The Role of Artificial Intelligence in Enhancing Supply Chain Performance within Nigeria's Oil and Gas Sector

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ABSTRACT

This study examines the application of artificial intelligence (AI) in enhancing supply chain performance within Nigeria's oil and gas sector, with a focus on efficiency, agility, and resilience. As global energy demands and operational complexities rise, the need for digital transformation in supply chain management has become increasingly vital. However, in many developing economies, AI adoption remains limited due to organizational, cultural, and infrastructural barriers.

A quantitative research design was employed, using survey data collected from professionals within the Nigerian oil and gas industry. The dataset was analyzed using Random Forest and Gradient Boosting algorithms to predict transformation of oil and gas supply chain operations based on organizational readiness, familiarity, improvement initiatives, risk tolerance, and upskilling intent. Descriptive statistics and machine learning models were used to assess both perception-based insights and the predictive capacity of key transformation indicators.

Findings revealed a high level of AI awareness (83.7%) among respondents but low organizational adoption (23.3%). Digital readiness and infrastructure development were generally rated poor, while resistance to change and implementation cost were identified as the primary barriers. Despite this, a majority of participants believed AI would improve operational performance, and over 70% expressed willingness to pursue AI-related upskilling. Machine learning results indicated that risk level, improvement, and readiness were the strongest predictors of digital transformation of supply chain operations in the oil and gas industry. Both models demonstrated moderate predictive performance, with Gradient Boosting slightly outperforming Random Forest in classification accuracy.

The study concludes that while the foundation for AI adoption exists, strategic readiness and investment are critical for tangible transformation. It recommends prioritizing risk-aware leadership, infrastructure upgrades, and regulatory support to foster a digitally capable supply chain. The findings have practical implications for policymakers, industry leaders, and supply chain strategists aiming to align AI technologies with organizational capabilities.

Keywords: Artificial Intelligence, Supply Chain Performance, Oil and Gas, Machine Learning, Nigeria, Readiness, Digital Transformation.

INTRODUCTION

The oil and gas industry plays a pivotal role in Nigeria's economy, contributing significantly to government revenue, export earnings, and energy security (Brown, 2022). Despite its importance, the sector is often fraught with complex challenges that hinder optimal supply chain performance, including operational inefficiencies, infrastructure limitations, geopolitical risks, and fluctuating market conditions (Attah, 2024). These challenges underscore the need for innovative solutions to improve supply chain agility, efficiency, and resilience. In this context, the integration of Artificial Intelligence (AI) into supply chain operations has emerged as a transformative force, offering advanced capabilities for predictive analytics, automation, decision-making, and real-time monitoring (Abubakar, 2023).

Furthermore, Artificial Intelligence encompasses a wide array of technologies such as machine learning, natural language processing, robotic process automation, and data analytics. These technologies are increasingly being adopted in global supply chain management to optimize demand forecasting, inventory management, logistics, and risk mitigation (Brown, 2022). For a dynamic and often unpredictable sector like oil and gas, AI holds the promise of transforming supply chain operations by enhancing visibility, streamlining operations, minimizing costs, and boosting adaptability to disruptions. In developed economies, several oil and gas companies have begun leveraging AI to drive operational excellence; however, in Nigeria, the adoption of AI remains relatively nascent and fragmented (Onukwulu, et al., 2024).

However, the incorporation of Artificial Intelligence (AI) within Nigeria's oil and gas supply chain is dramatically changing the sector, increasing performance, agility, efficiency, and resilience (Onukwulu, et al., 2024). The oil and gas sector, as a major contributor to the country's economy, is challenged by demand replenishment and fluctuations, inefficient logistics and disruptions in operational processes. AI provides creative solutions by harnessing data and combining analytics, machine learning, and predictive modeling (Ijeomah, 2020). Also, Kumar, Choubey, et al., (2024) asserted that one of the main applications for AI is in demand forecasting; advanced AI algorithms analyze past and real-time data and use this analysis to help predict market trend, allowing for improved inventory control and waste reduction. Also, Attah (2024) affirms that the application improves the performance of the supply chain process by increasing the speed of product delivery while decreasing the excess stock. He further asserts that AI can also increase agility through dynamic routing and scheduling of shipments.

Given the strategic importance of the oil and gas sector to Nigeria's economic development, understanding the potential of AI in enhancing supply chain performance is both timely and crucial (Ijeomah, 2020). Onukwulu, et al., (2024) stated that Nigerian oil and gas supply chains are often exposed to numerous vulnerabilities, ranging from pipeline vandalism and logistical delays to regulatory bottlenecks and environmental constraints. These issues are further compounded by the global shift towards cleaner energy sources and increased pressure for operational efficiency. As such, integrating AI-driven technologies can serve as a key enabler for fostering greater agility and resilience in supply chains, ensuring continuity, adaptability, and competitiveness in a rapidly evolving global energy landscape (Olisah, 2023).

Furthermore, Ogunboye, et al., (2023) expressed that AI-based predictive maintenance delivers efficiency gains through monitoring equipment health in real-time from sensors and IoT devices. However, Ohalete, et al., (2023) affirms that AI examines data trends to predict potential failures before they happen, which helps reduce downtime and maintenance expenditures. The study highlighted that it is a proactive approach which could help to streamline the upstream, midstream, and downstream component of the oil and gas supply chain.

Also, Onukwulu, et al., (2024) emphasize that AI enhances supply chain resilience by mitigating risks identifying weaknesses and simulating possible disruption scenarios as well as enhances transparency and traceability in supply chains via connecting blockchain technology, which enhances regulatory compliance and fraud detection (Adewale, et al., 2022). This research investigates the role of artificial intelligence in the oil and gas supply chain in Nigeria, considering its influence on performance, resiliency, agility, and efficiency and also examines the use of key AI technologies in oil and gas supply chains, key benefits and challenges, and the future of AI in the Nigeria's oil and gas sector.

LITERATURE REVIEW

The use of Artificial Intelligence (AI) in Nigeria's oil and gas supply chain is creating a paradigm shift, moving from traditional operational models to intelligent, data-driven ecosystems (Ohalete, et al., 2023). This conceptual framework reviews how AI technologies fundamentally transform four key dimensions of supply chain management: performance, agility, efficiency, and resilience in the context of Nigeria's energy sector.

Supply Chain in the Oil and Gas Sector in Nigeria

The oil and gas supply chain are a complex and interrelated system that includes exploration and extraction as well as transport and delivery of refined products (Akintokunbo & Arimie, 2021). According to Adam (2019), the supply chain is often classified into three major segments: upstream, midstream, and downstream, each of which plays an important role in the entire operation of the sector. The upstream segment is responsible for the discovery and extraction of crude oil and natural gas. Nigeria, one of Africa's top oil producers, has several offshore and onshore oil fields (Ogbaini, 2025). However, the upstream industry confronts obstacles such as inadequate infrastructure, changing global oil prices, and security concerns, particularly in the Niger Delta area. Pipeline vandalism, theft, and environmental damage all make it difficult for extraction activities to run smoothly. Furthermore, the regulatory environment, while improving, remains a problem, with complicated licensing, environmental laws, and fiscal policies influencing operations (Akintokunbo & Arimie, 2021).

Furthermore, the midstream sector is responsible for the shipping, storing, and wholesale distribution of crude oil and natural gas. In Nigeria, pipelines, tankers, and trucks are largely utilized to carry raw materials to refineries and export ports. However, the midstream supply chain is riddled with problems including pipeline breaches, insufficient storage facilities, and the possibility of sabotage. Transportation infrastructure, such as roads and rail networks, frequently requires considerable renovations to enhance efficiency and lower costs. Furthermore, a lack of dependable and secure pipeline infrastructure has rendered the industry subject to theft and interruptions, raising operational costs and causing supply delays (Amue & Ozuru, 2014).

Additionally, the downstream industry in Nigeria includes refining crude oil into consumable goods such as petrol, diesel and jet fuel, as well as distributing these products to other markets (Akintokunbo & Arimie, 2021). However, Amue and Ozuru (2014) observed that Nigeria's refining capability has been undeveloped for years, resulting in a dependency on imported refined goods. The downstream industry confronts issues such as insufficient refinery infrastructure, variable crude oil supply to refineries, and erratic pricing practices. These concerns frequently result in fuel shortages, price increases, and a lack of continuous product supply.

Performance Enhancement through Cognitive Systems

Okpala (2023), avowed that AI enhances supply chain performance by leveraging cognitive capabilities that exceed human analytical capabilities. He further stated that machine learning algorithms analyze multidimensional datasets, including production values, market price, and geopolitical determinants, to enhance decision-making. Also, Akinola & Odeniyi (2023) assert that in Nigeria's challenging operational environment, where pipeline vandalism and crude oil cause significant business disruption, AI-enhanced surveillance systems, using computer vision and acoustic monitoring help to identify potential threats in real-time. Predictive analytics models (that combine historical disruption patterns in addition to current security intelligence data) increase accuracy and preemptively mitigate risk exposure (Attah, et al., 2024).

Furthermore, Ohalete, et al., (2023) stated that another important AI application that contributes to operational performance is predictive maintenance. In Nigeria, where aging infrastructure and equipment failures can lead to losses in production, AI systems analyze data from sensors built into the equipment, along with maintenance logs, and operational data, to forecast failures before they happen. The system can schedule maintenance activities in ideal time blocks, minimizing downtime and increasing the life of the equipment. In the case of rotating equipment, such as pumps and compressors, AI-based vibration analysis can identify developing faults weeks before they would be discovered using conventional monitoring methods (Attah, et al., 2024). This is especially important in Nigeria’s offshore industry, where having to deal with unplanned equipment failures leads to production shut-downs and expensive repair work.

Agility in Dynamic Operational Environments

The dynamic and volatile landscape of Nigeria's oil and gas sector requires a level of supply chain agility that traditional systems simply cannot provide (Olisah, 2023). Artificial intelligence (AI) now supports dynamic response processes through self-learning logistics networks. Also, Olugbade, et al., (2022) highlighted that through the processing of real-time data streams including security alerts from the Niger Delta, port congestion rates, and weather data reinforcement learning algorithms continually adapt transportation routing. However, Moshood, et al., (2021) expressed that digital twin technology enables the construction of virtual representations of physical supply chains, allowing operators to more effectively experiment with and optimize planned responses to various disruption scenarios.

Furthermore, Abubakar (2023) expressed that the framework of rules and regulations brings challenges and opportunities to AI adoption. While the government of Nigeria has publicly endorsed technological innovation in the oil and gas industry through initiatives such as the National Digital Economy Policy and Strategy in 2020, there has not been much substantial progress in actually implementing supporting policies (Ijeomah, 2020). Data privacy regulations and restrictions on the movement of data across international borders may increase the complexity of cloud-based AI solutions when they rely on data centers located outside Nigeria (Aderibigbe, et al., 2023).

Operational Efficiency through Intelligent Automation

Onukwulu, et al., (2024) stressed that AI enhances efficiency throughout the hydrocarbon value chain by automating complex optimization processes. The further asserted that mechanical systems that utilize neural networks analyze decades worth of maintenance records coupled with sensor data that can predict equipment failures with high percent of accuracy transforming asset management principles. Natural language processing systems implement automated contract management by generating extractions and analysis of critical terms from thousands of contract procurement documents while naturally minimizing administrative overhead (Attah, et al., 2024). AI-driven smart grids across fuel distribution networks in Nigeria balance supply and demand on a regional basis, thereby minimizing the economic impact of frequent product shortages.

Also, Olisah (2023) asserted that smart contracts can help automate and attest transactions throughout the supply chain, thus limiting opportunities for fraud and increasing compliance with predetermined contracts. This represents a particularly significant opportunity for Nigeria, where crude oil theft and product adulteration have long plagued the country's oil and gas industry. The study further affirms that AI algorithms can use transaction data patterns along the blockchain to recommend exceptions that might indicate fraudulent activities, while the immutable blockchain ledger will yield auditable records of all product movements from wellhead to end-user.

Similarly, Ghosh, et al., (2022) stated that there is significant economic opportunity that could be gained from implementing AI solutions broadly within Nigeria’s oil and gas supply chain. This value and efficiency would ultimately provide Nigeria’s petroleum products a clearer competitive advantage, both domestically and internationally. The study also avowed that the opportunity around reducing environmental impacts with AI-based optimization of the oil and gas supply chain is part of a global sustainability movement as well as an important commitment Nigeria has made in several climate agreements. The study further stressed that these opportunities would exist through flaring reduction, improved leak detection, and enhanced transportation efficiency, which would have lasting impacts on Nigeria’s economy and the environment.

Resilience Building via Adaptive Intelligence

Olisah (2023) stated that Nigeria's oil and gas supply chain exhibits improved resilience through AI's ability to learn and adapt naturally. Forces of AI-enabled scenario planning perform simulations to predict the influences of a plethora of crisis events - from a militant attack to global pandemics - leading to strong planning (Okpala, 2023). AI systems integrated with blockchain build tamper-proof audit trails for crude oil flows, ultimately tackling the persistent divisive method for product diversion and theft (Akinola & Odeniyi, 2023).

However, Abubakar (2023) stressed that the resilience of Nigeria's oil and gas supply chain derives significant advantages from the ability of AI to manage multiple risks. This sector is vulnerable to a wide array of risks such as physical security risks of oil and gas infrastructure; threats of cyberattacks; changed regulatory regimes; and events such as severe weather and natural disasters. The study further noted that AI risk assessment tools can analyze data from multiple representations, these data sources can include security reports, weather reports, and commodity prices and provide a comprehensive risk profile and suggested risk management response. However, AI simulation models can anticipate the potential impact of multiple scenarios of risk disrupting the supply chain; scenarios such as militancy attacks on oil and gas infrastructure and sudden changes in global oil demand. These technologies allow corporate leadership in the oil and gas sector to develop contingency plans that are comprehensive, empower resource allocation toward key decisions, and allow for broader menu of risk response interventions for its supply chain.

Theoretical Framework

Ogunboye (2023) asserted that the significant consequences of artificial intelligence on Nigeria's oil and gas production system can be fully appreciated through a few theoretical lenses. These lenses provide strong explanations for how AI can improve performance, agility, efficiency and resilience in a complex operational environment.

Resource-Based View Theory

The Resource-Based View (RBV) theory, was proposed by Jay Barney in 1991. The theory states that a firm's distinctive resources and skills are the basis of its long-term competitive advantage (Ikegwuru, et al., 2023). According to RBV, resources that give a long-term advantage must be valuable, rare, inimitable, and non-substitutable (VRIN). These resources might be either real (such as infrastructure) or intangible (such as technology and skill). The philosophy emphasises harnessing inherent capabilities over relying only on external circumstances. In the context of oil and gas, RBV emphasises how AI technologies, as strategic resources, may improve supply chain efficiency and resilience if appropriately leveraged and secured (Abubakar, 2023).

Furthermore, Ikegwuru, et al., (2023) highlighted that the theory provides foundation for understanding why the adoption of AI enables competitive advantages for Nigerian oil and gas firms. The study further asserted that from a theory perspective, firms can perform better by creating and utilizing valuable, rare, inimitable, and non-substitutable resources. In Nigeria, AI capabilities meet these criteria in various ways; the controlled operational data that Nigerian firms already have, becomes even more valuable when processed by the AI system and produces insights that cannot easily be replicated by other firms (Abubakar, 2023). The technical complexity of building and deploying AI solutions is a significant barrier to imitation, especially when designed for the specific operational issues in Nigeria e.g., pipeline security and crude oil theft prevention.

Contingency Theory

Contingency Theory was created by Fred Fiedler in 1964. The theory holds that there is no one ideal approach to govern or organize an organization. Instead, the ideal path of action is determined by the internal and external variables that a company encounters. The theory's major components include organizational structure, environmental unpredictability, technology, and leadership style (Udegbunam, et al., Nwafor, 2023). It emphasizes that successful decision-making and performance depend on aligning plans with unique situational elements. In the Nigerian oil and gas sector, the use of artificial intelligence in supply chain management should be tailored to the industry's specific conditions such as regulatory challenges, infrastructure limitations, and market volatility highlighting the need for a flexible, situational approach to AI adoption for improved performance and resilience (Olisah, 2023).

Also, this theory offers critical perspectives on the need for timely AI solutions in Nigeria's operational landscape. Ijeomah (2020) opined that this theoretical model indicates that there is no 'best' way of structuring or managing a firm; rather the best way is contingent on different internal and external contingencies. This means that when considering AI for Nigeria's oil and gas supply chain, solutions designed for more stable operational environments may not only be agile but also problematic. This theoretical perspective helps us understand why off-the-shelf AI solutions, even those from nations with structural conditions marginally similar to Nigeria often do not work unless they are substantially localized to account for the specific challenges of Nigeria's oil and gas economy (Li, 2022).

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Institutional Theory

Institutional Theory was developed by John W. Meyer and Brian Rowan in 1977. The theory describes how social, cultural, and legal norms inside an institution determine organizational behavior (Ijeomah, 2020). According to the notion, in order to obtain legitimacy and thrive, organizations must follow established norms, practices, and expectations. Coercive pressures (from rules and laws), normative pressures (from professional norms), and mimetic pressures (the imitation of successful peers) are all important components of Institutional Theory (Atolagbe & Mohammed, 2022). Institutional pressures such as government rules, industry norms, and stakeholder expectations all affect the use of Artificial Intelligence in supply chain management in Nigeria's oil and gas business (Olugbade, et al., 2022). Understanding these forces enables businesses to align AI programs with institutional norms, resulting in legitimacy, compliance, and long-term competitive advantage.

Furthermore, this theoretical lens contributes to our understanding of the challenges and opportunities related to AI adoption in the Nigerian oil and gas industry. Brown (2022) expressed that this theoretical perspective highlights the significance of regulatory, normative, and cultural-cognitive institutions and how they shape organizational practice. Aderibigbe, et al., (2023) expressed that in the case of Nigeria, the regulatory landscape for the use of data and implementation of AI is starting to mature, creating challenges for organizations considering investments in AI technologies. At the same time, normative pressures from international partners and investors are motivating organizations to offer digital technologies more frequently as well as cultural-cognitive factors, such as workforce perceptions of technology use, drive implementation outcomes in knowledge-based organizations (Ikegwuru, et al., 2023). This theory also helps to explain the successful use of AI design in contrast to others that may fail based on the institutional forces that they interact with. It also indicates that AI adoption needs to be more than simply implementing technology, but involves influencing the institutional environment through policy and investment in organizational development and support initiatives (Akinola & Odeniyi, 2023).

Dynamic Capabilities Theory

The Dynamic Capabilities Theory, developed by David Teece, Gary Pisano, and Amy Shuen in 1997, builds on the Resource-Based View by emphasizing a company's ability to adapt, integrate, and reconfigure internal and external resources in response to quickly changing circumstances (Olugbade, et al., 2022). The hypothesis is especially applicable in volatile and technologically advanced sectors such as oil and gas. Its major components include identifying opportunities and risks, capturing chances, and altering organizational processes to stay competitive. Firms with dynamic capacities may innovate, adjust to market fluctuations, and make use of developing technology like artificial intelligence (Moshood, et al., 2021). In Nigeria's oil and gas business, creating dynamic skills is critical for successfully integrating AI solutions to improve supply chain agility, efficiency, and resilience in a complex and uncertain environment.

This theory provides a compelling lens through which to examine the degree AI provides Nigerian oil firms the capabilities to respond to the volatility of the oil sector (Ghosh, et al., 2022). The theory offers three key capabilities that drive organizational success in changing environments: sensing opportunities and threats, seizing opportunities, and transforming resources to remain competitive. Also, Olugbade, et al., (2022) stressed that AI significantly enhances sensing capabilities with real-time monitoring systems that can detect everything from equipment failure to breaches in security throughout Nigeria's extensive pipeline system. The study also highlights that AI will assist firms detecting patterns that will allow them to predict changes in market conditions and operational risks in ways that are specific to the Nigerian context.

In terms of seizing capabilities, AI assists with improved and sped up decision-making around resource allocation, logistics, and crisis response (Moshood, et al., 2021). The transforming capability is advanced through AI's ability to process vast amounts of data and discover key opportunities to improve supply chain design and operations that would not be possible through 'traditional' means.

Complex Adaptive Systems Theory

The Complex Adaptive Systems (CAS) Theory was proposed by John H. Holland in 1992. It regards organizations and systems as dynamic networks of interacting agents that adapt and change over time. It is based on complexity research and is especially beneficial for comprehending nonlinear, unpredictable systems like supply chains. Agents, interactions, adaptability, self-organization, and emergence are the five main components of CAS. These systems are constantly learning and evolving in response to input and environmental changes (Onukwulu, et al., 2024). In the context of Nigeria's oil and gas supply chain, CAS theory suggests that incorporating Artificial Intelligence can improve the system's ability to self-organise, respond to disruptions, and improve overall agility and resilience by enabling smarter, more adaptive decision-making processes across interconnected supply chain nodes (Attah, et al., 2024).

However, Onukwulu, et al., (2024) posited that this theory offers a framework for understanding how AI can assist in navigating the complicated, interconnected structure of Nigeria's oil and gas supply chain. This theoretical perspective also portrays supply chains as dynamic networks for which local interactions among the components bring about emergent behaviors at the system level. AI can help navigate this complexity by providing a model of the nonlinear relationships among the various elements of the supply chain (Attah, et al., 2024). In the case of Nigeria, where supply chains encounter unreliable infrastructure, security vulnerabilities, and regulatory uncertainty, AI systems can model the extent to which adjustments in one element of the system affect other components (Ijeomah, 2020).

Gaps in Literature

New scholarly contributions have taken a critical view on gaps in research that takes account of Indigenous knowledge systems in Nigeria's oil and gas supply chain management. The study conducted by Attah, et al., (2024) stated that the academic literature on artificial intelligence in Nigeria's petroleum supply chain reveals significant knowledge gaps, hindering its practical application but despite the increased global research, there is a significant gap in understanding the operational reality of Nigeria's oil and gas industry. Also, the study by Udegbunam, et al., (2023) focus on developed economies with established digital infrastructure, neglecting Nigerian realities like inconsistent power delivery, lack of internet connectivity in remote areas, and varying technology adoption rates which results in unrealistic solutions for local applications. Furthermore, there is a lack of empirical studies that consider the application of AI systems in Nigeria's constrained infrastructure environment while maintaining operational reliability.

Also, Masiko, et al., (2022) highlighted that the area of human capital presents another major research gap in his study. While the literature recognizes the skills gap, it does not provide a detailed analysis of the specific skills required for AI use in Nigeria's petroleum supply chain. Moreover, there is little discussion about training approaches, organizational change management, and how educational institutions can develop AI talent in Nigeria. This gap is especially notable in terms of overcoming workforce transitions, meaning how traditional supply chain jobs will change to accommodate AI, and what reskilling programs would suit the Nigerian environment.

However, Ijeomah (2020) asserted that another significant gap in the research is inter-organizational dynamics. The study expressed that there has been overwhelming focus on intra-organizational AI applications and, to a lesser extent, the prospect of AI to improve interactions among the various actors in Nigeria's petroleum value chain. There is very little research on AI-enabled collaboration, even though it has the potential to address coordination difficulties among international oil companies, local suppliers, logistics service providers, or regulatory agencies. This is a particularly salient gap in research owing to the fractured characteristics of Nigeria's oil and gas ecosystem and this provides minimal discussion of the long-term implications associated with AI applications. (Zhang, 2022) averred that most research is only considering the short-term operational improvements gains, and very little of these studies consider the implications of AI structural changes to the Nigerian petroleum supply chain and thus gives a scanty consideration to the possible dislocation of conventional actors in the supply chain, new opportunities for digital economy work, or potential avenues for competitive advantage that may emerge following AI adoption. However, none of these studies have examined how AI technologies can enhance the efficiency and resilience of oil and gas supply chains in Nigeria.

Therefore, this study aims to examine how AI technologies can enhance the efficiency and resilience of oil and gas supply chains in Nigeria.

METHODOLOGY

Research Design

This study adopts a quantitative research design to explore the impact of Artificial Intelligence (AI) applications in the oil and gas industry using machine learning techniques. Data will be collected through structured surveys distributed to industry professionals, ensuring firsthand insights. The responses will be preprocessed and analyzed using supervised learning algorithms to identify patterns, relationships, and predictive trends. The research emphasizes a data-driven approach, leveraging participant-generated data instead of historical datasets. This design allows for a deeper understanding of current perceptions, adoption levels, and the predictive influence of AI on operational efficiency within the sector.

Data Collection

Data for this research will be collected through an online survey targeted at professionals within the oil and gas industry. The questionnaire is designed to capture structured responses related to the adoption and impact of Artificial Intelligence (AI) technologies. The features to be extracted from the survey responses include: job role, years of experience, level of AI awareness, current use of AI, perceived impact on productivity, training received, company size, department, challenges in AI implementation, and openness to future adoption. These variables will serve as input features for the machine learning model. The target variable will be “AI Adoption Level,” a categorical label indicating whether the respondent’s organization has adopted, plans to adopt, or has not adopted AI technologies.

Data Preprocessing

Prior to model training, the collected survey data will undergo thorough preprocessing to ensure quality and consistency. This will involve handling missing values through imputation or removal, encoding categorical variables using label encoding or one-hot encoding, and standardizing numerical features to a uniform scale. Outliers will be detected and addressed to prevent model distortion. Additionally, data will be checked for inconsistencies, duplicates, and irrelevant entries. The cleaned dataset will then be split into training and testing sets to evaluate model performance. This preprocessing phase is critical to enhance the accuracy and reliability of the machine learning analysis in the study.

Machine Learning Models

This study will employ Random Forest and Gradient Boosting algorithms to analyze the survey data. These ensemble learning methods are selected for their robustness, predictive accuracy, and ability to handle both categorical and numerical features. Random Forest offers interpretability through feature importance measures and is effective in reducing overfitting by aggregating multiple decision trees. Gradient Boosting is chosen for its capacity to sequentially optimize model performance by minimizing classification errors. Both models will be trained and tested on the preprocessed dataset, and their effectiveness will be evaluated using standard performance metrics such as accuracy, precision, recall, F1 score, and AUC.

Model Evaluation Metrics

To assess the performance of the machine learning models, this study will utilize key evaluation metrics including accuracy, precision, recall, and F1-score. Accuracy will measure the overall correctness of the predictions, while precision will indicate the proportion of true positive predictions among all positive predictions made. Recall will evaluate the model’s ability to correctly identify all relevant cases, and the F1-score will provide a balance between precision and recall, especially useful in cases of class imbalance. These metrics will enable comprehensive evaluation and comparison of the Decision Tree and Support Vector Machine models for reliable interpretation of results.

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Ethical Consideration

This study adheres to strict ethical guidelines in data collection and analysis. Participants will be fully informed about the research objectives and their consent will be obtained prior to survey participation. Anonymity and confidentiality of responses will be ensured, with data used solely for academic purposes. No personally identifiable information will be collected or shared. The study will also ensure transparency in algorithm development and prevent biases in model interpretation. Ethical clearance will be sought from the appropriate institutional review board to ensure that all research processes align with established ethical standards in handling human-centered data.

RESULTS

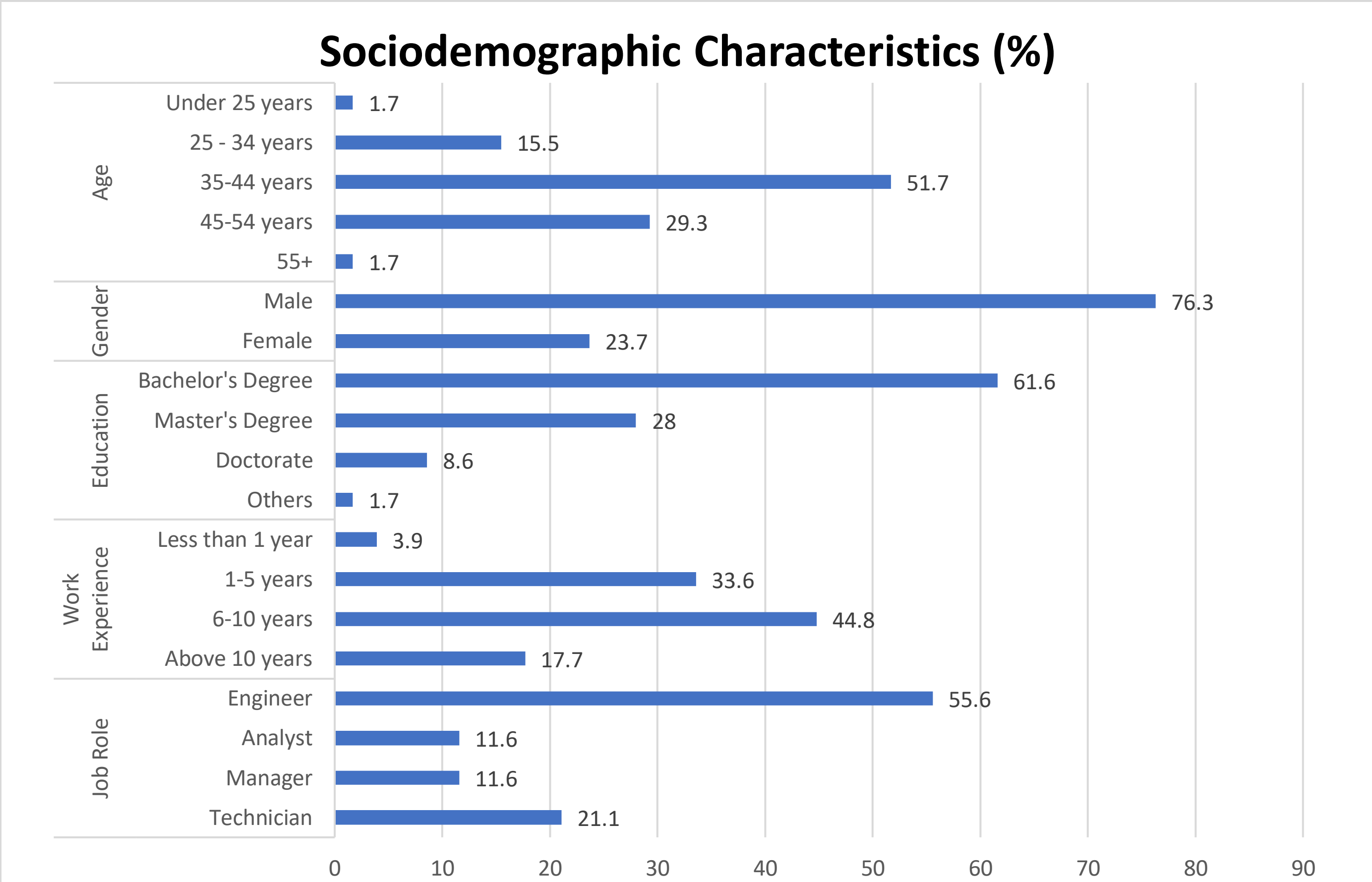

Figure 1: Sociodemographic Characteristics of the Participants (%)

The sociodemographic profile of respondents, as illustrated in the chart, reveals a predominantly male workforce (76.3%) with most individuals aged between 35–44 years (51.7%), followed by those aged 45–54 (29.3%). Educationally, a large portion hold at least a Bachelor's degree (61.6%), with 28% possessing a Master's and 8.6% a Doctorate, indicating a highly educated sample. In terms of work experience, 44.8% have 6–10 years of experience, while 33.6% have between 1–5 years, suggesting a relatively experienced workforce. Job roles are mostly engineering-based (55.6%), with technicians (21.1%), analysts (11.6%), and managers (11.6%) making up the rest, highlighting a technical and professional demographic within the industry.

Table 1: Perception on Awareness and Readiness

Technological Awareness and Readiness	Frequency	Percentage
How familiar are you with Artificial Intelligence (AI)?		
Not Familiar	4	1.7

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Slightly Familiar	10	4.3
Neutral	24	10.3
Somewhat Familiar	137	59.1
Very Familiar	57	24.6
Has your organization adopted AI-Based solutions in any capacity?		
Yes	54	23.3
No	178	76.7
Which AI applications are currently used in your organization?		
Predictive Maintenance	13	5.6
Reservoir Modeling	11	4.7
Drilling Optimization	19	8.2
Safety Monitoring	11	4.7
None	178	76.7
Organization's level of digital infrastructure readiness for AI deployment		
Very High	10	4.3
High	19	8.2
Moderate	31	13.4
Low	128	55.2
Very Low	44	19.0

The findings from Table 1 indicate that while a majority of respondents (83.7%) are at least somewhat familiar with AI, actual implementation within organizations remains limited, with 76.7% stating that their organization has not adopted AI-based solutions. Among those that have, usage is minimal and scattered across functions like drilling optimization (8.2%) and predictive maintenance (5.6%). Furthermore, digital infrastructure readiness is notably low, with 74.2% of respondents rating their organization's readiness as either low or very low. This suggests that although awareness of AI is relatively high, organizational adoption and infrastructure development are lagging, highlighting a gap between knowledge and practical readiness for AI integration.

Table 2: Perception of Awareness and Readiness

Perception, Challenges, and Opportunities	**Frequency**	**Percentage**
In your opinion, what is the biggest challenge to AI adoption in your company?		
Lack of Expertise	18	7.8
Data Availability	10	4.3
Cost	78	33.6
Resistance to Change	108	46.6
Ethical/Regulatory Concerns	18	7.8
AI will significantly improve operational efficiency in oil & gas		

Strongly Agree	56	24.1
Agree	106	45.7
Neutral	23	9.9
Disagree	39	16.8
Strongly Disagree	8	3.4
What level of risk do you associate with AI integration in critical operations?		
Very High	24	10.3
High	46	19.8
Moderate	49	21.1
Low	66	28.4
Very Low	47	20.3
Would you be willing to participate in AI-related upskilling programs?		
Yes	168	72.4
No	20	8.6
Maybe	44	19.0

The results from Table 2 reveal significant insights into stakeholders' perceptions of AI awareness and readiness within the oil and gas sector. The major barrier to AI adoption is “Resistance to Change” (46.6%), followed by “Cost” (33.6%), indicating that organizational culture and financial constraints are the top concerns. Despite these challenges, the outlook on AI’s impact is largely positive, with 69.8% of respondents either agreeing or strongly agreeing that AI will significantly improve operational efficiency. Risk perceptions are generally moderate to low, with 69.8% rating AI integration risks as moderate or below. Notably, 72.4% expressed willingness to participate in AI-related upskilling programs, showing a strong inclination toward capacity building and future readiness.

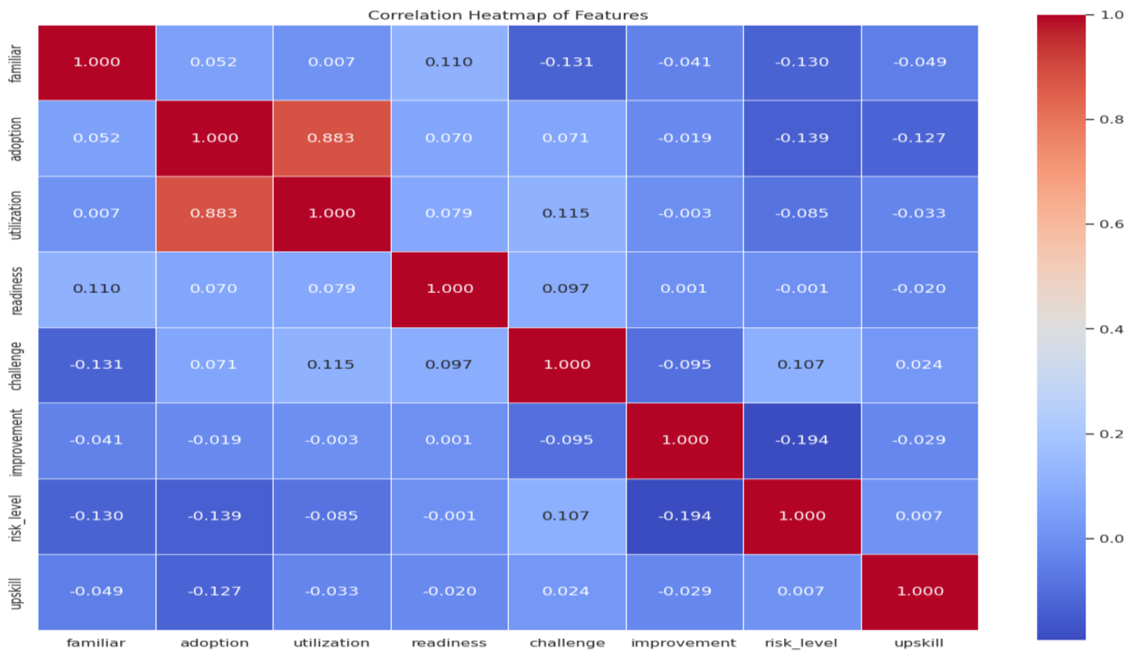

Figure 2: Correlation Matrix

The correlation matrix reveals generally weak linear relationships among most features, with coefficients close to zero. However, a strong positive correlation (r = 0.883) is observed between adoption and utilization, indicating multicollinearity. To avoid redundancy and ensure model stability, utilization was dropped from the analysis. Other features, such as familiar, readiness, and challenge, show low to moderate correlations with one another, suggesting that they each capture distinct aspects of the respondents' experiences. This lack of multicollinearity among the retained variables supports their inclusion in the machine learning models without a risk of inflating variance or distorting predictions.

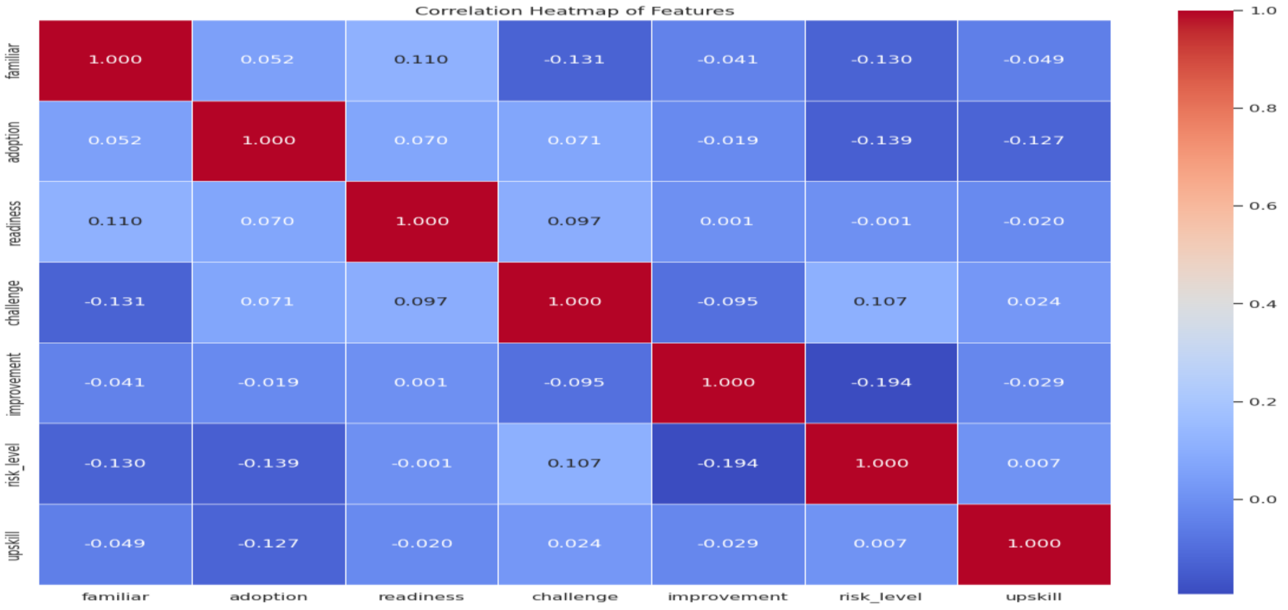

Figure 3: Correlation Matrix after dropping features with high coefficient

Presented in Figure 3 is the correlation matrix with the exclusion of utilization due to the problem of multicollinearity. These features will be included in the trained model as their correlation coefficients are lower than the threshold of 0.8.

Performance of the Gradient Boosting and Random Forest Classifiers

Both the Random Forest and Gradient Boosting models were trained and tuned using 5-fold cross-validation to predict digital transformation outcomes. The Random Forest model with optimized parameters (n_estimators = 100, max_depth = 10), while the Gradient Boosting model with optimized parameters (n_estimators = 100, max_depth = 10, and max_features = None). Classification metrics are presented in Tables 3, and both models correctly classified the majority of cases, as reflected in their confusion matrices (Figures 5). Analysis of feature importance (Figures 6) revealed consistent patterns across models, with adoption, readiness, and risk level emerging as the most influential predictors of transformation. While both models showed above-chance performance, their modest AUC values suggest that additional factors may contribute to transformation outcomes. Nonetheless, the alignment in key predictors reinforces their significance and offers practical insight for strategic interventions.

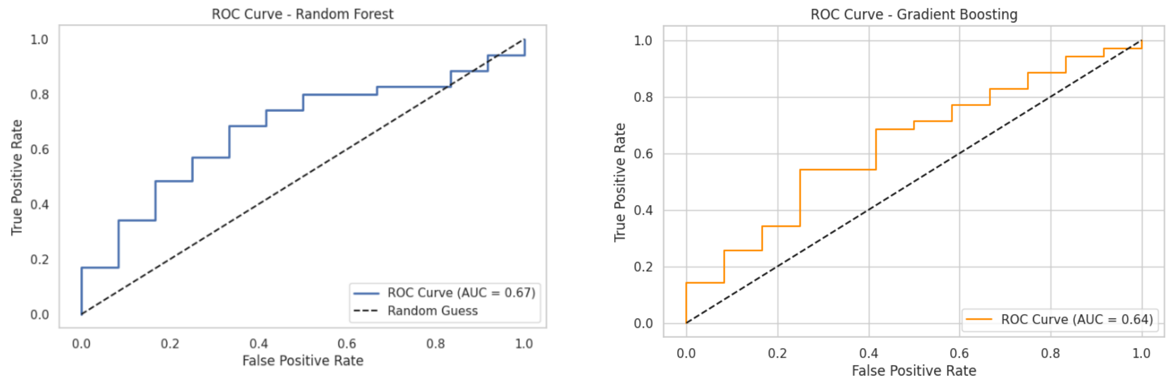

Figure 4: ROC Curves

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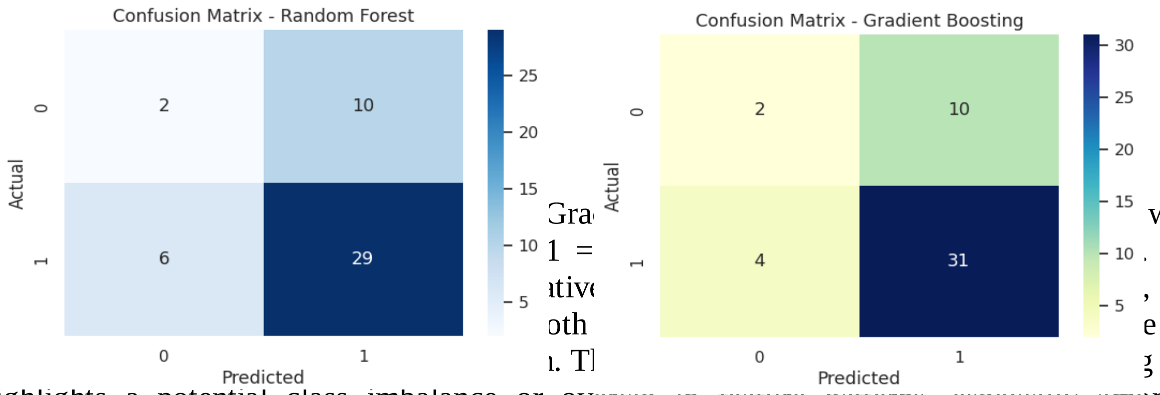
The ROC curves illustrate the predictive performance of both models in classifying transformation outcomes. The Random Forest model achieved an AUC of 0.67, while the Gradient Boosting model followed closely with an AUC of 0.64. Both curves lie above the diagonal reference line, indicating that each model performs better than random guessing. However, their AUC values suggest moderate discriminative ability at best. The similarity in curve shape and AUC scores implies that while both models are somewhat effective, neither demonstrates strong predictive power



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T ... Gra ... were more effective at ... 1 = ... Gradient Boosting ac... ative ..., which had 29 true p... oth ... e cases (actual class 0) ... n. T... transformation and highlights a potential class imbalance or overlap in feature patterns, especially among nontransformed instances.

Figure 6: Feature Importance

The feature importance plots for both the Random Forest and Gradient Boosting models reveal consistent patterns in the predictors of digital transformation of the oil and gas industry. In both models, risk level emerged as the most influential feature, indicating its critical role in predicting the transformation of the oil and gas industry. This was followed closely by improvement and readiness, suggesting that organizations perceived risks, efforts to improve, and preparedness significantly influence transformation. Less impactful features included adoption, familiar, and upskill, with adoption ranked lowest in both models. The alignment of top-ranking features across both models enhances the robustness of the findings and highlights key focus areas for strategic intervention.

Table 3: Evaluation Metrics

Metric	Random Forest	Gradient Boosting
Accuracy	0.659	0.702
Precision	0.18	0.648
Recall	0.659	0.702

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F1 Score	0.635	0.664

As shown in Table 3, the Gradient Boosting model outperformed the Random Forest classifier across all evaluation metrics. Gradient Boosting achieved an accuracy of 0.702 and an F1 score of 0.664, compared to 0.659 and 0.635, respectively, for Random Forest. Similarly, both precision (0.648) and recall (0.702) were higher for Gradient Boosting than for Random Forest (0.618 and 0.659, respectively). These results suggest that while both models demonstrated moderate predictive capabilities, Gradient Boosting offered more consistent performance, indicating a slight advantage in classifying digital transformation in the oil and gas industry.

DISCUSSION OF FINDINGS

This study examined the role of artificial intelligence (AI) in enhancing supply chain performance within Nigeria's oil and gas industry. The findings provide insight into organizational readiness, perceived benefits, existing barriers, and the predictive capacity of AI adoption with respect to supply chain agility, efficiency, and resilience. Though there was a high level of familiarity with AI technologies among respondents, actual adoption remains limited. While over 80% of participants reported being familiar with AI, only 23.3% indicated that their organizations had implemented AI solutions within their supply chain operations. This gap between awareness and execution mirrors patterns observed in similar studies conducted in emerging economies. Adewale et al. (2022) found that while digital awareness among supply chain professionals in West Africa was growing, the translation into actionable digital adoption remained constrained by infrastructural and financial limitations. Similarly, Moshood et al. (2021) emphasized that awareness is a necessary but insufficient condition for AI integration, particularly in industries reliant on traditional operational models.

Perceptions of readiness within the sector were also notably low. A majority of respondents rated their organizational readiness for AI adoption as poor, citing limited digital infrastructure, absence of a strategic roadmap, and lack of leadership commitment as key impediments. These findings align with the findings of Kumar et al. (2021), who noted that digital transformation in African industrial sectors is often hindered by both technological underdevelopment and weak institutional support structures. Resistance to change and cost emerged as the most significant barriers to adoption. These challenges have been consistently reported in literature examining digital transformation in traditional sectors. Zhang (2022) found that organizational culture and upfront implementation costs were key inhibitors of AI deployment across global supply chains. Within the context of the Nigerian oil and gas industry, these barriers are further compounded by legacy systems, regulatory bottlenecks, and fragmented infrastructure.

Respondents strongly acknowledged the potential of AI to improve supply chain performance. The majority agreed that AI could enhance efficiency, responsiveness, and resilience. key indicators of supply chain success. These perspectives are supported by prior research, including Ogunboye et al. (2023), which demonstrated that AI-powered predictive analytics and automation significantly improve demand forecasting, inventory control, and supplier coordination. The strong belief in AI's value also extended to human capital development, with over 70% of participants expressing willingness to engage in upskilling. This reflects a workforce that is open to transformation and ready to align with global trends in intelligent supply chain management, as highlighted by Olawale (2023).

The machine learning models used in this study further reinforce these findings. Both Random Forest and Gradient Boosting algorithms demonstrated moderate predictive accuracy in identifying organizations undergoing AI-enabled supply chain transformation. Although not highly discriminative, the models successfully identified core features that significantly influence transformation outcomes. This included risk tolerance, readiness, and a focus on continuous improvement. In particular, risk level emerged as the most influential feature in both models, highlighting the importance of an organization's willingness to embrace operational uncertainty in the pursuit of innovation. This supports the argument made by Kumar et al. (2021), who emphasized that resilient supply chains require risk-aware strategic planning, particularly in high-volatility sectors like oil and gas. Similarly, readiness and improvement were found to be strong predictors of transformation, indicating that internal digital maturity and process optimization are central to successful AI adoption. These findings echo those of Ikegwuru et al. (2023), who noted that digitally mature firms are more agile and better positioned to leverage AI in turbulent supply chain environments.

Interestingly, variables such as familiar, adoption, and upskill were less influential in predicting transformation. This may reflect the fact that familiarity with AI and willingness to upskill, while important, do not independently drive transformation unless accompanied by broader organizational alignment and strategic investment. This insight reinforces the position of Onukwulu et al. (2024), who argue that technology adoption in supply chains must be embedded within a supportive cultural and strategic context to yield meaningful outcomes.

CONCLUSION AND RECOMMENDATION

This study investigated the role of artificial intelligence (AI) in enhancing supply chain performance within Nigeria's oil and gas industry, focusing on efficiency, agility, and resilience. The findings revealed a high level of AI awareness among professionals but a significantly lower rate of actual adoption. Most organizations were found to lack the digital readiness required for meaningful AI integration, with resistance to change and implementation costs emerging as the most prominent barriers. Despite these challenges, there was strong optimism about AI's potential benefits, especially in improving operational performance and strengthening the adaptability of supply chain systems. Machine learning analysis using Random Forest and Gradient Boosting models demonstrated that while predictive performance was moderate, key transformation drivers could still be identified. Features such as organizational risk tolerance, commitment to process improvement, and readiness were found to significantly influence AI adoption and transformation outcomes. These results align with existing literature that positions strategic alignment and digital maturity as prerequisites for successful supply chain digitization.

Based on these findings, it is recommended that industry stakeholders prioritize digital readiness by investing in infrastructure, leadership training, and strategic change management. Organizations should also focus on building a culture of continuous improvement and calculated risk-taking to create an enabling environment for AI adoption. Policymakers and regulatory bodies can support this transformation by offering incentives for digital innovation and facilitating knowledge-sharing platforms across the industry. Lastly, future research should explore longitudinal data to assess how sustained AI engagement shapes long-term supply chain performance, particularly in dynamic sectors such as oil and gas.

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