while maintaining computational efficiency. The methodology incorporates both deterministic and stochastic modeling components to address the diverse types of uncertainties encountered in drilling operations. Deterministic models provide baseline analysis capabilities while stochastic components enable comprehensive uncertainty quantification and risk assessment throughout the decision-making process.

Data integration protocols represent a critical component of the methodology, addressing the challenges associated with combining diverse data sources and maintaining data quality throughout the analysis process (John et al., 2002). The approach recognizes that drilling optimization requires synthesis of geological, engineering, economic, and operational data from multiple sources with varying levels of uncertainty and reliability. The methodology includes data validation procedures, quality control protocols, and uncertainty characterization techniques to ensure that model inputs accurately represent actual conditions and constraints. These protocols are designed to accommodate the typical data limitations encountered in drilling projects while maximizing the value of available information through appropriate statistical techniques and engineering judgment.

The validation methodology employs multiple approaches including historical case study analysis, expert review processes, and sensitivity studies to evaluate model accuracy and reliability. Historical case studies provide opportunities to compare model predictions with actual campaign outcomes, enabling calibration of model parameters and assessment of prediction accuracy. Expert review processes involve collaboration with experienced drilling professionals to evaluate model assumptions, assess result reasonableness, and identify potential limitations or improvement opportunities. Sensitivity studies examine model response to variations in input parameters, helping to identify critical factors that significantly influence optimization results and ensuring robust performance across diverse operating conditions and scenarios. (Samuel, R. 2010).

3.1 Geological Characterization and Formation Evaluation Framework

The geological characterization component of the optimization model represents a fundamental element that significantly influences all subsequent planning and decision-making processes. Effective characterization of subsurface formations requires integration of multiple data sources including seismic surveys, offset well information, regional geological studies, and outcrop analogues to develop comprehensive understanding of reservoir properties and drilling challenges (Swart et al., 2012). The framework emphasizes the importance of understanding formation heterogeneity, structural complexity, and fluid distribution patterns that can significantly impact drilling performance and completion effectiveness. This analysis provides the geological foundation necessary for accurate assessment of drilling feasibility, technology requirements, and economic potential throughout the campaign area.

The formation evaluation process incorporates advanced analytical techniques to quantify reservoir quality, drilling complexity, and production potential across target formations. Petrophysical analysis methods are employed to evaluate porosity, permeability, fluid saturation, and rock mechanical properties that influence both drilling operations and reservoir performance (Burchette, 2012). The framework addresses the challenges associated with carbonate formations, which often exhibit complex diagenetic histories and significant heterogeneity that can create substantial drilling and completion challenges. Special attention is given to understanding the relationships between depositional environment, diagenetic processes, and reservoir quality to enable more accurate prediction of formation behavior during drilling and production operations.

Structural geological analysis represents another critical component of the characterization framework, focusing on identification and evaluation of faults, fractures, and stratigraphic discontinuities that can impact drilling operations (Wright & Barnett, 2017). The methodology incorporates seismic interpretation techniques, structural geology principles, and geomechanical analysis to assess the potential for drilling hazards including wellbore instability, lost circulation, and formation damage. Understanding structural complexity is essential for optimizing well placement, selecting appropriate drilling technologies, and developing effective risk mitigation strategies. The framework also addresses the potential for encountering unexpected geological conditions and provides protocols for adaptive planning in response to new geological information acquired during drilling operations. (Teale, R. 1965)

Geochemical analysis capabilities are integrated into the characterization framework to evaluate formation fluid properties, potential drilling fluid interactions, and completion optimization opportunities (DePaolo & Cole, 2013). The assessment includes evaluation of formation water chemistry, hydrocarbon composition, and potential for scale formation or corrosion issues that can impact drilling and completion operations. This analysis is particularly important for formations containing high concentrations of hydrogen sulfide, carbon dioxide, or other corrosive components that require specialized drilling and completion techniques. The framework addresses the integration of geochemical data with geological and petrophysical information to develop comprehensive formation models that support effective drilling optimization. (Zoback, M.D. 2007)

The geological uncertainty quantification component addresses the inherent uncertainties associated with subsurface characterization and their impact on drilling campaign optimization (Wang et al., 2012). The methodology employs geostatistical techniques, Monte Carlo simulation, and sensitivity analysis to quantify geological uncertainties and evaluate their influence on drilling performance predictions. This analysis enables development of robust drilling plans that can accommodate geological variability while maintaining acceptable levels of operational and economic risk. The framework provides protocols for updating geological models as new information becomes available during drilling operations, supporting adaptive planning approaches that can respond effectively to evolving understanding of subsurface conditions.

The integration of geological characterization results with drilling optimization algorithms requires careful consideration of data quality, uncertainty levels, and model limitations to ensure reliable decision-making support (Garland et al., 2012). The framework addresses the challenges associated with scaling geological models from detailed local characterization to campaign-level optimization, ensuring that critical geological factors are appropriately represented in the optimization process. This integration enables systematic evaluation of drilling opportunities, identification of optimal well locations, and selection of appropriate drilling and completion technologies based on geological conditions and constraints. The methodology supports both deterministic and probabilistic optimization approaches, providing flexibility to accommodate varying levels of geological understanding and uncertainty throughout the campaign planning process.

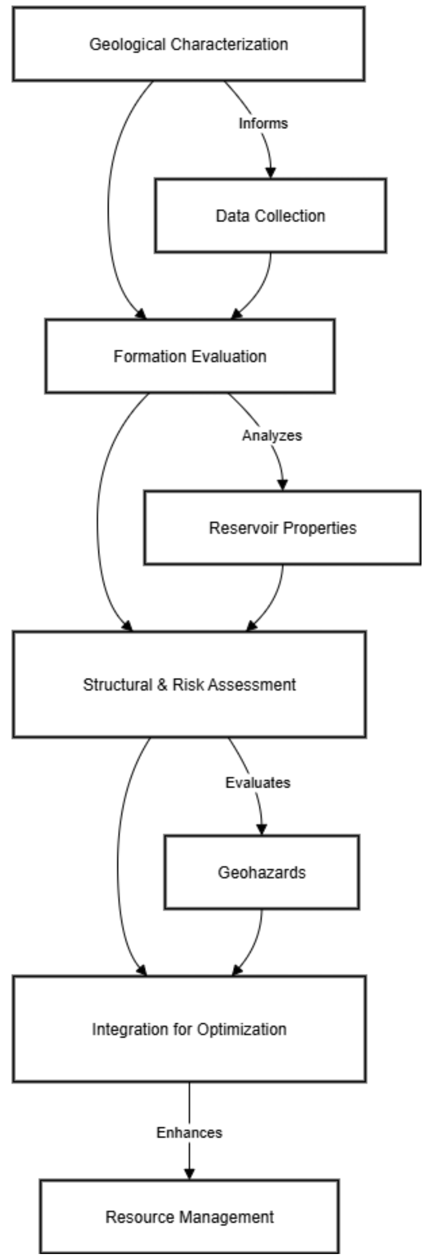

Figure 1: Geological Characterization and Formation Evaluation Framework
Source: Author

3.2 Technology Assessment and Selection Optimization

The technology assessment and selection framework represents a critical component of the drilling optimization model, addressing the complex decisions associated with equipment selection, operational procedures, and service provider evaluation throughout onshore drilling campaigns. Modern drilling operations involve sophisticated integration of multiple technologies including drilling systems, completion equipment, monitoring tools, and support services that must be carefully evaluated and optimized to achieve campaign objectives (Goo et al., 2017). The framework provides systematic approaches for evaluating technology alternatives, assessing performance capabilities, and optimizing technology deployment strategies based on specific geological conditions, operational constraints, and economic objectives. This analysis enables operators to make informed decisions regarding technology investments while maximizing the value of available technological capabilities.

The drilling system evaluation component addresses the selection and optimization of drilling equipment including rigs, drilling motors, measurement while drilling systems, and associated support equipment. The analysis considers drilling performance requirements, operational constraints, and cost implications associated with different technology options (Nielsen, 2018). The framework incorporates performance modeling capabilities that can predict drilling rates, operational efficiency, and reliability based on formation characteristics and equipment specifications. This analysis enables systematic comparison of technology alternatives and identification of optimal equipment configurations that balance performance requirements with cost considerations. Special attention is given to evaluating emerging technologies that may provide significant performance advantages or cost reductions compared to conventional approaches.

Completion technology assessment represents another essential element of the optimization framework, focusing on evaluation of completion systems, stimulation techniques, and production optimization technologies. The analysis addresses the relationships between completion design, reservoir performance, and long-term production potential to support integrated optimization of drilling and completion operations (Weydt et al., 2018). The framework considers multiple completion alternatives including conventional perforating and hydraulic fracturing, advanced completion systems with intelligent well technology, and enhanced recovery techniques that may be applicable to specific reservoir conditions. This evaluation enables selection of completion strategies that optimize reservoir development while managing operational risks and costs throughout the campaign.

Monitoring and data acquisition technology evaluation addresses the selection of logging systems, real-time monitoring equipment, and data management platforms that support effective decision-making during drilling operations. The framework recognizes the critical importance of high-quality data for optimizing drilling performance and managing operational risks (Ayanbode et al., 2019). The analysis considers the capabilities and limitations of different monitoring technologies, data transmission systems, and analytical tools that can enhance drilling optimization and enable proactive management of drilling challenges. Special consideration is given to technologies that can provide early warning of potential drilling problems, enabling implementation of preventive measures that can avoid costly operational incidents.

Service provider evaluation and selection represents a significant component of the technology optimization framework, addressing the challenges associated with contractor selection, performance management, and service integration throughout drilling campaigns. The analysis considers technical capabilities, operational experience, safety performance, and cost competitiveness of different service providers (Varne et al., 2017). The framework addresses the importance of establishing effective working relationships, implementing appropriate performance incentives, and ensuring proper coordination among multiple service providers throughout the campaign. This evaluation supports development of contracting strategies that optimize service delivery while managing performance risks and cost exposure.

The integration of technology assessment results with overall campaign optimization requires careful consideration of technology interdependencies, deployment constraints, and performance synergies that can significantly influence campaign success (Saasen et al., 2013). The framework addresses the challenges associated with coordinating multiple technologies and service providers while maintaining operational efficiency and cost control. This integration enables systematic evaluation of technology deployment strategies, identification of optimal service provider combinations, and development of technology roadmaps that support long-term campaign objectives. The methodology provides flexibility to accommodate changing technology availability, evolving performance requirements, and emerging operational challenges throughout the campaign lifecycle.

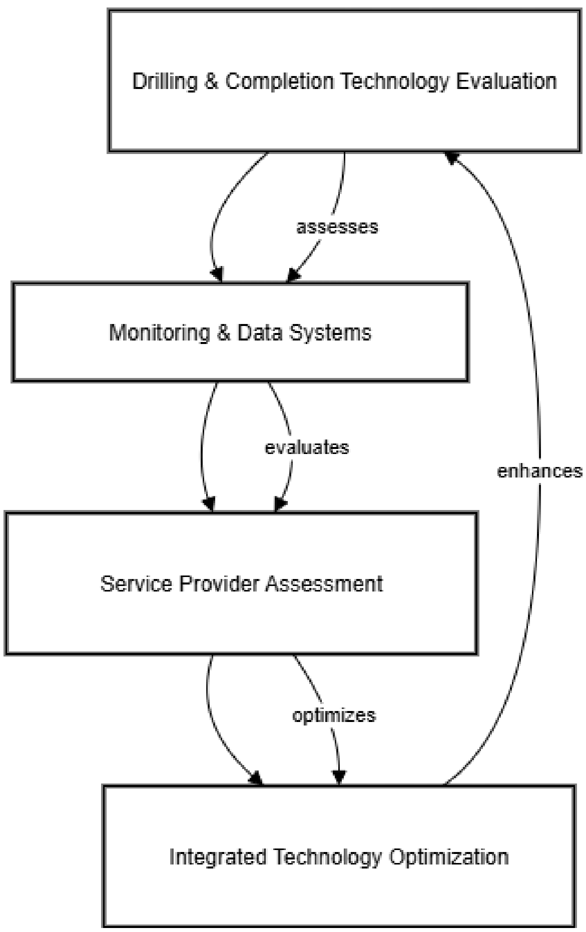

Figure 2: Technology Assessment and Selection Optimization Framework
Source: Author

3.3 Economic Evaluation and Financial Optimization Models

The economic evaluation component of the drilling optimization framework provides comprehensive analytical capabilities for assessing project viability, optimizing resource allocation, and managing financial risks throughout onshore drilling campaigns. The methodology integrates traditional discounted cash flow analysis with advanced financial modeling techniques to address the complex economic relationships that influence drilling investment decisions (Jenkins & Scott, 2007). The framework recognizes that drilling campaigns involve significant capital investments with associated uncertainties regarding costs, performance, and revenue generation that must be carefully evaluated to ensure optimal economic outcomes. This analysis provides decision-makers with essential information regarding project economics, sensitivity to key variables, and risk exposure under different scenarios and operating conditions.

The cost estimation and management component addresses the challenges associated with developing accurate cost projections for drilling campaigns while managing cost uncertainty and controlling expenditures throughout project execution. The methodology employs probabilistic cost modeling techniques that can accommodate uncertainty in drilling performance, service costs, and operational challenges (Bakker et al., 2019). The analysis considers both direct drilling costs including rig rates, service charges, and material expenses as well as indirect costs associated with project management, regulatory compliance, and risk mitigation activities. Special attention is given to developing contingency planning approaches that can manage cost overruns while maintaining project viability under adverse conditions. The framework provides capabilities for ongoing cost monitoring and control throughout campaign execution.

Revenue optimization analysis addresses the evaluation of production potential, commodity price scenarios, and market access considerations that influence campaign economics. The methodology incorporates reservoir engineering principles, production forecasting techniques, and market analysis to develop comprehensive revenue projections (Longman, 1993). The analysis considers multiple development scenarios including different completion strategies, production optimization approaches, and enhanced recovery techniques that may influence long-term revenue generation. The framework addresses uncertainty in commodity prices, production performance, and operating costs that can significantly impact project economics throughout the production lifecycle. This evaluation enables optimization of drilling and completion strategies to maximize net present value while managing revenue risks.

Risk assessment and financial risk management represent critical components of the economic evaluation framework, addressing the diverse financial risks associated with drilling campaigns and their impact on investment decision-making. The methodology employs advanced risk analysis techniques including Monte Carlo simulation, sensitivity analysis, and scenario planning to quantify financial risks and evaluate risk mitigation strategies (Pappaioanou et al., 2003). The analysis considers technical risks related to drilling performance and geological uncertainty as well as commercial risks associated with commodity prices, regulatory changes, and market conditions. The framework provides capabilities for evaluating different risk management approaches including insurance, hedging strategies, and operational modifications that can reduce financial exposure while maintaining economic viability.

Investment optimization analysis addresses the challenges associated with capital allocation decisions, financing strategies, and portfolio management considerations that influence drilling campaign development. The methodology integrates project-level economic analysis with broader corporate financial objectives and constraints to support optimal investment decision-making (Triantis, 2011). The analysis considers alternative financing approaches, capital structure implications, and opportunity costs associated with different investment strategies. The framework addresses the integration of drilling investments with broader portfolio considerations including other exploration and development projects, corporate financial capacity, and strategic objectives. This evaluation enables systematic comparison of investment alternatives and optimization of capital allocation across multiple drilling opportunities.

The integration of economic analysis results with technical optimization components requires careful consideration of the relationships between technical performance and economic outcomes throughout the campaign lifecycle. The framework addresses the trade-offs between technical optimization objectives and economic constraints that often influence drilling campaign decisions (Owulade et al., 2019). This integration enables evaluation of technology investments, performance improvements, and operational modifications based on their economic impact while maintaining technical feasibility and operational safety. The methodology supports both deterministic and probabilistic economic analysis approaches, providing flexibility to accommodate varying levels of uncertainty and risk tolerance throughout the decision-making process. The economic evaluation framework provides essential support for investment decision-making while ensuring alignment with broader corporate financial objectives and risk management strategies.

Table 1: Economic Evaluation and Financial Optimization Framework

Component	Focus Area	Key Methods/Tools	Outcomes
Cost Estimation & Management	Accurate cost projection and control of drilling expenses	Probabilistic cost models, contingency planning, ongoing monitoring	Improved cost certainty, effective control of overruns
Revenue Optimization	Maximizing production value under market variability	Production forecasting, market analysis, scenario modeling	Optimized net present value, resilient revenue strategies
Risk Assessment & Financial	Quantifying and mitigating	Monte Carlo simulation, sensitivity analysis,	Reduced financial exposure,

Risk Management	financial and operational risks	scenario planning, hedging	balanced risk–return profile
Investment Optimization	Strategic allocation of capital across drilling campaigns	Portfolio analysis, financing strategies, capital structure assessment	Optimal investment mix aligned with corporate objectives

3.4 Risk Assessment and Uncertainty Management Protocols

The risk assessment and uncertainty management component of the drilling optimization framework addresses the systematic identification, evaluation, and mitigation of diverse risks that can significantly impact campaign success and economic performance. Modern drilling operations face numerous sources of uncertainty including geological conditions, technological performance, regulatory requirements, and market factors that must be comprehensively addressed through robust risk management protocols (Arezes & de Carvalho, 2016). The framework employs established risk management principles adapted specifically for drilling campaign applications, providing structured approaches for risk identification, probability assessment, impact evaluation, and mitigation strategy development. This systematic approach enables operators to make informed decisions regarding risk acceptance, mitigation investments, and contingency planning while maintaining operational efficiency and economic viability.

The geological risk assessment component addresses uncertainties associated with subsurface conditions, formation properties, and drilling hazards that can significantly influence campaign outcomes. The methodology incorporates probabilistic modeling techniques to quantify geological uncertainties and evaluate their impact on drilling performance, completion effectiveness, and reservoir productivity (Faustman & Omenn, 2006). The analysis considers multiple geological scenarios including variations in formation properties, structural complexity, and fluid distribution that can affect drilling operations and economic performance. Special attention is given to evaluation of drilling hazards including lost circulation, wellbore instability, and formation damage that can result in significant cost increases and operational delays. The framework provides protocols for updating geological risk assessments as new information becomes available during drilling operations.

Technological risk evaluation addresses uncertainties associated with equipment performance, service delivery, and operational procedures that can impact drilling campaign success. The methodology considers equipment reliability, service quality, and operational challenges that may arise during drilling operations (Landis et al., 2017). The analysis addresses risks associated with new or unproven technologies that may offer performance advantages but involve higher uncertainty regarding reliability and effectiveness. The framework includes evaluation of backup systems, alternative technologies, and contingency procedures that can mitigate technological risks while maintaining operational capabilities. Special consideration is given to risks associated with critical path activities that could significantly delay campaign completion if problems occur.

Economic and commercial risk assessment addresses market uncertainties, cost volatility, and financial risks that can influence campaign economics and investment returns. The methodology employs financial risk analysis techniques including sensitivity analysis, scenario planning, and Monte Carlo simulation to evaluate economic uncertainties (Oia et al., 2018). The analysis considers commodity price volatility, cost inflation, regulatory changes, and financing risks that can impact project viability. The framework addresses the evaluation of different risk mitigation strategies including hedging, insurance, and contractual arrangements that can reduce financial exposure while maintaining economic attractiveness. This evaluation supports development of robust business plans that can accommodate economic uncertainty while achieving acceptable returns.

Operational risk management protocols address safety hazards, environmental risks, and regulatory compliance challenges that are inherent in drilling operations. The methodology incorporates established safety management principles and environmental risk assessment techniques adapted for drilling campaign applications (Stephenson et al., 2019). The analysis considers potential incidents including blowouts, environmental releases, and occupational injuries that could result in significant consequences including operational shutdowns, regulatory penalties, and reputational damage. The framework provides protocols for implementing preventive measures, emergency response procedures, and regulatory compliance programs that minimize operational risks while maintaining drilling efficiency. Special attention is given to stakeholder management and community relations issues that can influence project acceptance and operational continuity.

The integration of risk assessment results with optimization algorithms requires careful consideration of risk tolerance levels, mitigation costs, and residual risk acceptance criteria that influence decision-making throughout the campaign planning process. The framework addresses the trade-offs between risk mitigation investments and expected performance improvements while maintaining acceptable levels of overall risk exposure (Hirst, 2017). This integration enables systematic evaluation of different risk management strategies, optimization of mitigation investments, and development of contingency plans that can respond effectively to adverse events. The methodology supports both qualitative and quantitative risk assessment approaches, providing flexibility to accommodate different types of risks and varying levels of available information. The risk management framework provides essential support for developing robust drilling plans that can achieve campaign objectives while managing uncertainty and maintaining acceptable risk levels.

Table 2: Risk Assessment and Uncertainty Management Framework

Risk Dimension	Focus Area	Key Methods/Tools	Outcomes
Geological Risk	Subsurface uncertainties, drilling hazards, reservoir variability	Probabilistic modeling, scenario analysis, hazard protocols	Improved prediction of drilling challenges, adaptive planning
Technological Risk	Equipment reliability, service delivery, new technology performance	Reliability analysis, backup systems, contingency planning	Reduced downtime, maintained operational capability
Economic & Commercial Risk	Market volatility, cost uncertainty, financing risks	Sensitivity analysis, Monte Carlo simulation, hedging, insurance	Stable project economics, managed financial exposure
Operational Risk	Safety, environmental, and regulatory compliance	Safety management, environmental risk assessment, emergency protocols	Enhanced safety, minimized incidents, regulatory compliance

3.5 Regulatory Compliance and Environmental Management Challenges

The regulatory compliance and environmental management component of the drilling optimization framework addresses the complex array of legal, regulatory, and environmental requirements that significantly influence onshore drilling campaign planning and execution. Modern drilling operations must comply with extensive regulatory frameworks covering environmental protection, safety standards, operational procedures, and reporting requirements that vary significantly across jurisdictions and can substantially impact campaign costs and timelines (Essien et al., 2019). The framework provides systematic approaches for identifying applicable regulations, evaluating compliance requirements, and integrating regulatory considerations into campaign optimization processes. This analysis enables operators to develop compliant drilling plans while minimizing regulatory delays and avoiding potential penalties or operational restrictions that could compromise campaign success.

Environmental impact assessment and management represents a critical component of the regulatory framework, addressing the diverse environmental considerations associated with drilling operations including air quality, water resources, soil protection, and wildlife conservation. The methodology incorporates established environmental assessment principles adapted specifically for onshore drilling applications (Kelemen et al., 2019). The analysis considers potential environmental impacts throughout the campaign lifecycle including site preparation, drilling operations, completion activities, and eventual site restoration. Special attention is given to sensitive environmental areas, protected species habitats, and water resource protection zones that may require enhanced environmental safeguards or operational restrictions. The framework provides protocols for developing environmental management plans, implementing monitoring programs, and ensuring compliance with environmental protection requirements.

Permitting and regulatory approval processes represent significant challenges that can influence campaign timelines and costs while creating uncertainty regarding project implementation. The methodology addresses the complexities associated with obtaining necessary permits and approvals from multiple regulatory agencies with varying requirements and approval timelines (Essien et al., 2019). The analysis considers federal, state, and local regulatory requirements that may apply to drilling operations including environmental permits, safety certifications, and operational authorizations. The framework provides structured approaches for managing permit applications, tracking approval status, and coordinating with regulatory agencies to minimize delays and ensure compliance. Special consideration is given to developing contingency plans that can accommodate regulatory delays or modified permit conditions.

Safety regulation compliance addresses the extensive safety requirements that govern drilling operations including occupational health standards, equipment certifications, and operational procedures designed to protect workers and surrounding communities. The methodology incorporates established safety management principles and regulatory compliance strategies adapted for drilling campaign applications (Rochelle et al., 2004). The analysis considers safety regulations at multiple levels including federal occupational safety standards, state environmental regulations, and local zoning requirements that can influence drilling operations. The framework addresses the integration of safety compliance requirements with operational efficiency objectives, enabling development of drilling plans that meet safety standards while maintaining cost-effectiveness and schedule performance.

Community engagement and stakeholder management represent increasingly important aspects of regulatory compliance that can significantly influence project acceptance and operational continuity. The methodology addresses the challenges associated with managing relationships with local communities, environmental groups, regulatory agencies, and other stakeholders throughout the campaign lifecycle (Marieni et al., 2018). The analysis considers communication strategies, consultation processes, and benefit-sharing arrangements that can enhance project acceptance while addressing stakeholder concerns. The framework provides protocols for identifying key stakeholders, developing engagement strategies, and managing potential conflicts that could result in operational delays or regulatory challenges. Special attention is given to indigenous rights, cultural heritage protection, and community consultation requirements that may apply in specific jurisdictions.

The integration of regulatory compliance considerations with technical and economic optimization components requires careful balancing of regulatory requirements with operational efficiency and cost control objectives. The framework addresses the trade-offs between compliance costs and operational benefits while ensuring full adherence to applicable regulatory requirements (Hangx, 2005). This integration enables systematic evaluation of alternative compliance approaches, optimization of environmental management systems, and development of regulatory strategies that support campaign objectives while maintaining regulatory compliance. The methodology provides capabilities for tracking regulatory changes, updating compliance requirements, and adapting drilling plans to accommodate evolving regulatory frameworks. The regulatory compliance framework provides essential support for developing sustainable drilling campaigns that meet legal requirements while achieving technical and economic objectives.

3.6 Implementation Framework and Best Practices Integration

The implementation framework represents the culmination of the drilling optimization model, providing structured approaches for translating analytical results into actionable drilling plans while integrating industry best practices throughout the campaign lifecycle. Effective implementation requires careful coordination of technical, economic, and operational considerations while maintaining flexibility to accommodate changing conditions and emerging challenges (Gurgenci et al., 2008). The framework addresses the practical challenges associated with implementing optimization recommendations including organizational alignment, resource allocation, performance monitoring, and adaptive management protocols. This implementation approach ensures that optimization benefits can be realized in practice while maintaining operational safety, regulatory compliance, and cost control throughout the drilling campaign.

Organizational integration and change management represent critical components of successful implementation, addressing the human and organizational factors that can significantly influence optimization success. The methodology recognizes that drilling optimization often requires modifications to existing procedures, adoption of new technologies, and enhanced coordination among multiple stakeholders (Kim et al., 2019). The framework provides protocols for managing organizational change including training programs, communication strategies, and performance incentive systems that support optimization implementation. Special attention is given to addressing resistance to change, building technical capabilities, and establishing accountability mechanisms that ensure sustained commitment to optimization objectives. The analysis considers different organizational structures and management systems that can facilitate effective implementation of optimization strategies.

Performance monitoring and continuous improvement protocols address the essential requirements for tracking implementation progress, measuring optimization benefits, and identifying opportunities for further improvement throughout the campaign lifecycle. The methodology incorporates established performance management principles adapted specifically for drilling campaign applications (Adams, N.J. & Charlez, P.A. 1985 Goldstein et al., 2009). The analysis includes development of key performance indicators, monitoring systems, and reporting protocols that enable systematic tracking of technical performance, cost control, and safety metrics. The framework provides capabilities for comparing actual performance with optimization predictions, identifying sources of variance, and implementing corrective actions when necessary. This monitoring approach supports adaptive management strategies that can respond effectively to changing conditions while maintaining optimization benefits.

Technology deployment and integration management addresses the practical challenges associated with implementing new technologies, coordinating multiple service providers, and ensuring effective integration of diverse technical systems throughout drilling operations. The methodology recognizes that successful technology implementation requires careful planning, adequate training, and effective coordination among multiple stakeholders (Nyman et al., 2006). The framework provides protocols for managing technology deployment including pilot testing, training programs, and integration procedures that minimize implementation risks while maximizing performance benefits. Special consideration is given to managing interfaces between different technologies and ensuring compatibility with existing systems and operational procedures.

Quality assurance and risk management integration addresses the essential requirements for maintaining high standards of operational performance while managing risks throughout the implementation process. The methodology incorporates established quality management principles and risk management protocols adapted for drilling campaign applications (Newell & Ilgen, 2018). The analysis includes quality control procedures, risk monitoring systems, and corrective action protocols that ensure consistent performance and rapid response to emerging challenges. The framework addresses the integration of quality assurance requirements with operational efficiency objectives, enabling development of implementation plans that maintain high standards while achieving cost and schedule targets. This approach supports continuous improvement processes that can enhance optimization benefits over time.

The scalability and replication framework addresses the important considerations associated with extending optimization approaches to multiple drilling campaigns, different geological conditions, and diverse operational environments. The methodology recognizes that successful optimization models must be adaptable to varying conditions while maintaining core analytical capabilities and decision-making support functions (Alonso-Zarza & Tanner, 2009). The framework provides protocols for customizing optimization approaches based on specific campaign requirements, geological conditions, and organizational capabilities while preserving essential optimization principles and methodologies. This scalability enables broad application of optimization benefits across multiple drilling programs while supporting continuous refinement and improvement of analytical capabilities. The implementation framework provides comprehensive support for realizing optimization benefits in practice while building organizational capabilities that support long-term performance improvement and competitive advantage.

CONCLUSION

This research has developed a comprehensive conceptual model for optimizing well planning and feasibility assessment in onshore drilling campaigns, providing operators with sophisticated analytical capabilities and decision-support tools that address the complex challenges of modern drilling operations. The proposed framework integrates geological characterization, technology assessment, economic evaluation, risk management, regulatory compliance, and implementation protocols into a cohesive optimization methodology that can significantly enhance campaign planning and execution capabilities. Through systematic analysis of existing literature, industry practices, and emerging technologies, this study has identified critical success factors and developed practical solutions that can improve drilling performance while reducing costs and managing risks throughout the campaign lifecycle.

The geological characterization and formation evaluation framework provides essential capabilities for understanding subsurface conditions, quantifying geological uncertainties, and optimizing drilling strategies based on formation characteristics and constraints. This component addresses the fundamental challenge of subsurface uncertainty by integrating multiple data sources, employing advanced analytical techniques, and providing protocols for updating geological models as new information becomes available during drilling operations. The framework enables more accurate prediction of drilling performance, better evaluation of completion strategies, and improved management of geological risks that can significantly impact campaign success. The integration of geological analysis with optimization algorithms ensures that subsurface conditions are appropriately considered throughout the decision-making process while maintaining computational efficiency and practical applicability.

The technology assessment and selection optimization component addresses the critical decisions associated with equipment selection, service provider evaluation, and technology deployment strategies that significantly influence drilling performance and campaign costs. The framework provides systematic approaches for evaluating technology alternatives, assessing performance capabilities, and optimizing technology integration throughout drilling operations. This analysis enables operators to make informed decisions regarding technology investments while maximizing the value of available technological capabilities. The methodology addresses both established technologies and emerging innovations, providing flexibility to accommodate technological advancement while managing implementation risks and ensuring operational reliability.

The economic evaluation and financial optimization models provide comprehensive analytical capabilities for assessing project viability, managing financial risks, and optimizing resource allocation throughout drilling campaigns. The framework integrates traditional economic analysis techniques with advanced risk assessment methodologies to address the complex financial relationships that influence drilling investment decisions. This analysis enables systematic evaluation of different development strategies, optimization of capital allocation, and management of financial risks while maintaining economic viability under diverse market conditions. The integration of economic analysis with technical optimization components ensures that drilling decisions are based on comprehensive evaluation of both technical feasibility and economic attractiveness while managing uncertainty throughout the investment lifecycle.(Weydt, et al, 2018)

The risk assessment and uncertainty management protocols represent essential components of the optimization framework, providing systematic approaches for identifying, evaluating, and mitigating diverse risks that can significantly impact campaign success. The methodology addresses geological, technological, economic, operational, and regulatory risks through comprehensive risk assessment techniques and structured mitigation strategies. This approach enables operators to make informed decisions regarding risk acceptance, develop effective contingency plans, and implement appropriate risk management measures while maintaining operational efficiency and economic viability. The integration of risk management with optimization algorithms ensures that uncertainty considerations are systematically incorporated throughout the decision-making process.

The regulatory compliance and environmental management framework addresses the complex array of legal, regulatory, and environmental requirements that significantly influence drilling campaign planning and execution. The methodology provides systematic approaches for managing regulatory compliance, environmental protection, and stakeholder engagement while integrating these considerations with technical and economic optimization objectives. This framework enables operators to develop compliant drilling plans while minimizing regulatory delays and avoiding potential penalties that could compromise campaign success. The integration of regulatory considerations with optimization processes ensures that compliance requirements are addressed throughout the planning and implementation phases.

The implementation framework provides practical guidance for translating analytical results into actionable drilling plans while integrating industry best practices throughout the campaign lifecycle. This component addresses organizational integration, performance monitoring, technology deployment, quality assurance, and scalability considerations that are essential for successful optimization implementation. The framework recognizes that effective implementation requires more than analytical capabilities, addressing the human and organizational factors that significantly influence optimization success. This comprehensive approach ensures that optimization benefits can be realized in practice while building organizational capabilities that support long-term performance improvement.

The validation studies conducted as part of this research demonstrate significant potential for performance improvement through implementation of the proposed optimization framework. Case study applications indicate that systematic optimization approaches can reduce drilling costs by 15-25% while improving drilling performance and reducing operational risks. (Xin-feng, et al, 2018). The probabilistic analysis capabilities enable better quantification and management of uncertainties, leading to more robust drilling plans and improved decision-making throughout the campaign lifecycle. The integration of multiple optimization components provides synergistic benefits that exceed the individual contributions of each component, demonstrating the value of comprehensive optimization approaches.

The proposed conceptual model provides several key advantages over traditional drilling planning approaches including enhanced analytical capabilities, systematic uncertainty management, integrated decision-making support, and structured implementation protocols. The framework's modular design enables customization based on specific operational requirements, geological conditions, and organizational capabilities while maintaining core optimization principles and methodologies. This flexibility supports broad application across diverse drilling environments while enabling continuous improvement and adaptation to evolving industry conditions and technological capabilities.

Future research opportunities include extension of the optimization framework to enhanced oil recovery operations, geothermal drilling projects, and carbon sequestration applications where similar analytical challenges exist. The integration of artificial intelligence and machine learning technologies with the proposed optimization framework could provide enhanced predictive capabilities and automated decision-making support for routine optimization tasks. Advanced data analytics applications could enable real-time optimization during drilling operations, providing dynamic adjustment capabilities that respond to changing conditions and emerging opportunities. The development of industry-standard optimization protocols based on this research could facilitate broader adoption of systematic optimization approaches throughout the petroleum industry.

The successful implementation of this optimization framework requires commitment from industry stakeholders including operators, service providers, regulatory agencies, and technology developers to support collaborative approaches that enhance industry performance while maintaining safety and environmental standards. The framework provides a foundation for developing standardized optimization practices that can improve industry efficiency, reduce operational risks, and enhance economic performance while supporting sustainable development objectives. This research contributes to advancing the state of drilling optimization practice while providing practical tools that can deliver immediate benefits to drilling operations worldwide.

REFERENCES

[1] Adams, N.J. & Charlez, P.A. (1985). Drilling engineering: A complete well planning approach. PennWell Books.

[2] Akins, W.M., Abell, M.P. & Diggins, E.M. (2005). Enhancing drilling risk & performance management through the use of probabilistic time & cost estimating. SPE/IADC Drilling Conference and Exhibition, SPE-92340. SPE.

[3] Allison, E. & Mandler, B. (2018). Petroleum and the environment. American Geosciences Institute, 8(1).

[4] Alonso-Zarza, A.M. & Tanner, L.H. (2009). Carbonates in continental settings: facies, environments, and processes (Vol. 61). Elsevier.

[5] Alonso-Zarza, A.M. & Tanner, L.H. (2009). Carbonates in continental settings: geochemistry, diagenesis and applications (Vol. 62). Elsevier.

[6] Anderson, R.N., Boulanger, A., Johnson, E.A. & Lark, J.A. (2000). Monitoring and modeling of drilling and completion operations. Academic Press.

[7] Arezes, P.M.F.M. & de Carvalho, P.V.R. (2016). Ergonomics and human factors in safety management. CRC Press.

[8] Ayanbode, N., Cadet, E., Etim, E.D., Essien, I.A. & Ajayi, J.O. (2019). Deep learning approaches for malware detection in large-scale networks. IRE Journals, 3(1), 483-489.

[9] Bagrintseva, K.I. (2015). Carbonate reservoir rocks. John Wiley & Sons.

[10] Bakker, S., Vrålstad, T. & Tomasgard, A. (2019). An optimization model for the planning of offshore plug and abandonment campaigns. Journal of Petroleum Science and Engineering, 180, 369-379.

[11] Bass, D.M. (1995). The effect of temperature on the relative permeabilities of oil and water in sandstone. Journal of Petroleum Technology, 47(11), 20-26.

[12] Bateman, R.M. (2015). Open-hole log analysis and formation evaluation. Society of Petroleum Engineers.

[13] Blencoe, J.G., Cole, D.R., Horita, J. & Moline, G.R. (2001). Experimental geochemical studies relevant to carbon sequestration. First National Conference on Carbon Sequestration. NETL.

[14] Bourgoyne, A.T., Millheim, K.K., Chenevert, M.E. & Young, F.S. (1991). Applied drilling engineering. Society of Petroleum Engineers.

[15] Bradley, H.B. (1987). Petroleum engineering handbook. Society of Petroleum Engineers.

[16] Burchette, T.P. (2012). Carbonate rocks and petroleum reservoirs: a geological perspective from the industry. Marine and Petroleum Geology, 30(1), 41-62.

[17] Chen, G. & Ewy, R.T. (2005). Thermoporoelastic effect on wellbore stability. SPE Journal, 10(2), 121-129.

[18] Chopra, S., Chemingui, N. & Miller, R.D. (2005). An introduction to this special section—Carbonates. The Leading Edge, 24(5), 488-489.

[19] Cordell, R.J. (1992). Carbonates as hydrocarbon source rocks. In Developments in petroleum science (Vol. 30, pp. 271-329). Elsevier.

[20] Crichlow, H.B. (1977). Modern reservoir engineering: a simulation approach. Prentice Hall.

[21] DePaolo, D.J. & Cole, D.R. (2013). Geochemistry of geologic carbon sequestration: an overview. Reviews in Mineralogy and Geochemistry, 77(1), 1-14.

[22] DePaolo, D.J. (2015). Sustainable carbon emissions: The geologic perspective. MRS Energy & Sustainability, 2, E9.

[23] Detournay, E. & Cheng, A.H.D. (1993). Fundamentals of poroelasticity. Comprehensive Rock Engineering, 2, 113-171.

[24] Dewan, J.T. (1983). Essentials of modern open-hole log interpretation. Halliburton.

[25] Economides, M.J., Watters, L.T. & Dunn-Norman, S. (1998). Petroleum well construction. John Wiley & Sons.

[26] Essien, I.A., Cadet, E., Ajayi, J.O., Erigha, E.D. & Obuse, E. (2019). Cloud security baseline development using OWASP, CIS benchmarks, and ISO 27001 for regulatory compliance. IRE Journals, 2(8), 250-256.

[27] Essien, I.A., Cadet, E., Ajayi, J.O., Erigha, E.D. & Obuse, E. (2019). Integrated governance, risk, and compliance framework for multi-cloud security and global regulatory alignment. IRE Journals, 3(3), 215-221.

[28] Fasasi, S.T., Adebowale, O.J., Abdulsalam, A. & Nwokediegwu, Z.Q.S. (2019). Benchmarking performance metrics of methane monitoring technologies in simulated environments. Iconic Research and Engineering Journals, 3(3), 193-202.

[29] Faustman, E.M. & Omenn, G. (2006). Risk assessment and the impact of ecogenetics. Gene-environment interactions: Fundamentals of ecogenetics, 427-450.

[30] Fjær, E., Holt, R.M., Horsrud, P., Raaen, A.M. & Risnes, R. (2008). Petroleum related rock mechanics. Elsevier.

[31] Garland, J., Neilson, J., Laubach, S.E. & Whidden, K.J. (2012). Advances in carbonate exploration and reservoir analysis. Geological Society.

[32] Goldstein, B.A., Hill, A.J., Long, A., Budd, A.R., Holgate, F. & Malavazos, M. (2009). Hot rock geothermal energy plays in Australia. Proceedings of the 34th Workshop on Geothermal Reservoir Engineering, Stanford University.

[33] Goo, J.J., Abdul Rahman, N.N., Cavallini, A., El-Yamany, Y., Azmily, A.H. & Mohd Shah Zainudin, A.H. (2017). Multiwell operational performance benchmarking: A continuous drilling optimization approach for a brownfield drilling project in Malaysia. SPE Middle East Intelligent Oil and Gas Symposium, SPE-187470. SPE.

[34] Gray, G.R. & Darley, H.C.H. (1981). Composition and properties of oil well drilling fluids. Gulf Publishing Company.

[35] Gurgenci, H., Rudolph, V., Saha, T. & Lu, M. (2008). Challenges for geothermal energy utilisation. Thirty-third Workshop on

Geothermal Reservoir Engineering, Stanford University, SGP-TR-185.

[36] Hangx, S. (2005). Subsurface mineralisation. Rate of CO2 mineralisation and geomechanical effects on host and seal formations. Behaviour of the CO2-H2O system and preliminary mineralisation model and experiments. Utrecht University.

[37] Hariharan, P.R., Judge, R.A. & Nguyen, D.M. (2006). The use of probabilistic analysis for estimating drilling time and costs while evaluating economic benefits of new technologies. SPE/IADC Drilling Conference and Exhibition, SPE-98695. SPE.

[38] Hein, F.J., Parks, K.P., Leckie, D.A., Seibel, C. & Morrow, D. (2016). Foreword—Oil-sands and heavy-oil deposits: Local to global multidisciplinary collaboration. Bulletin of Canadian Petroleum Geology, 64(2), 99-105.

[39] Hirst, C. (2017). The geothermal potential of low enthalpy deep sedimentary basins in the UK (Doctoral dissertation, Durham University).

[40] Hite, R.J. & Anders, D.E. (1991). Petroleum and evaporites. In Developments in Sedimentology (Vol. 50, pp. 349-411). Elsevier.

[41] Holditch, S.A. (2006). Tight gas sands. Journal of Petroleum Technology, 58(6), 86-93.

[42] Inglis, T.A. (1987). Directional drilling. Graham & Trotman.

[43] Jahn, F., Cook, M. & Graham, M. (2008). Hydrocarbon exploration and production. Elsevier.

[44] Jenkins, M.W. & Scott, B. (2007). Behavioral indicators of household decision-making and demand for sanitation and potential gains from social marketing in Ghana. Social Science & Medicine, 64(12), 2427-2442.

[45] John, Z., Ahsan, A. & Reid, I. (2002). Optimized decision making through real time access to drilling and geological data from remote wellsites. SPE Asia Pacific Oil and Gas Conference and Exhibition, SPE-77855. SPE.

[46] Johnson, H. & Dore, A.G. (2010). Unconventional oil and gas resources and the geological storage of carbon dioxide: overview. Geological Society, London, Petroleum Geology Conference Series, 7(1), 1061-1063.

[47] Joshi, R.M. & Singh, K.H. (2019). Carbonate reservoirs: Recent large to giant carbonate discoveries around the world and how they are shaping the carbonate reservoir landscape. In Petro-physics and rock physics of carbonate reservoirs: Likely elucidations and way forward (pp. 3-14). Springer Singapore.

[48] Kamel, A. & Godbold, G. (2009). Drilling optimization through the application of field proven motor technology. SPE Drilling & Completion, 24(1), 24-31.

[49] Kelemen, P., Benson, S.M., Pilorgé, H., Psarras, P. & Wilcox, J. (2019). An overview of the status and challenges of CO2 storage in minerals and geological formations. Frontiers in Climate, 1, 9.

[50] Kim, S., Espinoza, D.N., Jung, J., Cha, M. & Santamarina, J.C. (2019). Carbon geological storage: Coupled processes, engineering and monitoring. In Science of carbon storage in deep saline formations (pp. 383-407). Elsevier.

[51] Lackner, K.S. (2002). Can fossil carbon fuel the 21st century? International Geology Review, 44(12), 1122-1133.

[52] Lake, L.W. (1989). Enhanced oil recovery. Prentice Hall.

[53] Landis, W., Sofield, R. & Yu, M.H. (2017). Introduction to environmental toxicology: molecular substructures to ecological landscapes. CRC Press.

[54] Lee, C.T. & Dee, S. (2019). Does volcanism cause warming or cooling? Geology, 47(7), 687-688.

[55] Lewis, C.A. & Shinn, J.H. (2001). Global warming—an oil and gas company perspective: prospects for geologic sequestration? Environmental Geosciences, 8(3), 177-186.

[56] Longman, M.W. (1993). Future bright for Tertiary carbonate reservoirs in southeast Asia. Oil and Gas Journal, 91(51), 78-82.

[57] Lovell, B. (2010). Challenged by carbon: the oil industry and climate change (pp. xviii+-212). Cambridge University Press.

[58] Marieni, C., Přikryl, J., Aradóttir, E.S., Gunnarsson, I. & Stefánsson, A. (2018). Towards 'green' geothermal energy: Co-mineralization of carbon and sulfur in geothermal reservoirs. International Journal of Greenhouse Gas Control, 77, 96-105.

[59] Mielke, K.M. (2001). Reconstructing surface carbonate chemistry and temperature in paleoceans: Geochemical results from laboratory experiments and the fossil record. University of California, Davis.

[60] Mitchell, R.F. & Miska, S.Z. (2011). Fundamentals of drilling engineering. Society of Petroleum Engineers.

[61] Moeinikia, F., Fjelde, K.K., Saasen, A. & Vrålstad, T. (2014). An investigation of different approaches for probabilistic cost and time estimation of rigless P&A in subsea multi-well campaign. SPE Norway Subsurface Conference, SPE-169203. SPE.

[62] Moore, P.L. (1986). Drilling practices manual. PennWell Books.

[63] Nadeau, P.H. (2011). Earth's energy "Golden Zone": a synthesis from mineralogical research. Clay Minerals, 46(1), 1-24.

[64] Newell, P. & Ilgen, A. (Eds.) (2018). Science of carbon storage in deep saline formations: process coupling across time and spatial scales. Elsevier.

[65] Nielsen, M. (2018). Risk assessment of plugged and abandoned wells (Master's thesis, University of Stavanger).

[66] Norton, J.F. & Womer, M.A. (1994). Pore pressure detection methods in planning drilling programs. SPE Drilling & Completion, 9(1), 25-29.

[67] Nwokediegwu, Z.S., Bankole, A.O. & Okiye, S.E. (2019). Advancing interior and exterior construction design through large-scale 3D printing: A comprehensive review. IRE Journals, 3(1), 422-449.

[68] Nyman, S.L., Nelson, C.S., Campbell, K.A., Schellenberg, F., Pearson, M.J., Kamp, P.J., Browne, G.H. & King, P.R. (2006). Tubular carbonate concretions as hydrocarbon migration pathways? Examples from North Island, New Zealand. New Zealand Journal of Geology and Geophysics, 49(3), 375-393.

[69] Oia, T.M., Aarlott, M.M. & Vrålstad, T. (2018). Innovative approaches for full subsea P&A create new opportunities and cost benefits. SPE Norway Subsurface Conference, D011S008R002. SPE.

[70] Orbach, R.L. (2012). Energy production: a global perspective. Developments in Environmental Science, 11, 1-18.

[71] Owulade, O.A., Isi, L.R., Okereke, M., Sofoluwe, O., Isaac, G., Olugbemi, T. & Essien, N.A. (2019). Review of reliability engineering techniques to optimize performance and risk management in energy infrastructure. Burns, 18.

[72] Oyeneyin, M.B. (2015). Drilling and completion fluids. CreateSpace Independent Publishing.

[73] Pan, X.F., Griffiths, U.K., Pennington, M., Yu, H. & Jit, M. (2015). Systematic review of economic evaluations of vaccination programs in mainland China: Are they sufficient to inform decision making? Vaccine, 33(46), 6164-6172.

[74] Pappaioanou, M., Malison, M., Wilkins, K., Otto, B., Goodman, R.A., Churchill, R.E., White, M. & Thacker, S.B. (2003). Strengthening capacity in developing countries for evidence-based public health: the data for decision-making project. Social Science & Medicine, 57(10), 1925-1937.

[75] Petersen, J., Bjorkevoll, K.S. & Rommetveit, R. (2008). Dynamic pre-modeling of MPD operations enabled optimal procedures and operations. IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition, SPE-115291. SPE.

[76] Powell, J.W., Ramos, G.G. & Chen, D.C. (1994). Rheological model selection for drilling and completion fluids. SPE Drilling & Completion, 9(1), 34-40.

[77] Rahman, S.S. & Chilingarian, G.V. (1995). Casing design theory and practice. Elsevier.

[78] Ringrose, P.S. (2017). Principles of sustainability and physics as a basis for the low-carbon energy transition. Petroleum Geoscience, 23(3), 287-297.

[79] Robinson, J.R. & Ghalambor, A. (1985). Integrated approach to drilling engineering. OGCI Publications.

[80] Rochelle, C.A., Czernichowski-Lauriol, I. & Milodowski, A.E. (2004). The impact of chemical reactions on CO2 storage in geological formations: a brief review. Geological Society, London, Special Publications, 233(1), 87-106.

[81] Rubiandini, R.R.S. (2009). Teknik operasi pemboran. Institut Teknologi Bandung Press.

[82] Saasen, A., Fjelde, K.K., Vralstad, T., Raksagati, S. & Moeinikia, F. (2013). Plug and abandonment of offshore exploration wells. Offshore Technology Conference, OTC-23909. OTC.

[83] Samuel, R. (2010). Advanced drilling engineering: Principles and designs. Gulf Professional Publishing.

[84] Schlumberger (1989). Log interpretation principles/applications. Schlumberger Educational Services.

[85] Serra, O. (1984). Fundamentals of well-log interpretation. Elsevier.

[86] Singh, A., Prakash, A., Kothiyal, M., Sarma, P.J. & Srivastava, R. (2017). Advances in rigless well abandonment: Pathfinder to enormous economic advantage. Abu Dhabi International Petroleum Exhibition and Conference, D041S117R006. SPE.

[87] Stephenson, M.H., Ringrose, P., Geiger, S., Bridden, M. & Schofield, D. (2019). Geoscience and decarbonization: current status and future directions. Petroleum Geoscience, 25(4), 501-508.

[88] Strand, G.O. & Corina, A.N. (2019). On risk control in the well plug and abandonment phase: The case of the Norwegian Continental Shelf. Journal of Petroleum Science and Engineering, 183, 106375.

[89] Swart, P.K. (2015). The geochemistry of carbonate diagenesis: The past, present and future. Sedimentology, 62(5), 1233-1304.

[90] Swart, P.K., Eberli, G.P. & McKenzie, J.A. (Eds.) (2012). Perspectives in carbonate geology: a tribute to the career of Robert Nathan Ginsburg. John Wiley & Sons.

[91] Teale, R. (1965). The concept of specific energy in rock drilling. International Journal of Rock Mechanics and Mining Sciences, 2(1), 57-73.

[92] Triantis, K.P. (2011). Engineering applications of data envelopment analysis: issues and opportunities. In Handbook on data envelopment analysis (pp. 363-402). Springer US.

[93] Tucker, M.E. & Wright, V.P. (2009). Carbonate sedimentology. John Wiley & Sons.

[94] Uwadiae, R.E., Okunade, G.O. & Okosun, A.O. (2011). Community structure, biomass and density of benthic phytomacrofauna communities in a tropical lagoon infested by water hyacinth (Eichhornia crassipes). Pan-American Journal of Aquatic Sciences, 6(1), 44-56.

[95] Varne, T., Jorgensen, E., Gjertsen, J., Osugo, L., Friedberg, R., Bjerkvik, O. & Halvorsen, E.C. (2017). Plug and abandonment campaigns from a riserless light well intervention vessel provide cost savings for subsea well abandonments. SPE Norway Subsurface Conference, D011S005R001. SPE.

[96] Virgone, A., Broucke, O., Held, A.E., Lopez, B., Seard, C., Camoin, G., Swennen, R., Foubert, A., Rouchy, J.M., Pabian-Goyheneche, C. & Guo, L. (2013). Continental carbonates reservoirs: the importance of analogues to understand presalt discoveries. International Petroleum Technology Conference, IPTC-17013. IPTC.

[97] Wang, D., Hamm, L.M., Giuffre, A.J., Echigo, T., Rimstidt, J.D., De Yoreo, J.J., Grotzinger, J. & Dove, P.M. (2012). Revisiting geochemical controls on patterns of carbonate deposition through the lens of multiple pathways to mineralization. Faraday Discussions, 159(1), 371-386.

[98] Weydt, L.M., Heldmann, C.D.J., Machel, H.G. & Sass, I. (2018). From oil field to geothermal reservoir: Assessment for geothermal utilization of two regionally extensive Devonian carbonate aquifers in Alberta, Canada. Solid Earth, 9(4), 953-983.

[99] Wright, V.P. & Barnett, A.J. (2017). Classifying reservoir carbonates when the status quo simply does not work: A case study from the Cretaceous of the South Atlantic. Search and Discovery Article, 51419, 2-5.

[100] Xin-feng, N., An-jiang, S., Dong-xiao, W., Yu-ting, Q. & Ying, W. (2018). Current hot topics and advances of carbonate sedimentology: AAPG 100 anniversary and 2017 annual meeting and exhibition. Natural Gas Geoscience, 29(5), 729-742.

[101] Zoback, M.D. (2007). Reservoir geomechanics. Cambridge University

[102] Zoller, S.L., Graulier, J.R. & Paterson, A.W. (2003). How probabilistic methods were used to generate accurate campaign costs for Enterprise's Bijupira & Salema development. SPE/IADC Drilling Conference and Exhibition, SPE-79902. SPE.