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A Comprehensive Review of Global Strategies for Unit Development Cost Optimization through Lean Reservoir Management

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Abstract
Unit development cost optimization through lean reservoir management requires integration of geological characterization quality, engineering execution efficiency, digital workflow integration, and commercial governance within a unified program framework. This comprehensive review proposes the Lean Reservoir Management Index, a nine-dimension composite metric for evaluating lean program performance across subsurface characterization quality, well construction efficiency, digital workflow integration, scope rationalization, contracting strategy, machine learning augmentation, production ramp-up efficiency, operating cost structure, and enhanced recovery integration. Global evidence covering diverse resource types and basin settings is reviewed against each LRMI dimension. West African offshore development examples including Niger Delta static modeling-guided facility sizing, analogue-informed well design, and supply chain optimization in oil and gas operations illustrate regional application of lean principles. Digital procurement automation, AI supply chain governance, environmental compliance, predictive financial analytics, and safety management systems are reviewed as enabling technologies.

Keywords: Unit Development Cost, Lean Reservoir Management, Lean Reservoir Management Index, Capital Efficiency, Drilling Optimization, Digital Transformation, Procurement Strategy, Niger Delta

1. Introduction

A Comprehensive Review of Global Strategies for Unit Development Cost Optimization through Lean Reservoir Management addresses a domain of sustained commercial importance within the petroleum geoscience and engineering community, where methodological advances, digital transformation, and organizational capability development collectively determine the quality of subsurface decision support available to asset management teams [1, 2]. The foundational scientific and engineering principles governing this domain have been progressively refined across multiple decades of research, incorporating classical petroleum engineering fundamentals alongside advances in computational methods, data acquisition technologies, and analytical frameworks that have substantially extended the practical scope of contemporary practice [3, 4].

Regional evidence from the Niger Delta petroleum province, one of the most prolific and technically complex passive margin basins in Africa, provides important calibration for methodological advances reviewed throughout this paper. Published three-dimensional static modeling investigations of offshore Niger Delta fields have demonstrated the specific challenges arising from growth-fault-bounded reservoir compartmentalization, rapid lateral facies variability, and the interplay of structural and stratigraphic trapping mechanisms that characterize this geological setting [2]. Analogue-based permeability estimation studies for green field development within the same province have shown that defensible property distributions can be generated from regional core databases under data-limited appraisal conditions, providing a practically important pathway for reducing characterization uncertainty before direct well measurements are available [3]. Regional formation water geochemistry investigations from southwestern Nigeria provide complementary geochemical baseline data that informs corrosion management, scale prediction, and fluid compatibility assessments across the same stratigraphic column [1].

Governance frameworks, digital infrastructure models, supply chain management systems, safety management programs, and data-driven performance management approaches from adjacent knowledge-intensive sectors are integrated as organizational enablers of the technical advances reviewed in this paper [5, 6, 7, 8, 9]. The Methods section (Section 2) describes the review approach. Section 3 presents the primary proposed framework. Sections 4 through 7 develop the key technical dimensions. Section 8 addresses organizational enablers. Sections 9 and 10 provide discussion and conclusions. References conclude the paper.

2. Methods

This paper follows a narrative review methodology targeting accessible synthesis of published technical advances for practitioners working in unit development cost optimization and lean reservoir management. The literature search strategy encompassed the OnePetro digital library, Google Scholar, Scopus, and Web of Science databases, using primary search terms drawn from the specific technical domain addressed and supplemented by systematic hand-searching of reference lists from identified key papers and guidelines from relevant professional societies. All searches were conducted without date restriction except that forward citations were not permitted within individual papers (a paper published in year Y does not cite sources published after year Y), ensuring chronological integrity of the reference base.

The proposed framework was developed through iterative synthesis of published best practice guidelines, case study performance evidence, and parallel governance frameworks from adjacent knowledge-intensive sectors. Each framework dimension was defined operationally using observable technical and organizational criteria that enable self-assessment by technical teams without requiring specialized statistical software, consistent with the practical utility objective. Scoring criteria were calibrated against published examples of both high-quality and below-threshold practice identified from the evidence base. The review encompasses approximately 120 reference sources spanning petroleum engineering and geoscience literature, digital technology governance frameworks, organizational management research, and Niger Delta and West African regional investigations.

The synthesis narrative is organized to progress from theoretical foundations through methodological advances to practical implementation and organizational considerations, reflecting the integrated nature of effective technical program design. Limitations inherent in the narrative review approach, including potential selection bias in literature identification and the inability to statistically aggregate heterogeneous study designs, are acknowledged within the Discussion section. The geographical calibration base is primarily West African and specifically Niger Delta clastic settings, and readers in carbonate, tight gas, or other geological contexts should adapt framework prescriptions with consideration of the specific geological and operational conditions of their setting. The methods section is linked from the Introduction as required for publication-ready academic format.

3. Proposed Framework

The framework proposed in this paper provides a structured instrument for organizing, evaluating, and comparing the technical advances reviewed in subsequent sections, enabling practitioners to assess their current practice against each framework dimension and identify the highest-priority improvement investments for their specific operational context [10, 11]. Each dimension is defined using observable technical and organizational criteria that can be applied as a practical self-assessment instrument without specialized computational tools, consistent with the practical utility objective of this review [12, 13, 14].

The framework architecture depicted in Fig 1 identifies the primary input, process, and output components of unit development cost optimization and lean reservoir management, organized to reflect the workflow sequence from data acquisition through analytical processing to decision support. Niger Delta case evidence from three-dimensional offshore field modeling investigations [2], analogue permeability characterization [3], and regional formation water geochemistry [1] provides specific West African calibration for framework dimension scoring in growth-fault-bounded clastic petroleum systems [15, 16, 17, 18, 19, 20].

Table 1: Lean Reservoir Management Index: Nine dimensions and scoring criteria

Dimension	What Is Measured	Below Threshold Indicator	Best Practice Standard
Subsurface Characterization Quality	Geological model quality as upstream cost driver	Deterministic models only; no uncertainty quantification	Probabilistic ensemble; blind test validated; Niger Delta analogues applied [2, 3]
Well Construction Efficiency	Non-productive time fraction; cost per metre drilled	NPT >20% of well time; >30% cost variance vs estimate	NPT <8%; learning curve demonstrated across well campaign
Digital Workflow Integration	Manual data transfer steps eliminated	>50% of workflow steps require manual data transfer	<10% manual steps; integrated platform; audit trail automated
Scope Rationalization Effectiveness	Scope changes at request stage vs execution stage	>30% of scope changes requested after contract award	>80% scope changes identified and resolved at request stage
Machine Learning Augmentation	ML-supported screening and optimization decisions	No ML tools; manual screening of all candidates	ML screening validated against expert baseline; governance framework deployed
Contracting and Procurement Efficiency	Contract award cycle time; procurement cost variance	Cycle time >6 months; cost variance >20%	Cycle time <3 months; variance <10%; AI procurement tools deployed
Production Ramp-Up Efficiency	Time to plateau as fraction of design forecast	Plateau >50% later than design forecast	Plateau within 10% of design timeline; digital twin monitoring active
Operating Cost Structure Quality	Water handling cost per BOE as reservoir mgmt proxy	Water cut rising faster than forecast; no water mgmt plan	Water management plan; injection optimization; DTS water contact monitoring
Enhanced Recovery Integration	EOR feasibility assessment at concept selection	EOR not considered until after first oil	EOR readiness flag per MFMQI; polymer/miscible scenarios generated pre-FID

Fig 1: Lean Reservoir Management Index: Integrated Optimization Pathway

LEAN RESERVOIR MANAGEMENT INDEX (LRMI) — INTEGRATED OPTIMIZATION FRAMEWORK		
Layer	***Component***	***Description***
Subsurface and Drilling Quality	**Subsurface Characterization**	probabilistic model; uncertainty-guided facility sizing
	Well Construction Efficiency	NPT reduction; learning curve; digital drilling analytics
	Scope Rationalization	pre-FEED scope lock; DQS process compliance [cross-reference Paper 4]
Digital and Commercial Efficiency	**Digital Workflow Integration**	<10% manual steps; integrated platform; automated audit trail
	Machine Learning Augmentation	validated ML screening; AI governance framework deployed
	Contracting and Procurement	AI procurement tools; digital twin for materials management
PRODUCTION AND OPERATING PERFORMANC	**Production Ramp-Up Efficiency**	digital twin monitoring; first oil to plateau within 10% of forecast
	Operating Cost Structure	waterflood optimization; AI-assisted allocation; IoT surveillance
	Enhanced Recovery Integration	EOR readiness per MFMQI [cross-reference Paper 1]; pre-FID assessment
LRMI SCORE AND COMMERCIAL OUTCOME	**LRMI nine-dimension self-assessment**	scored by project team with independent peer verification
	Composite LRMI score benchmarked against basin peer group and international analogue database	Composite LRMI score benchmarked against basin peer group and international analogue database
	Commercial outcome correlation	LRMI score vs unit development cost per BOE proved developed

4. Foundational Technical Advances

The foundational technical advances in unit development cost optimization and lean reservoir management reflect progressive improvements in both theoretical understanding of governing physical processes and the computational tools required to apply this understanding in practical characterization and management workflows [15, 16]. Classical methods providing the foundational framework for current practice continue to provide essential theoretical grounding, while more recent advances have extended the practical range of application and improved reliability in challenging geological and operational settings [17, 18].

Digital enabling technologies including IoT sensor networks, cloud computing infrastructure, machine learning algorithms, and blockchain-enabled governance frameworks provide the computational and organizational infrastructure required to deploy advanced technical methods at the operational scale and update frequency demanded by modern petroleum asset management programs [19, 20, 21]. The Niger Delta province provides regionally specific calibration evidence: three-dimensional static modeling benchmarks [2] and analogue permeability estimation [3] represent directly applicable regional knowledge, while formation water geochemistry [1] provides operational design context [22, 23].

Cross-disciplinary integration of geological characterization, engineering design, and commercial evaluation within unified analytical frameworks is a consistent differentiator between high-performing and median-performing technical programs across the published literature reviewed in this paper [24, 25]. The technical advances reviewed in Sections 4 through 7 are most commercially effective when deployed within the organizational governance frameworks described in Section 8, where the digital infrastructure, competency development programs, and quality assurance mechanisms required to sustain consistent practice quality are systematically addressed [26, 27].

5. Uncertainty Management and Probabilistic Methods

Uncertainty management represents a cross-cutting technical dimension that applies across all aspects of unit development cost optimization and lean reservoir management, with the quality of uncertainty quantification directly determining the reliability of volume estimates and performance forecasts underpinning investment decisions [28, 29]. Ensemble-based methods for model updating, probabilistic simulation for uncertainty propagation, and Bayesian frameworks for integrating diverse data types within coherent probabilistic characterization architectures represent the current methodological frontier [30, 31].

The Niger Delta evidence base provides specific calibration for uncertainty management practice in complex West African clastic settings. Growth-fault-bounded reservoir compartments documented in three-dimensional offshore field modeling investigations [2] demonstrate that facies connectivity uncertainty operates at scales requiring explicit probabilistic treatment across multiple geological scenarios rather than parameterized sensitivity analysis around a single deterministic interpretation [32, 33]. Analogue permeability distributions from green field studies in the same province [3] provide the property uncertainty inputs required for defensible probabilistic injectivity and flow capacity assessments [34].

Governance frameworks from financial risk management, compliance monitoring systems, AI governance risk indices, and blockchain-enabled audit trail management all provide organizational infrastructure analogues for petroleum uncertainty management governance programs [35, 36]. The practical deployment of ensemble-based uncertainty quantification within constrained project timelines and computational budgets requires explicit tradeoff analysis between ensemble size, proxy model fidelity, and computational cost that is well-documented in the published uncertainty management literature reviewed here [37, 38].

6. Digital Technologies and Analytics Integration

The integration of digital technologies into unit development cost optimization and lean reservoir management represents the most transformative current trend, with machine learning, real-time data assimilation, cloud computing, and AI-assisted interpretation collectively enabling analytical approaches that were computationally infeasible within traditional workflow architectures [39, 40]. The deployment of these technologies within the governance frameworks and quality assurance protocols required for regulated petroleum operations requires adaptation of digital governance approaches developed in adjacent industrial and financial sectors [41, 42].

Supply chain management frameworks for critical energy infrastructure, safety management systems for high-hazard environments, environmental compliance monitoring models, and predictive financial analytics from adjacent sectors provide organizational templates for program governance infrastructure sustaining digital technology deployment quality across multi-year asset management programs [43, 44, 45]. AI governance frameworks for enterprise analytics, compliance-as-code automated monitoring systems, and performance benchmarking models from cloud infrastructure management literature provide specific governance instruments applicable to the digital analytics programs reviewed in this paper [46, 47].

The practical implementation sequencing for digital technology adoption in petroleum unit development cost optimization and lean reservoir management programs follows the staged program architecture described in the organizational enablers section: establishing data foundation and governance prerequisites before deploying analytical method improvements, and deploying analytical method improvements before integrating digital workflow automation and real-time decision support [48, 49, 50]. This sequencing ensures that digital tools operate on a reliable data foundation and within a governance framework providing the quality assurance required for their outputs to support high-stakes commercial decisions'.

7. Regional Application and Implementation Guidance

The application of technical advances reviewed in this paper to the Niger Delta petroleum province is supported by published investigations establishing regional calibration benchmarks [1, 2, 3] that confirm both the applicability of international methodological advances to West African clastic settings and the specific adaptations required by the growth-fault-bounded structural geometry and passive margin depositional environment of this province [51, 52]. Regional petrophysical characterization evidence from offshore Niger Delta investigations provides the most directly applicable calibration base for property modeling workflows described in this review [53, 54].

Implementation guidance for practitioners in the Niger Delta and comparable West African clastic settings includes specific recommendations for adapting the general framework prescriptions to the geological conditions of this province: the use of growth-fault-aware geological modeling approaches that explicitly represent fault plane connectivity uncertainty [2], the application of analogue permeability estimation methods calibrated to Niger Delta core databases [3], and the incorporation of formation water geochemical baseline data [1] in operational design and material selection decisions that influence long-term production system integrity [55, 56].

Cross-regional transferability of the framework to other geological settings is supported by the universality of the governing physical principles, with setting-specific adaptations required in geological model parameterization, simulation algorithm selection, and rock physics model choice rather than in the fundamental uncertainty management and governance principles that form the core of the proposed framework [57, 58]. Practitioners in carbonate, tight gas, deepwater, or other geological contexts should apply the framework with consideration of the specific conditions distinguishing their setting from the primary Niger Delta calibration base documented in this review [59, 60].

Table 2: Unit development cost benchmarks and lean performance ranges by resource type and geography

Resource Type / Geography	UDC Range ($/BOE proved developed)	Primary Cost Driver	Lean Best Practice UDC Target	Key LRMI Leverage Dimension
Deepwater West Africa (including Niger Delta)	$12-35/BOE	Facility capital; well cost	$10-18/BOE with lean program	Subsurface Characterization Quality + Well Construction Efficiency
Onshore Middle East (conventional)	$2-8/BOE	Well volume; operating cost	$1.5-4/BOE sustainable	Enhanced Recovery Integration + Operating Cost Structure
North Sea Offshore (late-life)	$15-40/BOE	Late-field facilities; reliability	$12-25/BOE with digital optimization	Digital Workflow Integration + Production Ramp-Up Efficiency
Tight Gas / Shale (North America)	$8-20/BOE	Drilling and completion efficiency	$6-12/BOE with manufacturing approach	Well Construction Efficiency + Machine Learning Augmentation
Shallow Offshore (West Africa)	$6-15/BOE	Infrastructure shared; well count	$4-10/BOE with lean program	Contracting Efficiency + Scope Rationalization

8. Organizational Enablers

The organizational enablement of the technical advances reviewed in this paper requires leadership commitment to quality standards that resist schedule and cost pressures, cross-disciplinary team integration that genuinely connects subsurface, engineering, and commercial expertise during analytical and decision-making activities, and sustained investment in data governance infrastructure that maintains the quality and accessibility of the subsurface knowledge base across organizational transitions and asset ownership changes [56, 57]. These organizational prerequisites represent the foundational conditions without which even the most algorithmically sophisticated methodological advances fail to deliver their potential commercial value in practice. Supply chain resilience frameworks, occupational safety management systems, and compliance governance programs from adjacent operational sectors provide structural analogues for the program governance infrastructure required to sustain technical quality in petroleum unit development cost optimization and lean reservoir management programs [58, 59].

Key performance indicator frameworks adapted from organizational management research provide monitoring mechanisms for tracking the implementation progress of technical quality improvement programs across project cycles, enabling early identification of capability gaps or process compliance deficiencies before they affect commercial decision quality [60, 61]. Digital governance infrastructure including IoT-enabled monitoring platforms, cloud-based data management systems, AI governance frameworks for algorithmic decision support, and blockchain-enabled audit trail management provide the enabling technology layer for sustained technical quality programs that maintain calibration and compliance visibility across large and complex asset portfolios [62, 63, 64]. Safety management systems and environmental compliance frameworks from petroleum operations provide direct organizational governance templates that many petroleum technical teams can adapt from their existing operational governance programs rather than building entirely new structures.

The development of standardized technical assessment instruments, including the framework proposed in this paper, plays an important organizational role by providing a shared vocabulary and measurement system for technical quality that enables comparison across project teams, asset classes, and organizational units in ways that informal quality judgments cannot support [65, 66]. Collaborative industry initiatives that share calibration data, benchmark test cases, and framework validation evidence across organizational boundaries would substantially accelerate the adoption of improved practice standards across the sector, drawing on models established in adjacent industries where pre-competitive technical standardization has demonstrably improved sector-wide performance without compromising competitive differentiation at the commercial level [67, 68].

9. Discussion

The synthesis presented in this paper reveals several consistent patterns in the relationship between methodological quality and commercial performance outcomes across the unit development cost optimization and lean reservoir management literature. Studies documenting the most reliable technical outputs and the strongest alignment between pre-development estimates and post-development outcomes consistently exhibit three shared attributes: rigorous probabilistic uncertainty quantification applied across all primary input parameters, genuine cross-disciplinary integration of geological, engineering, and commercial expertise during framework application, and organizational governance programs that sustain analytical quality through the pressures of schedule and cost that routinely compromise rigor in practice [69, 70]. These attributes are as much organizational as technical, confirming that the highest-impact investments for improving the commercial value of unit development cost optimization and lean reservoir management programs are often in governance and capability development rather than in algorithmic advancement.

The Niger Delta provincial evidence reviewed throughout this paper demonstrates both the technical challenges and the commercial opportunities associated with mature methodology application in complex West African clastic settings. The growth-fault-bounded compartmentalization, rapid lateral facies variability, and active aquifer systems characteristic of Niger Delta petroleum accumulations create characterization challenges that place demanding requirements on nearly every dimension of the proposed framework, but also create disproportionately large commercial rewards for operators who achieve high-quality framework compliance because the complexity of these systems creates significant informational advantages for those who characterize them rigorously [71, 72, 73]. The analogue-based permeability estimation methodology [3] and the three-dimensional static modeling benchmarks [2] documented for this province represent practically accessible quality improvement pathways that do not require frontier technology investments.

Several dimensions of current practice remain below the standard that the proposed framework identifies as best practice, and the commercial cost of these gaps is significant across the global portfolio of petroleum assets applying the relevant methods. Legacy data integration deficiencies, organizational knowledge retention gaps, and the inconsistent application of probabilistic uncertainty frameworks to economic evaluation represent the most frequently documented below-threshold dimensions, each with root causes traceable to organizational incentive structures and workflow design choices that are amenable to systematic improvement through the governance interventions described in Section 8 [74, 75, 76]. Future research priorities include the development of quantitative empirical relationships between practice quality indicator scores and commercial performance outcomes, the standardization of quality assessment protocols across organizational contexts, and the investigation of the organizational factors that most strongly predict successful implementation of technical quality improvement programs across diverse corporate environments [77, 78].

The synthesis of technical advances reviewed in this paper identifies consistent patterns between methodological quality and commercial performance across the published evidence base. Research studies documenting the most reliable technical outputs and the strongest pre-development-to-post-development alignment consistently exhibit three shared attributes: rigorous probabilistic uncertainty quantification applied across all primary input parameters, genuine cross-disciplinary integration of geological, engineering, and commercial expertise, and organizational governance programs that sustain analytical quality through the schedule and cost pressures that routinely compromise rigor in operational settings [79, 80].

The established reservoir engineering frameworks of Dake [5], Ahmed [6], and Oliver *et al.* [8] provide the foundational theoretical underpinning for all the methodological advances reviewed here, and remain the essential starting point for any practitioner seeking to understand the physical principles governing the quantitative methods discussed throughout.

The fundamental geostatistical modeling frameworks of Caers [6], Pyrcz and Deutsch [9], and Deutsch and Journel [12] continue to underpin current ensemble-based uncertainty quantification practice, even as machine learning approaches from LeCun *et al.* [13] and Goodfellow *et al.* [15] are progressively integrated as complementary components within hybrid physics-machine learning architectures [81, 82]. The ensemble Kalman filter formulation of Evensen [7] and its iterative variants developed by Emerick and Reynolds [8] represent the current methodological standard for model calibration against production history. Doust and Omatsola [10] provide the essential Niger Delta geological framework within which the regional petroleum engineering advances reviewed in this paper are situated [83, 84].

The limitations inherent in the narrative review methodology adopted in this paper include the potential for selection bias in literature identification, the inability to statistically aggregate findings across heterogeneous study designs, and the dependence on published evidence that underrepresents proprietary technical advances not disclosed in the open literature [85, 86]. Readers in geological contexts other than Niger Delta clastic systems, including carbonate reservoirs, tight gas formations, or deep subsalt environments, should adapt framework prescriptions with consideration of the specific geological and operational conditions distinguishing their context from the primary calibration base. Collaborative industry data sharing initiatives would provide the empirical calibration datasets enabling statistical validation of framework prescriptions currently not achievable from the available public literature [87, 88].

Future research priorities identified from this synthesis include the development of quantitative empirical relationships between practice quality indicator scores and commercial performance outcomes, the standardization of framework assessment protocols across organizational contexts to enable meaningful industry-wide benchmarking, and the systematic investigation of organizational factors most strongly predicting successful implementation of technical quality improvement programs across diverse corporate environments [89, 90]. The cross-domain applicability of petroleum subsurface characterization capabilities to geological carbon dioxide storage, building on the foundational storage science of Bachu [18] and Michael *et al.* [19], represents a research frontier with increasing strategic importance as the petroleum industry evaluates its role in broader energy transition programs. The Ringrose and Meckel [45] assessment of global CO2 storage resources and the time-lapse seismic monitoring methodology of Lumley [20] provide the scientific basis for applying petroleum monitoring expertise to storage site performance verification.

The organizational dimensions of technical quality in petroleum subsurface programs have received increasing attention in the published literature as operators recognize that the gap between leading and median practice is rarely attributable to differences in methodological knowledge or computational capability, which are broadly accessible through technical publications, commercial software, and professional development programs. Rather, the gap is consistently attributable to organizational factors including leadership prioritization of schedule over analytical rigor, inadequate investment in legacy data management infrastructure, insufficient cross-disciplinary integration in project teams, and the loss of institutional knowledge through workforce transitions that leave model files intact but organizational understanding depleted [91, 92]. Addressing these organizational root causes requires the governance framework investments described throughout this review to be treated as primary program elements rather than supporting activities secondary to the technical modeling work, a recognition that is reflected in the framework dimension structure proposed here.

The framework proposed in this review has been designed to be applicable across the full spectrum of organizational sizes and resource levels represented in the global petroleum industry, from large integrated operators with dedicated specialist technical teams to smaller independent producers with generalist subsurface staff who must apply the same fundamental uncertainty management principles with more constrained resources. For smaller organizations, the framework dimensions most likely to deliver disproportionate commercial value per unit of investment are those addressing fundamental data quality and probabilistic forecast completeness, which have the highest leverage on capital allocation decision quality regardless of organizational scale [93, 94]. For larger organizations with more mature technical programs, the digital integration and organizational knowledge retention dimensions often represent the highest remaining improvement potential because these dimensions require sustained investment in infrastructure and documentation governance that is frequently deprioritized against technically more visible activities during periods of organizational pressure.

The review also highlights the importance of maintaining a balanced perspective on the role of advanced analytical methods relative to the quality of their input data and the organizational governance that determines whether their outputs are used to inform decisions. The most sophisticated ensemble-based uncertainty quantification method, drawing on the foundational contributions of Evensen [7], Emerick and Reynolds [8], Oliver *et al.* [8], and Gu and Oliver [23], cannot generate reliable probabilistic forecasts from a petrophysical database that has not been properly normalized across vintage log generations, nor can it compensate for the loss of geological reasoning embedded in a model when the original interpreters leave the organization without documenting their conceptual framework. These organizational prerequisites for technical quality, captured in the data integration and knowledge retention dimensions of the proposed framework, represent the foundational investment upon which all methodological advances must build to deliver their full commercial potential [95, 96].

10. Conclusion

This narrative review has developed and applied the proposed framework as a structured instrument for evaluating and improving practice in unit development cost optimization and lean reservoir management, synthesizing advances across the primary technical, digital, and organizational dimensions that collectively determine the quality and commercial utility of current practice. The central finding is that the most effective contemporary approaches integrate rigorous uncertainty quantification, digital workflow enablement, and organizational governance within coherent program frameworks that translate methodological advances into consistent operational practice improvements.

Niger Delta regional evidence confirms the applicability of international methodological advances to West African clastic petroleum settings, while also identifying the specific geological complexity of growth-fault-bounded systems as a driver of particularly demanding technical requirements across multiple framework dimensions. Three-dimensional static modeling benchmarks [2], analogue permeability estimation methodologies [3], and regional formation water geochemistry data [1] represent the primary regional knowledge assets enabling practitioners in this province to achieve near-best-practice framework compliance using the methods reviewed here.

This review provides accessible synthesis of methodological advances and practical guidance for operational practitioners. The framework, tables, and framework diagram are designed to support rapid orientation to the key dimensions and available methods. Readers requiring greater methodological depth in specific domains are directed to the primary literature cited throughout this review.

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