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Artificial Intelligence in Well Digitalisation: Cultural and Organisational Challenges in the Oil and Gas Industry

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ABSTRACT

Artificial intelligence (AI) is transforming global industries, including the oil and gas sector. As part of ongoing digital transformation, AI has become a key driver of well digitalisation, improving how wells are designed, drilled, monitored, and managed. Through advanced data analytics, predictive modelling, and real-time automation, AI enhances operational decision-making and optimises complex processes. Well digitalisation integrates digital technologies, automation, and data-driven intelligence across the entire well life cycle, enabling systems to process large datasets, identify patterns, predict outcomes, and recommend actions with minimal human intervention. This results in higher efficiency, reduced non-productive time, improved safety, and quicker responses to operational challenges. However, achieving effective well digitalisation with AI remains difficult due to cultural and organisational constraints, including resistance to change, limited digital literacy, siloed structures, traditional work norms, and reliance on legacy systems. This paper investigates these barriers and outlines strategies to support sustainable transformation. Using a hybrid approach—industry field observations complemented by a systematic literature review—it finds that success requires a strong digital culture, strategic investment in digital skills, organisational alignment, and visionary leadership. Addressing these factors enables organisations to unlock AI's full potential, strengthen resilience, and remain competitive in the evolving energy landscape.

1. INTRODUCTION

Artificial intelligence (AI) has become an integral component of modern society, facilitating data processing, pattern recognition, and autonomous decision-making with minimal human intervention. In the oil and gas sector, these technologies are driving the latest wave of digital transformation, particularly through well digitalisation. Well digitalisation refers to the integration of digital technologies, data analytics, automation, and AI into the operations and management of oil and gas wells (Haouel &

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Nemeslaki, 2024). This shift enhances operational efficiency, safety, and cost management, offering a strategic advantage to organisations that can adopt and scale these technologies effectively.

The integration of AI into the oil and gas industry extends across the entire life cycle. In exploration, AI algorithms interpret seismic data to identify drilling prospects with higher accuracy (Tariq et al., 2021). During drilling, AI-powered systems optimise parameters such as weight on bit and rate of penetration, while real-time analytics detect early signs of equipment failure to prevent costly non-productive time. In production and well intervention, AI models forecast reservoir performance, automate well monitoring, and support decision-making for maintenance and abandonment planning. These applications collectively enable data-driven operations that reduce uncertainty and improve overall asset performance. Koroteev and Tekic (2021) reported that AI in drilling operations has the potential to deliver 20%-time savings and reduce 15% of the overall well costs.

However, the implementation of AI-driven well digitalisation is complex and often hindered by cultural and organisational barriers. Resistance to change, risk aversion, data privacy concerns, and limited digital literacy are common issues that slow adoption (Lamb, 2018). In an industry where operational reliability is critical, the perceived risks of relying on data-driven technologies can outweigh their potential benefits in the minds of decision makers and operational staff. Employees accustomed to conventional workflows may view AI-enabled tools with scepticism, and the lack of skills to interact with these systems adds another layer of difficulty.

Organisational barriers such as fragmented data systems, hierarchical decision making, outdated legacy infrastructure, and unclear digital strategies also pose considerable challenges. These structural issues often result in siloed operations (Alshibani et al., 2024), inconsistent implementation, and underutilisation of available technologies. Without leadership that prioritises digital transformation and aligns technological change with business strategy, organisations may struggle to realise the full potential of AI in well operations. Digital transformation can only be achieved when oil and gas companies comprehensively and strategically redefine their operations, encompassing organisational structure, processes, business models, and workforce competencies (Su et al., 2022).

This paper examines the complexities involved in implementing AI-powered digitalisation in the oil and gas industry. It draws on field observations during project implementation at clients' sites. This paper also integrates insights from current literature. The study also offers practical recommendations to address the cultural and organisational challenges identified, aiming to enable more effective and sustainable adoption of AI technologies in well operations.

2. BACKGROUND

2.1. Historical Context and Technological Advancements

The oil and gas industry has always been characterised by its reliance on technology. The initial drilling methods were basic, but the industry quickly adopted more sophisticated techniques. The development of rotary drilling in the early 20th century, the introduction of offshore drilling platforms in the mid-20th century, and the advent of hydraulic fracturing in recent decades are just a few examples of how technological innovation has driven the industry forward (Zhao & Dai, 2023). These advancements have not only increased the efficiency of oil and gas extraction but also expanded the industry's reach to previously inaccessible reserves. Alongside drilling technologies, refining processes have seen significant improvements. Modern refineries are highly complex facilities capable of producing a wide range of petroleum products with minimal waste. Additionally, the development of robust transportation infrastructure, including pipelines, tankers, and rail systems, has facilitated the global distribution of oil and gas, ensuring a steady supply to meet the world's energy needs.

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2.2. The Emergence of Digital Transformation

In the 21st century, digital transformation has become a critical focus for industries worldwide. Digitalisation involves the integration of digital technologies into all areas of business, fundamentally changing how companies operate and deliver value to customers. In the oil and gas industry, this transformation is being realised through well digitalisation. Well digitalisation encompasses a range of technologies and practices designed to optimise the exploration, extraction, and production of oil and gas (Al-Rbeawi, 2023). Key components include data analytics, automation, the Internet of Things, and AI. By leveraging these technologies, companies can gain deeper insights into their operations, improve decision-making, and enhance overall efficiency.

Well digitalisation integrates a broad spectrum of technologies and practices that collectively aim to optimise the management and performance of oil and gas wells (Trevathan, 2020). Within this vast domain, the present paper focuses specifically on AI-powered well digitalisation within the well engineering segment. In the oil and gas industry, the challenge surrounding digital transformation is not merely one of technological acceptance, but rather one of confidence and accountability (Abdalla, 2023). The industry operates in an environment characterised by high-value assets, complex subsurface uncertainties, and significant safety risks, where human expertise and judgement have traditionally been central to operational decision-making. Consequently, there remains a pervasive hesitation to delegate critical decisions to AI-driven systems, particularly when such decisions have direct implications for equipment integrity, well control, and personnel safety. The concern is not whether technology can be adopted, but whether it can be trusted to perform reliably and transparently under extreme operational conditions. Building this confidence requires not only technological maturity, but also a demonstrable assurance of system reliability, ethical accountability, and regulatory compliance. These factors are essential for the responsible integration of AI in high-stakes engineering environments.

3. METHODOLOGY

This research employs a hybrid approach combining a systematic literature review (SLR) and field observations to investigate the cultural and organisational challenges influencing the adoption of AI in well digitalisation. The SLR was conducted to establish a theoretical and empirical foundation for understanding the integration of AI within well operations and broader digital transformation initiatives in the oil and gas sector. Academic journal articles, technical papers, and industry reports were systematically reviewed from recognised databases such as Scopus, ScienceDirect, and OnePetro, covering publications between 2015 and 2025. Selection criteria focused on studies addressing themes of organisational change, digital maturity, workforce readiness, and AI-driven decision-making in upstream operations. The literature was then synthesised to identify patterns, recurring challenges, and enabling factors relevant to digital adoption, forming the conceptual framework for the subsequent field observations.

Field observations were carried out during AI-enabled well digitalisation projects implemented at two client organisations, (i) large multinational operator with an established digital infrastructure, and (ii) a smaller independent company at an early stage of digital transformation. Observations were gathered through direct participation in project meetings, workflow assessments, and system integration sessions across both organisations. The data collected focused on how teams interacted with digital systems, the nature of decision-making processes, and the readiness of organisational culture to accommodate AI-supported operations. Although the two organisations differed significantly in size, resources, and digital maturity, these contextual variations provided valuable comparative insights into how organisational scale influences the pace and depth of AI integration in well operations. Alshibani et al. (2024) developed a hybrid framework that integrates technological, organisational, environmental, and strategic dimensions to evaluate digital transformation challenges within the oil and gas industry. The present study aligns with this theoretical model but concentrates specifically on the organisational and cultural dimensions of the framework, which are critical to understanding the barriers affecting AI-driven well digitalisation.

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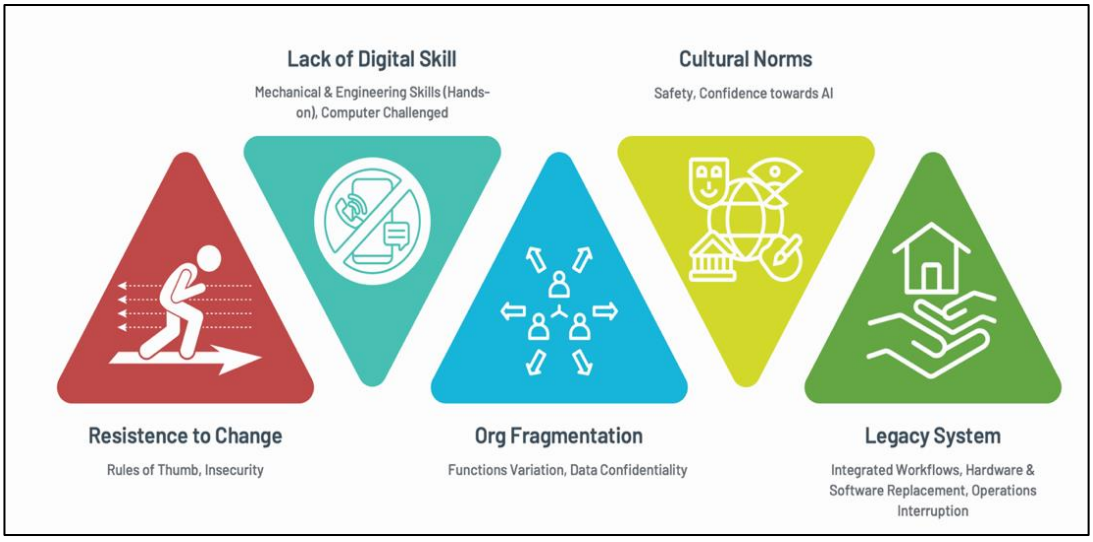
While the outcomes of the implementations reflected different levels of success, this paper focuses on the commonalities rather than the contrasts. The analysis centres on the shared cultural and organisational barriers observed in both contexts, such as resistance to process automation, limited digital competencies, and the persistence of traditional management hierarchies. These common challenges provide a representative view of the systemic issues facing AI-driven well digitalisation across the industry. By triangulating findings from both literature and field evidence, the study develops a nuanced understanding of how cultural and organisational dynamics shape digital transformation outcomes, offering a grounded perspective that links theoretical insights with real-world application.

4. FINDINGS: CULTURAL AND ORGANISATIONAL BARRIERS

Despite the clear benefits of well digitalisation, its implementation is often impeded by deep-rooted cultural and organisational barriers. Culturally, the oil and gas industry is traditionally risk-averse and built upon decades of established engineering practices that prioritise safety, reliability, and procedural compliance. This culture, while vital for operational integrity, often discourages experimentation and limits the willingness to trust automated or AI-driven systems (Sundaramurthy et al., 2022). Engineers and decision-makers may perceive digital technologies as threats to professional autonomy or as untested interventions that could compromise operational control.

Organisationally, the challenges stem from structural rigidity, fragmented workflows, and siloed data systems that restrict collaboration and knowledge sharing across disciplines. Many organisations continue to rely on legacy infrastructures, hierarchical decision-making processes, and traditional project management models that are not easily compatible with agile, data-driven frameworks. These cultural and organisational dynamics are manifested through resistance to change, insufficient digital competency, and misalignment between technology initiatives and corporate strategy that collectively hinder the effective integration of AI-driven well digitalisation. Overcoming these barriers requires not only technological readiness but also a strategic transformation in mindset, leadership, and organisational design. Fig. 1 shows the five cultural and organisational barriers in implementing well digitalisation that was observed to be common in the organisations implementing AI-driven well digitalisation projects.



Source: Developed by author

Fig. 1. Cultural and organisational barriers in well digitalisation implementation

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4.1 Resistance to Change (Cultural Barrier)

Resistance to change is a common challenge in many industries, but it is particularly pronounced in the oil and gas sector, which has a long history and deeply rooted ways of working. There are many "rules of thumb" in the industry, which have been around for years and work for many of the cases. For example, "pulling wet pipe, with no slug can cause about four times more pressure loss, per increment of pipe, than pulling dry pipe with good slug" (Murchison, 1993). This is the safe way of working. Can the operations be done better? What is the science behind this rule of thumb? The attitude that "what is not broken does not need to be fixed", makes process improvement through well digitalisation a challenge. The necessity of changing something that is already working well is usually not an option. Another element of resistance to change is insecurity. Employees may be sceptical of new technologies, fearing that digitalisation might render their skills obsolete or lead to job losses. In a case study conducted by Zhang et al. (2024), the survey results show that resistance to change is very much related to employees' ability to understand what digital technologies are about. This resistance can slow down the adoption of well digitalisation and create friction within the organisation.

4.2 Lack of Digital Skills (Cultural Barrier)

Well digitalisation demands a workforce that is proficient in digital technologies, data analytics, and automation. However, many workers in the oil and gas industry have traditionally developed their expertise in mechanical and engineering skills. This skills gap is evident across the board, from offshore crews to office personnel. Bridging this gap requires substantial investment in training and education, a task that can be particularly challenging for companies already operating on tight margins (Musa, 2023). For instance, during the initial implementation of a drilling data management application in the 1990s, drilling supervisors had to be trained in using the new software. This transition was revolutionary, as it marked a significant shift for the company, enabling them to analyse data and apply lessons learned to future wells. However, most drilling supervisors at the time were not accustomed to using computers, let alone navigating a keyboard. This required extensive practice and many hours of on-site training provided by software companies. The process was not only time-consuming but also costly, placing additional financial strain on companies. Despite these challenges, the investment in training was crucial to embracing digitalisation and reaping its long-term benefits.

4.3 Organisational Fragmentation (Organisational Barrier)

Large oil and gas companies often operate in siloed structures, where different departments and divisions work independently. This organisational fragmentation can significantly hinder the seamless integration of digital technologies across the company (Evseeva et al., 2023). To overcome these barriers, a cohesive digital transformation strategy is required—one that aligns all parts of the organisation towards a unified goal. For example, in the process of implementing well digitalisation within a company's drilling department, the well intervention department may not be included in the same digitalisation effort. This is due to the differing functions and workflows of the two departments, which often resist integration. However, this separation poses challenges because well data generated by the drilling department is also critical for well intervention activities when the well needs to be accessed in the upcoming future. Later, once the well intervention work is complete, the drilling department will require the updated data to carry out tasks like well plugging and abandonment.

Fig. 2 illustrates the well life cycle highlighting the responsible departments for each phase of the well. It illustrates the typical life cycle of an oil and gas well, highlighting the key operational phases and the corresponding departmental responsibilities throughout its lifespan. The cycle begins with the Exploration Well phase, which involves drilling activities aimed at identifying hydrocarbon presence and assessing reservoir potential. Once commercial viability is confirmed, the Development Well phase follows, focusing on the systematic drilling of production wells to optimise field output. As production

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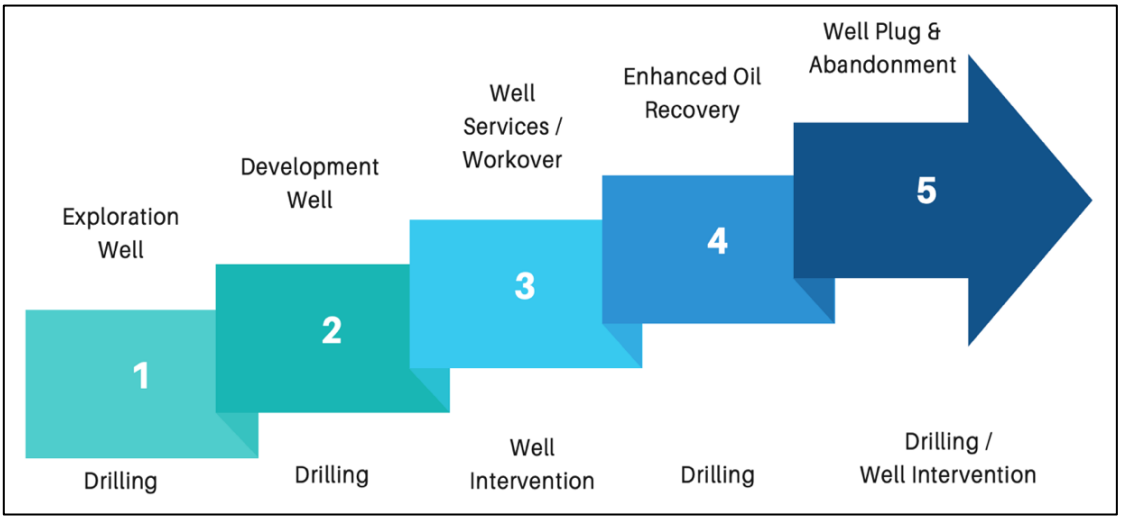
stabilises, the Well Services/Workover phase becomes critical for maintaining well integrity and performance through intervention operations such as stimulation, recompletion, or equipment replacement. Subsequently, Enhanced Oil Recovery (EOR) operations are undertaken to maximise hydrocarbon extraction through advanced drilling or injection techniques, extending the productive life of the field. Finally, the Well Plug and Abandonment (P&A) phase concludes the life cycle, ensuring the safe and environmentally responsible closure of the well. Each phase involves a different balance of drilling and well intervention activities, reflecting the continuous technical and operational interplay between these disciplines across the well's entire lifespan.



Source: Developed by the author

Fig. 2. Well life cycle - well phases and responsible departments

The figure also highlights the division of responsibilities across departments, namely drilling, well intervention, and drilling/well intervention, throughout the well life cycle. While this structure reflects clear functional specialisation, it often leads to siloed communication and limited data sharing between departments. Each phase tends to operate within its own technical and procedural boundaries, resulting in fragmented decision-making and duplication of effort. This lack of integration hinders knowledge transfer and continuity across the well's lifecycle, making it difficult to fully leverage data-driven insights. Overcoming these departmental silos is essential for achieving effective AI-driven well digitalisation, where seamless collaboration and unified data management are prerequisites for operational efficiency and system-wide optimisation.

The lack of integration between these departments not only complicates workflows but also makes the exchange of information difficult. For instance, accessing data from each department can be a cumbersome and time-consuming process. This is especially true for drilling data, which is often treated as highly confidential due to its sensitive nature and the potential risks associated with its misuse (Musa, 2023). Obtaining such information is not only difficult but also costly in the first place, with the added concern of undesirable consequences if the data is made available to unauthorised parties. This example underscores the importance of breaking down organisational silos and fostering better collaboration across departments to fully realise the benefits of digitalisation in the oil and gas industry in a secured environment.

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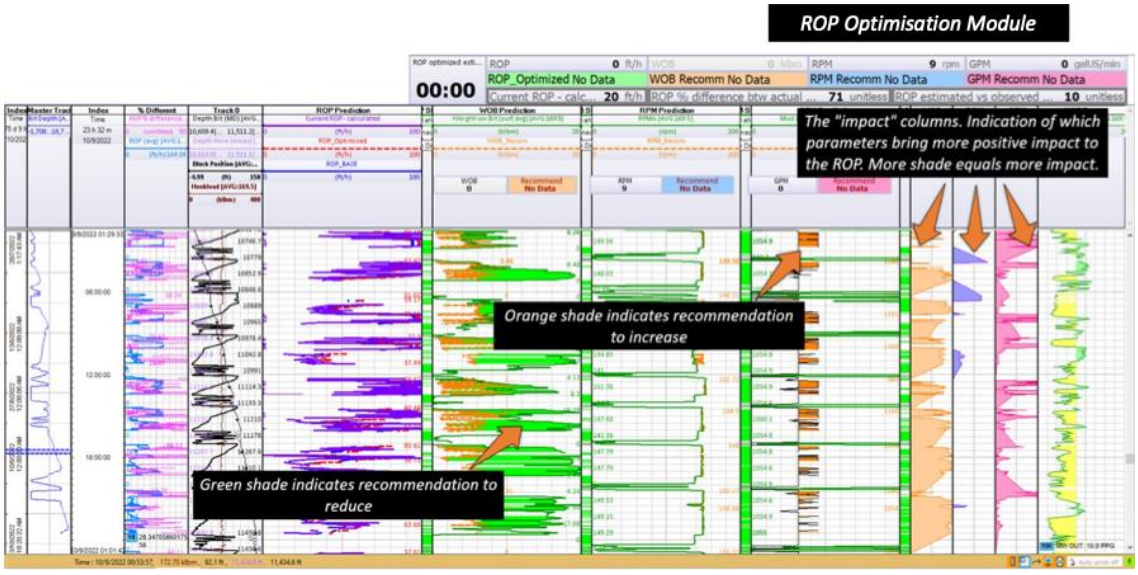
4.4 Adherence to Cultural Norms (cultural barrier)

The oil and gas sector is deeply rooted in a culture of risk management and strict adherence to established protocols. While this culture is crucial for ensuring safety and operational reliability, it can also inadvertently discourage innovation and slow down the adoption of new technologies. Shifting this ingrained culture to embrace digital innovation requires a thoughtful approach to change management and strong leadership committed to guiding the transition.

For instance, safety is of paramount importance in the oil and gas industry, as incidents can have catastrophic consequences, such as the Deepwater Horizon tragedy. As part of well digitalisation efforts, automation is being increasingly introduced to minimise human contact with heavy equipment on the rig floor, such as replacing manual pipe makeup with the use of an iron roughneck. Similarly, determining the rate of penetration (ROP) during drilling traditionally involves human supervision, raising the question of whether a computer should be entrusted to make real-time decisions about adjusting the drilling speed. Entrusting such critical decisions to machines is not an easy choice, as it involves both the safety of personnel and the protection of valuable assets (Musa, 2023). Fig. 3 shows the ROP charts that drilling personnel analyse during drilling operations to decide whether to speed up or slow down the process.



Source: Sample taken from random well operations (collected by author)

Fig. 3. ROP monitoring with real time operation application (this figure is meant for the reader to appreciate the pattern of data presented in real time operations monitoring and not meant for detailed information)

The long-standing safety culture in the oil and gas industry has been instrumental in minimising incidents that could endanger lives and jeopardise operations. As a result, there is understandable hesitation in fully embracing automation, particularly when it comes to life-critical decisions. Convincing stakeholders that AI and automation can match, or even surpass, human decision-making in ensuring safety will be a significant challenge. Building trust in these new technologies will require not only technological advancements but also a careful balance between innovation and the unwavering commitment to safety that has defined the industry for decades.

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4.5 Reliance on Legacy Systems (organisational barrier)

Many oil and gas companies have made significant investments in existing infrastructure and technologies, which often create a barrier to adopting newer digital solutions. These legacy systems, while state-of-the-art at the time of implementation, may not be compatible with the modern digital platforms required for today's industry demands (Lalovich, 2018). Transitioning from these established systems to more advanced digital technologies can be an intricate and costly process, necessitating careful planning and execution to minimise disruption and ensure a seamless transition.

For example, consider an organisation that implemented a cutting-edge system in the early 2000s. At that time, this system was considered state-of-the-art and was fully integrated into the company's operations. Fast forward twenty years, and a new system has been introduced, featuring cloud-based software applications and databases. The process of switching from the legacy system to this new platform presents a significant challenge. The costs associated with this transition are substantial, not only due to the need for new hardware and software but also because the existing system has become deeply embedded in the organisation's workflows. Employees have been extensively trained on the legacy system, making them proficient in its use, and disrupting this familiarity could affect productivity.

Moreover, ongoing operations present another layer of complexity. Shutting down the legacy system to migrate to the new one seems almost impossible, as continuous operation is crucial in the oil and gas sector. Any downtime could lead to operational inefficiencies or even financial losses. In addition, the compatibility of the new system with other integrated systems across various departments is a critical concern. If the new digital platform cannot seamlessly integrate with the existing systems in other parts of the organisation, it could lead to data silos, inefficiencies, and further complications.

This situation highlights a significant challenge that many large organisations face when attempting to implement well digitalisation. The transition from legacy systems to modern digital platforms is not merely a technological upgrade but a complex transformation that involves rethinking processes, retraining personnel, and ensuring that all parts of the organisation can work together smoothly (Haouel & Nemeslaki, 2024). As a result, many companies struggle to strike the right balance between maintaining operational continuity and embracing the efficiencies and advancements that digitalisation can bring.

5. INTERVENTIONS: ADDRESSING CULTURAL AND ORGANISATIONAL BARRIERS

Addressing the cultural and organisational barriers to well digitalisation requires a multifaceted approach. Companies must focus on change management, workforce development, and fostering a culture of innovation. Effective change management is critical to overcoming resistance to change. This involves engaging with employees at all levels of the organisational, addressing their concerns, and providing clear communication about the benefits of digitalisation. Leaders must articulate a compelling vision for well digitalisation and create a sense of urgency around the need for change (Hawash et al., 2020).

Investing in workforce development is essential to bridge the digital skills gap. Companies should provide comprehensive training programs to equip employees with the necessary digital skills (Abdalla, 2023). This can include formal education, on-the-job training, and partnerships with educational institutions. Additionally, fostering a culture of continuous learning can help employees stay up to date with the latest technological advancements. Shifting the organisational culture to embrace innovation requires strong leadership and a commitment to change. Leaders must encourage experimentation and risk-taking, create an environment where new ideas are valued, and recognize and reward employees who contribute to digital initiatives. By fostering a culture of innovation, companies can overcome the inertia that often impedes the adoption of new technologies (Lalovich, 2018).

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A cohesive digital transformation strategy or strategic integration is essential to overcome organisational fragmentation. This strategy should align all parts of the organisation towards common goals and ensure that digital initiatives are integrated into the overall business strategy. Cross-functional teams and collaborative initiatives can help break down silos and promote a more integrated approach to well digitalisation (Olajiga et al., 2024). Managing the transition from legacy systems to modern digital platforms requires careful planning and execution (Abdalla, 2023). Companies should conduct thorough assessments of their existing infrastructure and identify areas where digital technologies can be integrated. This process should be phased to minimize disruption and ensure that the transition is smooth and manageable. Investing in scalable and flexible digital solutions can also help future-proof the organisation.

6. ROLE OF VISIONARY LEADERSHIP

Navigating the complexities of well digitalisation requires more than just technological solutions; it demands strong, visionary leadership. Leaders in the oil and gas industry must be able to articulate a clear vision for digital transformation and inspire their organisations to embrace change. They must foster a culture of innovation, encourage collaboration across departments, and invest in the development of digital skills within their workforce. A visionary leader must also be proficient at managing resistance to change. This involves addressing the concerns of employees, providing reassurance about job security, and highlighting the long-term benefits of digitalisation. Effective communication is key to building trust and gaining buy-in from all levels of the organisation. Furthermore, leaders must prioritise the integration of digital technologies into the company's strategic agenda. This includes setting clear objectives, allocating resources, and establishing metrics to measure progress. By aligning digital transformation efforts with the company's overall business goals, leaders can ensure that well digitalisation delivers tangible benefits and drives sustainable growth. Fernandez-Vidal et al. (2022) mentioned that leadership behaviour, rather than technology capability, determines digital success.

7. CONCLUSION

AI-driven well digitalisation represents a transformative shift in how wells are designed, drilled, monitored, and managed. By integrating artificial intelligence, data analytics, and automation across the well life cycle, the oil and gas industry has the potential to achieve significant improvements in operational efficiency, cost management, and safety performance. The success of AI fundamentally relies on human intelligence. AI solutions are not one-size-fits-all products that can simply be purchased off the shelf. These solutions must still be tailored to suit the specific business context and the unique data available within an organisation (Koroteev & Tekic, 2021). The findings from this study, derived from both systematic literature review and field observations, indicate that while the technological capability to implement AI-driven solutions already exists, the greater challenge lies within the cultural and organisational dimensions of adoption. Both large and small organisations exhibited similar patterns of resistance, including risk aversion, limited digital literacy, and deeply entrenched legacy structures that inhibit collaboration and data sharing.

To enable sustainable transformation, organisations must look beyond technology deployment and prioritise leadership-driven cultural change. Visionary leaders play a pivotal role in communicating the strategic importance of AI integration, fostering a culture of trust in digital systems, and ensuring alignment between technology initiatives and business objectives. Building digital competencies, encouraging interdepartmental collaboration, and redefining traditional workflows are essential steps to unlock the full potential of AI in well operations. The research also highlights that successful adoption depends on confidence in the system’s reliability, in its capacity to safeguard high-value assets and human lives, and in its ability to complement rather than replace human expertise.

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Ultimately, AI-driven well digitalisation should not be viewed to replace the workforce, but as a strategy to enhance human capability and organisational intelligence. By empowering engineers and decision-makers with predictive insights and real-time data, AI enables more informed and agile operational strategies. Organisations that embrace this holistic approach—combining technological innovation with cultural adaptation and organisational alignment—will be better positioned to realise the full value of AI, achieving not only operational excellence but also long-term resilience and competitiveness in an increasingly digital energy landscape.

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9. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

10. AUTHORS' CONTRIBUTIONS

Abdul Razak Yakob conducted the research, drafted the manuscript, and carried out revisions. Hazilah Mad Kaidi critically reviewed the manuscript, provided constructive feedback, and approved the final submission.

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