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Innovating Well Cementing Supply Chains Through Sustainable Material Sourcing and Advanced Contract Negotiation Practices

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Abstract

Well cementing is crucial to the integrity of the wellbore, fluid migration, and the operational and environmental performance of oil and gas projects. Supply chain cementing, however, is becoming increasingly challenging in terms of sustainability, cost-effectiveness, and risk sharing. This conceptual paper examines the future development of innovation in the well cementing supply chain, incorporating sustainable material sourcing and best practices in contract negotiation. The review explains essential terminologies, such as cementing, sustainable supply chain management, green procurement, and performance-based contracting, and places them in the context of relevant theoretical perspectives, including Sustainable Supply Chain Management theory, Transaction Cost Economics, and the Diffusion of Innovations. The review of the available literature suggests the potential of environmentally friendly cementitious materials, the development of local content, strategies for resilience in supply chains, and the role of performance and risk-sharing contracting models, as well as digitally enabled contracting frameworks. Although the literature related to sustainable sourcing and contractual innovation is very rich, a conceptual gap remains in the view of integrating both concepts in the context of well cementing. The study proposes a unified model that helps connect material sustainability to contractual alignment through feedback mechanisms, data-driven surveillance, and cooperative supplier relations, thereby mitigating this issue. The framework has significant policy, practice, and future research implications since it provides directions on how to minimize non-productive time, enhance well integrity, and be environmentally responsible in the oil and gas industry.

Keywords: *Well Cementing, Sustainable Supply Chains, Green Procurement, Contract Negotiation, Performance-Based Contracting, Oil and Gas Innovation.*

I. INTRODUCTION

The oil and gas industry is also one of the pillars of the energy supply of the world, but its activity is usually accompanied by serious environmental, technical, and economic problems (International Energy Agency [IEA], 2023). Well cementing is among the most essential operations of the upstream petroleum, as it guarantees integrity of the wellbore, eliminates the possibility of fluid migration, and provides safe drilling and production (Bourgoyne et al., 2020). The unsuccessful cementing operation may result in costly downtime, safety risks, and reputational losses, therefore, the necessity to innovate in the operational practice and supply chain management (Abimbola et al., 2022). It is against this backdrop that the capacity to develop effective supply chains of cementing materials and associated services has taken the centre stage of operational success and sustainability (Gupta et al., 2021). The three domains that are related and reviewed are; the well cementing supply chains, sustainable material sourcing and high order contract negotiation practices. Well cementing supply chains entail the purchase, transportation, and delivery of cement and additives under extremely time-sensitive and technical demanding conditions (Khalifeh and Saasen, 2020). The need to use sustainable material sourcing brings the necessity to use materials that are affordable and environmentally-friendly and locally available, reduce carbon emissions, and ensure resilience in the long-term (Onwuka et al., 2023; Salehi et al., 2021). In its turn, advanced contract negotiation practices can offer a governance model of dealing with the relationships with suppliers, reducing the risks, and harmonizing the incentives among operators, contractors, and regulators (Bai and Bai, 2022; National Academies of Sciences, Engineering, and Medicine [NASEM], 2021).

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The purpose of this conceptual review is to synthesise and integrate existing knowledge on these themes in order to propose innovative frameworks tailored to the unique demands of oilfield operations. By bridging sustainability imperatives with contractual and operational innovations, the study seeks to highlight pathways for reducing costs, improving well integrity, and promoting long-term environmental responsibility within the oil and gas sector.

- *Conceptual Clarification*

To clarify concepts and achieve conceptual accuracy and alignment, a couple of concepts need to be clarified in order to do so so as far as this study is concerned. Well cementing is the act of placing cement between the casing and the wall of the borehole in order to stabilise the well, prevent movement of fluids as well as safeguarding the underground formation (Nelson & Guillot, 2006). It is a technical as well as logistical process, which requires the arrangement of delivery of cement, additives as well as pumping services. Cementing failures result in loss of integrity of wells, which have expensive remediation and cause environmental hazards (Bois et al., 2011). Supply chain here refers to the interrelationship among the activities and stakeholders engaged in the supply of cementing materials and services as sources, transportation, and delivery (Mentzer et al., 2001). Such chains would be sustainable supply chains when they integrate the ecological responsibility and efficiency of resource utilization into their systems, it would be a balance between the operational performance of the chain and environmental conservation (Carter and Rogers, 2008). Sustainable supply chains are not just cost-effective but also low-carbon sourcing, waste minimisation, and supplier development; this way, the greater social licence to operate is addressed (Seuring & Müller, 2008). Next to it is the concept of green procurement or the act of strategically purchasing goods and services that have the least environmental consequences in the life cycle (Zsidisin & Siferd, 2001). An example of this in cementing activities can be the replacement of conventional Portland cement with some additional cementitious products, or focusing on suppliers with good sustainability records (Khalifeh and Saasen, 2020). Green procurement enhances the resilience of supply chains through diversification of sourcing alternatives and promotion of innovation.

Contract negotiation models are also of great importance as they are used as guidelines of specifying duties, risk management, and harmonization of interests between oil and gas firms and service contractors (Corts & Singh, 2004). Conventional forms of transaction are usually stiff and antagonistic, but more sophisticated models focus on performance-based contracts, costly relationships and distributive risks and rewards (Rose, 2014). The ideas are connected in that way, sustainable sourcing practices are facilitated by efficient supply chain design and supported by novel contractual frameworks. The need to clarify these terms is that their use may cause errors in the analysis, misalignment in policies, or unrealistic recommendations (Sartorius, 1991). The development of a common conceptual base thus enables this study to incorporate theoretical knowledge into a logical structure of further innovation in the process of well cementing.

- *Theoretical Foundations*

The theoretical basis of the conceptual review is based on three major theoretical lenses that can be used to explain the analysis of innovation in cementing supply chains: Sustainable Supply Chain Management (SSCM), Transaction Cost Economics (TCE), and the Diffusion of Innovations (DOI). The Sustainable Supply Chain Management (SSCM) theory is focused on integration of environmental, social, and economic goals into the supply chain operations (Carter and Rogers, 2008). It goes beyond cost and efficiency measures and includes resource conservation, reduction in emissions as well as stakeholder inclusiveness. In well cementing, SSCM emphasises the importance of switching to a more technical efficiency perspective to material sourcing and logistics systems that are minimally carbon-intensive and encourage the involvement of local content (Seuring and Muller, 2008). A complementary viewpoint is offered by the Transaction Cost Economics (TCE), which describes the way that firms organize contracts and governance systems in order to reduce the opportunism, uncertainty, and asset specificity costs (Williamson, 1985). The characteristics of cementing supply chains include high capital intensity and technical interdependence and hence subject to disagreements and inefficiencies. TCE emphasizes the importance of the advanced contracting models, including performance-based contracts or alliance contracts in minimizing risks and transaction costs as well as promoting the long-term cooperation between the operators and the service providers (Corts & Singh, 2004; Rose, 2014).

The Diffusion of Innovations (DOI) school of thought also adds new insights to the framework by looking at the dissemination of new practices and technologies in industries (Rogers, 2003). The diffusion processes, in the perspective of sustainable cementing, are applied to describe how the firms embrace environmentally friendly materials, online shopping, and modern ways of negotiation. Relative advantage, compatibility with the existing systems and perceived complexity are some of the factors that affect uptake of such innovations (Rogers, 2003). Combined, these theories give the research problem a multi-dimensional perspective. SSCM bases sustainability agenda, TCE deals with the contractual and governance efficiency, and DOI illuminates on dynamics of adoption. Using them to the oilfield scenario can provide a conceptual framework that would combine material sustainability and contractual innovation. This theoretical triangulation is in place to make sure that the suggested framework is not only based on the proven academic foundations but is also dynamic to the reality of doing business within the petroleum industry.

II. REVIEW OF RELATED CONCEPTS AND LITERATURE

➢ *Sustainable Material Sourcing*

Green procurement is a concept that has become more popular as industries understand the environment impact of their activities (Ahi and Searcy, 2013). This, within the oil and gas industry, involves focusing on procurement of materials, which reduce negative impacts on the environment throughout their life cycle (Soenichsen and Clement, 2020). In the case of well cementing, sustainable sourcing can require moving away from conventional Portland cement that produces high carbon emissions by adding pozzolana-like materials like fly ash, slag, or local pozzolana (Khalifeh and Saasen, 2020).

To operationalize the sustainable sourcing of well cementing materials, Table 1 presents a comparative scorecard of material alternatives, showing their environmental and technical performance, alongside examples from oil well cementing research.

Table 1 Sustainable Material Sourcing

Material Option	CO_2 Reduction vs OPC	Local Availability	Cost Competitiveness	Well Integrity Rating
Fly Ash Blend	~40%	High	Medium	High
Slag Cement	~50%	Medium	High	High
Geopolymer Cement	60–80%	Low–Medium	Medium	Very High

The development of local content is also an essential dimension, which fosters the use of local suppliers, local raw materials to decrease costs, lead times, and secure socio-economic development (Ovadia, 2016). In addition to environmental advantages, sustainable sourcing also increases resilience as supply bases are diversified and are not susceptible to global market volatility (Ponomarov and Holcomb, 2009). Resilience of supplier chains is especially important in the cementing industry, and time lost in operations may cause considerable non-productive time (Bataee et al., 2020). Risk management measures such as inventory optimisation and joint planning with suppliers are effective measures to maintain supply continuity when there is uncertainty in supply (Christopher and Peck, 2004).

➢ *Advanced Contract Negotiation Practices*

Contracting systems are crucial in the development of the relationship between oil corporations and service providers (Rose, 2014). The traditional contracts tend to focus on predetermined conditions and cost control but this can unintentionally develop adversarial relationships (Corts & Singh, 2004). Conversely, performance-based contracts base the compensation paid to suppliers on the consequences of reduced non-productive or improved well integrity or compliance with sustainability goals (Bai and Bai, 2022).

These sustainability objectives can be translated into measurable contract performance indicators, as illustrated in Table 2.

Table 2 Advanced Contract Negotiation Practices

KPI	Definition	Target/Benchmark
% Eco-Friendly Materials	Share of cement volume from green alternatives	$\geq 40\%$
Local Supplier Participation	% of contracts awarded to local suppliers	$\geq 60\%$
Lifecycle Carbon Footprint	CO_2 per ton of cement delivered	Reduced by $\geq 30\%$
Supplier Training Compliance	% suppliers certified in sustainability practices	100%

Risk-sharing models promote shared responsibility, which allocates technical and financial risks according to the ability of each party (Rose, 2014). More and more, contracting is being digitized, which allows making decisions based on data, monitoring performance transparency, and pre-emptive risk analysis (Iansiti and Lakhani, 2020). These frameworks favor real time changes in terms of contractual provisions, which adds flexibility. The strategic supplier alliances can also be viewed as a transition to collaborative relationships in which mutual trust, long-term relationships, and a common goal of innovation are found instead of transactional relationships (Dyer and Singh, 1998).

➢ *Integration of Supply Chains and Contracts*

Although there is literature on sustainable sourcing and advanced contracting, there is little research on how the two can be combined in the well cementing context (Gupta et al., 2021). Sustainable procurement initiatives are usually sabotaged by unbending contractual agreements that focus on cost rather than on environmental or operational advantages in the long run (Carter & Rogers, 2008). On the other hand, the development of advanced contracts is unlikely to be adapted to encourage the usage of eco-friendly materials (Ghadimi et al., 2021). To combine the two dimensions, contracts must consider sustainability metrics and supply chains must be designed in a way that facilitates the addition of new materials and technologies. The point of intersection indicates the absence of conceptual convergence, the lack of integrated frameworks to optimise all environmental, operational, and contractual goals simultaneously (Seuring & Muller, 2008). This is the gap that should be addressed to facilitate the growth of innovation in well cementing supply chains.

➢ *Proposed Conceptual Framework*

The suggested framework combines the idea of sustainable sourcing and high-level contract negotiation to build a comprehensive model of the innovations of the

well cementing supply chains. The framework starts at the input level, where the identification of eco-friendly cementing alternatives is carried out, including supplementary cementitious materials, in addition to the conventional supplies. They are evaluated not only in terms of technical suitability, but also in terms of environmental performance and local availability. In line with this, processes of contracting should be intended to entrench the sustainability and performance targets as central requirements. The process dimension is a coordinated procurement and logistics with the assistance of digital platforms, which allows tracking goods in real time, monitoring the inventory and assessing suppliers. Here, the activation of performance-based contracts take place in a way that makes suppliers have the motivation to provide high-quality and sustainable materials within the required time. The risk-sharing systems also stabilise the system by harmonizing the interests of both the operator and the suppliers and minimising chances of conflict when there are operational uncertainties. The outcome dimension is described by a decrease in non-productive time, better well integrity, and less environmental impact due to the usage of green materials regularly. The digital monitoring systems and post-project evaluations used in the framework are the feedback loops that give an insight into supplier performance and material effectiveness. These lessons are used in the next round of procurement and contracting, and build a self-enhancing structure of improvement.

This combined framework has a conceptual gap in the literature as it acknowledges sustainability imperatives and contractual innovation simultaneously. It repositions supply chains not only as logistical processes by providing platforms of operational efficiency and environmental responsibility.

➢ *Implications for Policy and Practice*

To regulators and government, the framework points out the need to create closer interconnection in energy policies and sustainable sourcing policies. The government can stimulate adoption on an industry-wide basis through regulatory incentives like tax rebates on the use of eco-friendly materials, or the introduction of sustainability requirements in contracts. In the case of oil and gas operators, the framework will give a guide to integrate sustainability and performance in supply chain practices. Through the implementation of performance contracting and digital monitoring applications, operators will be able to minimize non-productive periods, improve transparency, and make sure that suppliers comply with environmental standards. This not only enhances operational effectiveness, but also enhances corporate image at a time when increased environmental scrutiny is being experienced. In the case of local suppliers, the model emphasizes the need to build capacity. With training, technological assistance, and partnership ventures, indigenous firms can be able to address the technical and sustainability needs of international players. Much more use of local suppliers facilitates community development, which further helps to enhance the social licence to operate. An illustration of how sustainability can be embedded into contract terms is presented below.

➢ *Example Sustainable Contract Clause*

Total Payment = Base Rate × (1 + Sustainability Index)

Sustainability Index = (Eco-Materials Used ÷ Total Materials) + (Local Suppliers ÷ Total Suppliers)

- Bonus: Use of ≥ 50% eco-friendly cement or ≥ 70% local suppliers → +5% payment.
- Penalty: Use of < 20% eco-friendly cement → -5% payment.

III. RECOMMENDATIONS

To operationalize this framework, several recommendations are provided. To start with, oil and gas companies can implement a gradual approach to sustainable sourcing, beginning with the replacement of old cementing materials with environmentally friendly ones. Pilot projects can serve as test beds for evaluating performance and scalability. Second, operators are supposed to incorporate sustainability requirements into their contract negotiation procedures. Models of performance-based and risk-sharing need to clearly reward suppliers who meet environmental and operational standards. This makes sustainability objectives not peripheral, but core contractual requirements. Third, it is advisable to invest in digital procurement and contracting platforms to increase transparency, utilize data to inform decisions, and enhance accountability. These platforms enable operators to monitor suppliers' performance in real-time and refine contracts based on empirical evidence. Fourth, the local suppliers need capacity building. To enable local firms to achieve sustainability standards, governments and multinational operators must work together to offer training and technical assistance to the firms, enabling them to acquire the necessary skills. Lastly, regulators should encourage sustainable operations through friendly policies, such as subsidies for environmentally friendly materials and fines for significant environmental impacts. Collectively, the steps have the capacity to make cementing supply chains models of innovation and sustainability.

IV. CONCLUSION

This conceptual review has demonstrated the importance of innovating the supply chains of well cementing by incorporating sustainable material sourcing and enhanced contract negotiation practices. Sustainable sourcing is more environmentally friendly and creates greater resilience, whereas advanced contracting brings flexibility, collaboration, and performance accountability. Although these two domains have their own strengths, a notable gap is observable in the integration of the two domains, particularly in the oil and gas sector. The novelty of this contribution lies in its suggestion of a framework where sourcing and contracting are viewed as

interdependent processes connected via a feedback loop, facilitated by digital monitoring. Such a strategy reinvents supply chains as systems of operation but also as strategic sources of sustainability and innovation. This framework can be tested in future research through case studies of drilling projects, interviews with industry stakeholders, or quantitative modeling of contract results. Future studies can test the framework's ability to minimize non-productive time, enhance well integrity, and make it more environmentally responsible by extending the conceptual interplay into practical analysis.

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