World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Review Article)

Check for updates

Optimizing maintenance logistics on offshore platforms with AI: Current strategies and future innovations

Ayemere Ukato [1,*], Oludayo Olatoye Sofoluwe [2], Dazok Donald Jambol [3] and Obinna Joshua Ochulor [4]

[1] *Independent Researcher, Port Harcourt, Nigeria.*
[2] *Terrarium Energy Resources Limited, Nigeria.*
[3] *Independent Researcher; Nigeria.*
[4] *SHEVAL Engineering Services Limited - Levene Energy Holdings Limited, Nigeria.*

World Journal of Advanced Research and Reviews, 2024, 22(01), 1920–1929

Publication history: Received on 20 March 2024; revised on 27 April 2024; accepted on 29 April 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.22.1.1315

Abstract

Offshore platforms are vital assets for the oil and gas industry, serving as the primary facilities for exploration, extraction, and processing. Maintenance logistics plays a crucial role in ensuring these platforms operate efficiently and safely. However, the remote and harsh environments of offshore platforms present significant challenges for maintenance activities. Traditional maintenance strategies often struggle to meet the demands of these environments, leading to inefficiencies, increased costs, and potential safety risks. This review discusses the application of Artificial Intelligence (AI) in optimizing maintenance logistics on offshore platforms. Current strategies involve a combination of preventive, predictive, and corrective maintenance approaches. Preventive maintenance schedules regular inspections and replacements based on predetermined intervals, while predictive maintenance utilizes data analytics to predict equipment failures and plan maintenance activities accordingly. Corrective maintenance addresses issues as they arise, often in response to unexpected failures. AI offers opportunities to enhance these strategies by leveraging advanced data analytics, machine learning, and optimization algorithms. AI-enabled predictive maintenance can analyze vast amounts of data from sensors, historical maintenance records, and environmental factors to forecast equipment failures with greater accuracy. This allows for proactive maintenance planning, minimizing downtime and reducing maintenance costs. Furthermore, AI can optimize maintenance logistics by improving resource allocation and scheduling. Through real-time monitoring and analysis, AI systems can prioritize maintenance tasks based on urgency, equipment criticality, and resource availability. This ensures that maintenance crews are deployed efficiently, reducing idle time and improving overall productivity. Future innovations in AI for maintenance logistics on offshore platforms include the integration of Internet of Things (IoT) devices and autonomous systems. IoT sensors can provide real-time data on equipment condition and environmental factors, enabling more precise predictive maintenance models. Autonomous maintenance robots equipped with AI algorithms can perform routine inspections and minor repairs, reducing the need for human intervention in hazardous environments. However, implementing AI in offshore maintenance logistics also poses challenges, including data quality, cybersecurity, and workforce readiness. Ensuring data accuracy and reliability is crucial for effective AI models, requiring robust data collection and management processes. Cybersecurity measures must be strengthened to protect AI systems from malicious attacks that could disrupt operations or compromise safety. Additionally, workforce training and education are essential to prepare personnel for working alongside AI systems and interpreting AI-generated insights. Optimizing maintenance logistics on offshore platforms with AI offers significant benefits in terms of efficiency, cost savings, and safety. By leveraging AI technologies, current maintenance strategies can be enhanced, and future innovations can revolutionize offshore maintenance practices, making operations more sustainable and resilient in the face of evolving challenges.

Keywords: Maintenance logistics; Offshore platform; Current strategies; Future innovation

* Corresponding author: Ayemere Ukato

1. Introduction

Offshore platforms represent the backbone of the oil and gas industry, serving as crucial infrastructures for exploration, extraction, and processing activities in offshore oil and gas fields (Stroykov *et al*., 2021). These platforms are situated in diverse and often challenging environments, ranging from shallow waters to ultra-deep seas, and they play a pivotal role in meeting the global demand for energy resources (Adumene *et al*., 2023). In this review, we will delve into the significance of maintenance logistics for offshore platforms and explore the potential of Artificial Intelligence (AI) in optimizing these logistics to ensure the efficiency, safety, and sustainability of offshore operations. Offshore platforms are engineering marvels designed to extract oil and gas from beneath the seabed (Sharapov, 2023). They come in various types, each suited to specific water depths and geological conditions. Fixed platforms include: Supported by legs that can be raised or lowered, allowing them to operate in shallow waters (Amaechi *et al*., 2022). Constructed of steel and installed directly onto the seabed, providing stability in deeper waters. These platforms are not fixed to the seabed and float on the surface. They are used in deeper waters and include: Convert oil and gas from subsea wells, store it onboard, and offload it to tankers for transportation (Duggal and Minnebo, 2020). Similar to FPSOs but without storage capabilities. Employ pontoons or columns that partially submerge to provide stability, commonly used in harsh environments. These consist of equipment installed on the seabed to extract oil and gas, with production fluids transported via pipelines to onshore or offshore processing facilities. Offshore platforms are complex structures that require regular maintenance to ensure operational integrity, safety, and environmental compliance (Amaechi *et al*., 2022).

Maintenance logistics is crucial for the uninterrupted operation of offshore platforms (Olugu *et al*., 2022). These facilities are subjected to harsh environmental conditions, including corrosive seawater, extreme temperatures, and high winds, which can accelerate equipment degradation and increase the risk of failures (Abbas and Shafiee, 2020.). Failure to maintain offshore platforms can result in: Disruption of production leading to significant financial losses. Malfunctioning equipment poses safety hazards to personnel and the environment. Oil spills or gas leaks can have catastrophic environmental consequences (Singh *et al*., 2020).

Effective maintenance logistics involves: Regular checks of equipment and structures to detect early signs of wear or damage (Ren *et al*., 2021). Scheduled maintenance activities to replace worn components or perform repairs before failures occur. Utilizing data analysis and condition monitoring to predict equipment failures and plan maintenance accordingly (Jimenez *et al*., 2020). Addressing unexpected failures promptly to minimize downtime and safety risks. However, traditional maintenance strategies face challenges in optimizing resources, scheduling activities, and predicting failures accurately, especially in the dynamic and remote environment of offshore platforms (Fox *et al*., 2022).

Artificial Intelligence (AI) encompasses technologies that enable machines to mimic human intelligence, including learning from data, recognizing patterns, and making decisions (Sarker, 2022). In recent years, AI has gained prominence across various industries, offering transformative solutions to complex challenges. In the context of offshore platforms, AI holds immense potential in optimizing maintenance logistics by: AI algorithms can analyze vast amounts of data from sensors, equipment history, and environmental conditions to predict equipment failures before they occur (Çınar *et al*., 2020). This allows for proactive maintenance planning, minimizing downtime and reducing maintenance costs. These systems can optimize the deployment of maintenance crews and resources by prioritizing tasks based on urgency, equipment criticality, and resource availability (Paul *et al*., 2024). Real-time monitoring and analysis enable efficient scheduling, reducing idle time and improving productivity. AI techniques such as machine learning can extract valuable insights from complex data sets, enhancing the accuracy of predictive models and enabling better decision-making (Bharadiya, 2023). AI-powered robots can perform routine inspections, repairs, and maintenance tasks autonomously, reducing the need for human intervention in hazardous environments and improving operational safety (Mathew *et al*., 2023; Olatunde *et al*., 2024). The integration of AI in maintenance logistics has the potential to revolutionize offshore operations, making them more efficient, safer, and sustainable (Mitchell *et al*., 2022). However, challenges such as data quality, cybersecurity, and workforce readiness need to be addressed to realize the full benefits of AI in offshore maintenance. In the subsequent sections, we will delve deeper into current maintenance strategies on offshore platforms, the role of AI in optimizing these strategies, and future innovations in AI-enabled maintenance logistics (Chelliah *et al*., 2023; Adelani *et al*., 2024).

2. Current Maintenance Strategies on Offshore Platforms

Offshore platforms, being critical infrastructures in the oil and gas industry, require robust maintenance strategies to ensure their operational integrity, safety, and reliability (Mohammed *et al*., 2022). Maintenance on these platforms is typically categorized into three main strategies: preventive maintenance, predictive maintenance, and corrective maintenance. Each strategy serves specific objectives and addresses different aspects of maintenance needs. This explores these strategies in detail, including their definitions, objectives, challenges, limitations, and examples of activities applied on offshore platforms.

Preventive maintenance involves scheduled inspections, repairs, and replacements of equipment and components before they fail or deteriorate (Hajej *et al*., 2021). The primary objectives of preventive maintenance are to: Prevent equipment failures and breakdowns. Extend the lifespan of equipment. Ensure safety and reliability of operations. Minimize unplanned downtime. Despite its benefits, preventive maintenance faces several challenges and limitations, including: Performing maintenance activities based on fixed schedules can be costly, especially if equipment doesn't require it (Chou and Yu, 2022). Some components may be replaced prematurely, leading to unnecessary expenses. Conversely, some critical components may be overlooked, leading to unexpected failures. Reliance on time-based schedules rather than actual equipment condition may result in ineffective maintenance. Offshore platforms present logistical challenges, making it difficult to access equipment for routine inspections and maintenance (Rinaldi *et al*., 2021). Examples of preventive maintenance activities commonly performed on offshore platforms include: Visual inspections of equipment, structures, and pipelines to identify signs of wear, corrosion, or damage. Regular lubrication of rotating equipment to prevent friction and reduce wear (Liu *et al*., 2020). Testing and calibration of safety systems, such as fire and gas detection systems. Application of protective coatings and cathodic protection systems to prevent corrosion of metal structures. Scheduled replacement of parts such as seals, gaskets, and filters before they fail.

Predictive maintenance uses data analysis and condition monitoring techniques to predict when equipment failures are likely to occur, allowing maintenance activities to be performed only when necessary (Kamat and Sugandhi, 2020; Sonko *et al*., 2024). The objectives of predictive maintenance are to: Reduce maintenance costs by targeting maintenance activities where they are most needed. Minimize downtime by identifying and addressing issues before they escalate. Extend equipment lifespan by detecting and correcting issues early. Data analytics and sensor technology play crucial roles in predictive maintenance by: Collecting data from various sources, including sensors, equipment logs, and maintenance records. Analyzing data to identify patterns, trends, and anomalies indicative of equipment degradation or impending failures. Monitoring equipment condition in real-time to detect changes that may indicate potential issues. Predictive maintenance finds numerous applications on offshore platforms, including: Monitoring vibration levels of rotating equipment to detect bearing wear or misalignment. Analyzing lubricating oil samples to detect contaminants, wear particles, and degradation. Using corrosion sensors to monitor corrosion rates on metal surfaces and predict maintenance requirements. Inspecting electrical systems and equipment for overheating indications using infrared cameras, installing online monitoring systems to continuously monitor equipment health and performance (Balakrishnan *et al*., 2022).

Corrective maintenance involves addressing equipment failures and breakdowns as they occur, with the primary objectives of: Restoring equipment functionality and operational capability (Martins *et al*., 2020). Minimizing downtime and production losses. Ensuring the safety of personnel and the environment. Corrective maintenance faces several challenges, including: Rapid response is essential to minimize downtime, requiring efficient coordination and logistics. Identifying the root cause of failures can be complex, especially for intermittent or unexpected issues. Availability of spare parts may pose challenges, particularly for critical components. Performing maintenance tasks in emergency situations can pose safety risks to maintenance crews. While preventive and predictive maintenance aim to reduce the need for corrective actions, corrective maintenance remains essential for minimizing downtime and addressing unforeseen issues (Achouch *et al*., 2022). Its role includes: Immediate repairs to restore functionality and prevent further damage. Identifying and rectifying issues to prevent recurrence. Investigating the underlying causes of failures to implement preventive measures. Using insights from corrective maintenance to refine preventive and predictive maintenance strategies, maintenance strategies on offshore platforms play a vital role in ensuring the reliability, safety, and efficiency of operations (Subrat, 2020; Chukwurah and Aderemi, 2024). Preventive maintenance aims to prevent failures through scheduled activities, while predictive maintenance uses data analysis to anticipate issues before they occur. Corrective maintenance addresses unexpected failures promptly to minimize downtime and maintain operational continuity. While each strategy has its challenges and limitations, integrating them effectively can optimize maintenance efforts and enhance offshore platform performance (Amiri *et al*., 2021).

2.1. Role of AI in Optimizing Maintenance Logistics

Artificial Intelligence (AI) has emerged as a powerful tool for optimizing maintenance logistics on offshore platforms (Agbaji, 2021). By leveraging advanced algorithms and data analytics, AI enables proactive maintenance planning, efficient resource allocation, and real-time monitoring. This explores the various roles of AI in optimizing maintenance logistics, including AI-enabled predictive maintenance, resource allocation and scheduling, and the integration of Internet of Things (IoT) devices.

AI-enabled predictive maintenance utilizes machine learning algorithms to analyze vast amounts of data and predict equipment failures before they occur (Dalzochio *et al.*, 2020). These algorithms learn patterns and trends from historical data, allowing them to make accurate predictions based on current conditions. Machine learning techniques used in predictive maintenance include: Predicting future values based on historical data. Identifying equipment states (normal, degraded, failed). Grouping similar equipment based on characteristics and failure patterns. Using neural networks to detect complex patterns and anomalies. AI-enabled predictive maintenance integrates various types of data, including: Records of past maintenance activities and equipment performance. Real-time data from sensors monitoring equipment condition, such as temperature, vibration, and pressure. External factors such as weather conditions and operational parameters. By analyzing this data, AI algorithms can identify patterns indicative of equipment degradation or impending failures, allowing maintenance activities to be scheduled proactively (Nunes *et al.*, 2023; Adeleke *et al.*, 2024). Proactive maintenance planning offers several benefits: By addressing issues before they escalate, AI-enabled predictive maintenance minimizes unplanned downtime. Preventing failures reduces the need for emergency repairs and costly production losses. Maintenance activities can be scheduled during planned downtime periods, minimizing disruption to operations. Proactive maintenance reduces the risk of unexpected failures, enhancing safety for personnel and the environment.

AI systems provide real-time monitoring and analysis capabilities, allowing for: continuous data collection, immediate detection of anomalies and automatic alerting (Paganelli *et al.*, 2022). AI systems prioritize maintenance tasks based on factors such as: The criticality of the issue and the potential impact on operations. The importance of the equipment to the overall operation of the platform. The availability of maintenance crews, spare parts, and equipment. Prioritizing tasks ensures that critical issues are addressed promptly, minimizing downtime and optimizing resource utilization. AI systems optimize the deployment of maintenance crews and resources by: Assigning tasks to maintenance crews based on skillsets, location, and availability. Planning the most efficient routes for maintenance crews to minimize travel time and maximize productivity (Qin *et al.*, 2020; Adeleke and Peter, 2021). Ensuring that the necessary equipment, tools, and spare parts are available when needed. By optimizing resource allocation, AI improves the efficiency and effectiveness of maintenance activities on offshore platforms.

IoT sensors play a crucial role in providing real-time data for maintenance activities (Ayvaz and Alpay, 2021). These sensors are deployed throughout the platform to monitor equipment condition, environmental factors, and operational parameters. Examples of IoT sensors used in offshore maintenance logistics include: Vibration sensors, temperature sensors, pressure sensors and corrosion sensors. By integrating IoT sensor data, AI-enabled predictive maintenance models become more accurate and reliable. These models can: detect anomalies, predict failures, and optimize maintenance intervals. Examples of IoT devices used in offshore maintenance logistics: fiber optic sensors, wireless sensor networks, remote operated vehicles (ROVs), and smart valves and actuators (Tan *et al.*, 2020). By integrating IoT devices into maintenance logistics, offshore platforms can achieve greater visibility into equipment health and performance, enabling more effective maintenance planning and execution. AI plays a crucial role in optimizing maintenance logistics on offshore platforms. By enabling predictive maintenance, resource allocation, and integration of IoT devices, AI enhances the efficiency, safety, and reliability of maintenance activities, ensuring the smooth operation of offshore platforms and reducing downtime and costs (Olowe, 2018; Wang *et al.*, 2022).

2.2. Future Innovations in AI for Offshore Maintenance

As technology continues to advance, the future of maintenance logistics on offshore platforms will be increasingly shaped by innovations in Artificial Intelligence (AI) (Gupta and Shah, 2022). These innovations promise to revolutionize maintenance practices, making them more efficient, safer, and sustainable.

Autonomous maintenance systems involve the use of robots equipped with AI algorithms to perform routine inspections, maintenance tasks, and minor repairs on offshore platforms. These robots are designed to operate autonomously, navigating complex environments and performing tasks without human intervention (Olowe and Kumarasamy, 2017). The role of autonomous robots in offshore maintenance includes: Autonomous robots can conduct regular inspections of equipment and structures, identifying signs of wear, corrosion, or damage. Robots equipped with tools and manipulators can perform minor repairs on components such as valves, actuators, and piping (Monk *et al.*, 2021). Robots can collect and transmit data in real-time, providing valuable insights into equipment condition and performance. The use of autonomous maintenance systems offers several benefits: Robots can work continuously without fatigue or breaks, improving inspection and repair speed. By performing tasks in hazardous or hard-to-reach areas, autonomous robots reduce the risk of accidents and injuries to human workers. Automation reduces the need for human labor and associated costs, leading to cost savings for maintenance activities (Tschang and Almirall, 2021). Robots equipped with sensors can collect vast amounts of data, providing more comprehensive insights into equipment condition. Despite the potential benefits, implementing autonomous maintenance systems on offshore platforms poses challenges: Developing reliable and robust autonomous systems suitable for offshore environments requires advanced technology and rigorous testing. Autonomous systems must comply with industry regulations and standards, requiring thorough validation and certification processes (Zaki *et al*., 2021). Autonomous systems need to integrate seamlessly with existing infrastructure and control systems, requiring careful planning and coordination. Ensuring acceptance and trust among human workers is crucial for successful implementation, requiring effective communication and training. AI algorithms continue to evolve, becoming more sophisticated and capable of handling complex data analysis tasks. Future advancements in AI algorithms for maintenance analytics include: Deep neural networks can analyze large and diverse data sets to extract valuable insights and patterns. NLP techniques enable AI systems to analyze unstructured data such as maintenance reports, manuals, and documentation. Advanced anomaly detection algorithms can identify subtle deviations from normal equipment behavior, indicating potential issues (Omole *et al*., 2024). Integration with big data analytics platforms allows AI systems to analyze vast amounts of data from various sources, including: Real-time data from sensors monitoring equipment condition and performance. Historical maintenance records and logs. Weather conditions, sea states, and operational parameters. By integrating AI with big data analytics platforms, offshore platforms can gain deeper insights into equipment health, predict failures more accurately, and optimize maintenance strategies (Nguyen *et* al., 2020; Ani *et al*., 2024). With advancements in AI algorithms and data analytics, predictive maintenance models can achieve higher accuracy and reliability. Future developments include: Predicting the remaining useful life of equipment and recommending optimal maintenance actions. AI models that continuously learn and adapt to changing conditions, improving prediction accuracy over time. By developing more accurate predictive maintenance models, offshore platforms can reduce downtime, extend equipment lifespan, and optimize maintenance resources. As AI becomes increasingly integrated into maintenance operations, ensuring workforce readiness and training becomes essential (Chowdhury *et al*., 2023). Future considerations include: Providing training to personnel on operating and interacting with AI systems. Educating workers on safety protocols and procedures when working alongside autonomous systems. Improving data literacy skills among personnel to understand and interpret AI-generated insights. Effective collaboration between humans and AI systems is crucial for optimizing maintenance operations. Future considerations include: Designing user-friendly interfaces that facilitate interaction and communication with AI systems. Providing AI-generated insights and recommendations to assist human operators in decision-making. Establishing feedback mechanisms to improve AI system performance based on user input and experience (Olowe *et* al., 2019; Sjödin *et al*., 2021). As AI becomes more pervasive in maintenance operations, ethical considerations become increasingly important. Future considerations include: Ensuring the privacy and security of data collected by AI systems. Addressing biases in AI algorithms that may impact decision-making. Providing transparency in AI decision-making processes and algorithms. Establishing accountability mechanisms for AI-related decisions and actions. By addressing these ethical considerations, offshore platforms can ensure the responsible and ethical use of AI in maintenance operations (Munoko *et al*., 2020). Future innovations in AI for offshore maintenance hold tremendous potential to transform maintenance practices, making them more efficient, reliable, and sustainable. Autonomous maintenance systems, advanced data analytics, and human-AI collaboration will play key roles in optimizing maintenance logistics and ensuring the continued success of offshore operations. However, addressing challenges and considerations in implementing these innovations is essential for their successful adoption and integration into offshore maintenance practices (Olowe and Kumarasamy 2021; Usman *et al*., 2024).

2.3. Challenges and Considerations in AI-Driven Offshore Maintenance

As the oil and gas industry embraces Artificial Intelligence (AI) for optimizing maintenance logistics on offshore platforms, several challenges and considerations must be addressed to ensure the successful implementation and integration of AI-driven solutions (Hussain *et al*., 2024). These challenges range from data quality and cybersecurity to workforce readiness and acceptance This explores these challenges and considerations in detail. Ensuring the accuracy and reliability of data inputs is crucial for the effectiveness of AI-driven maintenance systems (Kirschbaum *et al*., 2020). Challenges include: Inaccurate or incomplete data can lead to flawed predictions and decisions. It's essential to validate data sources and ensure data accuracy. Collecting and using only relevant data is important to avoid noise and improve the accuracy of AI models. Inconsistent data formats or units can lead to errors in analysis. Standardization of data formats and units is necessary for reliable analysis. Ensuring data integrity is crucial to prevent tampering or corruption of data, which can compromise the accuracy of AI models. Effective data collection and management processes are essential for ensuring data quality. Considerations include: Proper placement of sensors to collect relevant data without interference or bias is crucial. Storing data securely and efficiently to ensure accessibility and integrity, integrating data from various sources, such as sensors, maintenance records, and environmental data, to provide a comprehensive view of equipment health (Diène *et al*., 2020). Establishing policies and procedures for data access, usage, and sharing to ensure compliance and security.

AI-driven maintenance systems are susceptible to cyber-attacks, which can have severe consequences for offshore operations (Chelliah *et al*., 2023). Risks include: Unauthorized access to sensitive data, such as equipment performance data or maintenance schedules. Malicious software can compromise the functionality of AI systems or disrupt operations. Altering AI models or input data to produce incorrect results or recommendations. Overloading AI systems with requests to disrupt their operation. Enhancing cybersecurity in offshore maintenance operations requires a multi-layered approach. Strategies include: Implementing firewalls, intrusion detection systems, and encryption to secure network communications (Thapa and Mailewa, 2020). Restricting access to sensitive systems and data based on user roles and permissions. Keeping software and systems up-to-date with the latest security patches to address vulnerabilities. Educating personnel on cybersecurity best practices, including recognizing phishing attempts and maintaining strong passwords. Establishing and enforcing cybersecurity policies and procedures to govern system usage and response to security incidents. As AI becomes more prevalent in offshore maintenance operations, training and education requirements for personnel become essential (Wanasinghe *et al*., 2021). Considerations include: Providing training on operating and interacting with AI-driven systems, including data input, interpretation, and decision-making. Educating personnel on safety protocols when working alongside autonomous systems or interacting with data-driven insights. Improving data literacy skills among personnel to understand and interpret AI-generated insights and recommendations. Training personnel to adapt to new technologies and workflows resulting from the implementation of AI-driven systems. Resistance to AI implementation among personnel can hinder its successful adoption. Strategies for addressing concerns include: Open and transparent communication about the benefits of AI implementation and how it will impact workflows and job roles. Involving personnel in the decision-making process and seeking their input on AI implementation plans. Providing demonstrations of AI systems in action to showcase their benefits and capabilities (Campbell *et al*., 2020). Offering support and training to help personnel adapt to new technologies and workflows. Establishing feedback mechanisms to address concerns and make improvements based on user feedback. Addressing challenges and considerations in AI-driven offshore maintenance operations is essential for ensuring the success and effectiveness of AI implementations. By focusing on data quality and management, cybersecurity, and workforce readiness, offshore platforms can maximize the benefits of AI-driven maintenance systems while mitigating risks and ensuring the safety and reliability of operations (Jan *et al*., 2023).

3. Conclusion

In conclusion, the integration of Artificial Intelligence (AI) in optimizing maintenance logistics on offshore platforms holds tremendous promise for revolutionizing offshore maintenance practices. While challenges exist, addressing them can ensure a smooth transition to AI-enabled maintenance strategies and unlock numerous benefits for the oil and gas industry. AI offers a wide array of benefits for optimizing maintenance logistics on offshore platforms, including: AI-enabled predictive maintenance allows for proactive planning, minimizing downtime and optimizing resource allocation. Autonomous maintenance systems and real-time monitoring capabilities improve safety by reducing the need for human intervention in hazardous environments. Predictive maintenance helps reduce maintenance costs by minimizing the need for emergency repairs and optimizing maintenance schedules. AI-driven maintenance practices enhance equipment reliability by identifying potential issues before they escalate into failures. AI-driven maintenance reduces environmental impact by optimizing resource utilization and minimizing waste. The potential for AI to revolutionize offshore maintenance practices is significant, offering transformative solutions to age-old challenges: AI-driven predictive maintenance shifts maintenance practices from reactive to proactive, preventing failures before they occur. Autonomous maintenance systems equipped with AI algorithms can perform routine inspections and minor repairs without human intervention, improving efficiency and safety. AI-driven data analytics enables more accurate and reliable predictions, leading to optimized maintenance strategies and improved equipment performance. Effective collaboration between humans and AI systems enhances decision-making and overall operational efficiency, combining human expertise with AI-driven insights. While the benefits of AI in optimizing maintenance logistics on offshore platforms are substantial, addressing challenges and ensuring a smooth transition are crucial for success: Ensuring data accuracy, reliability, and integrity is essential for the effectiveness of AI-driven maintenance systems. Protecting AI systems from cyber-attacks is vital to prevent data breaches and ensure the safety and reliability of offshore operations. Providing adequate training and support for personnel is necessary to facilitate the adoption of AI-enabled maintenance strategies and mitigate resistance. Addressing ethical concerns such as data privacy, bias, and accountability is essential to ensure the responsible use of AI in offshore maintenance operations. By addressing these challenges and ensuring a smooth transition to AI-enabled maintenance strategies, the oil and gas industry can unlock the full potential of AI to optimize maintenance logistics on offshore platforms. This will lead to safer, more efficient, and more sustainable operations, ultimately driving greater value for stakeholders and ensuring the long-term viability of offshore energy production.

Compliance with ethical standards

Disclosure of conflict of interest

The authors did not submit a conflict-of-interest statement.

Reference

[1] Abbas, M. and Shafiee, M., 2020. An overview of maintenance management strategies for corroded steel structures in extreme marine environments. *Marine Structures*, *71*, p.102718.

[2] Achouch, M., Dimitrova, M., Ziane, K., Sattarpanah Karganroudi, S., Dhouib, R., Ibrahim, H. and Adda, M., 2022. On predictive maintenance in industry 4.0: Overview, models, and challenges. *Applied Sciences*, *12*(16), p.8081.

[3] Adelani, F.A., Okafor, E.S., Jacks, B.S. and Ajala, O.A., 2024. THEORETICAL INSIGHTS INTO SECURING REMOTE MONITORING SYSTEMS IN WATER DISTRIBUTION NETWORKS: LESSONS LEARNED FROM AFRICA-US PROJECTS. *Engineering Science & Technology Journal*, *5*(3), pp.995-1007.

[4] Adeleke, A. and Peter, O., 2021. Effect of Nose Radius on Surface Roughness of Diamond Turned Germanium Lenses.

[5] Adeleke, A.K., Montero, D.J.P., Olajiga, O.K., Ani, E.C. and Olu-lawal, K.A., 2024. Evaluating the impact of precision engineering education on industry standards and practices. *International Journal of Science and Research Archive*, *11*(1), pp.2336-2345.

[6] Adumene, S., Khan, F., Adedigba, S., Mamudu, A. and Rosli, M.I., 2023. Offshore oil and gas development in remote harsh environments: engineering challenges and research opportunities. *Safety in extreme environments*, *5*(1), pp.17-33.

[7] Agbaji, A.L., 2021, March. An empirical analysis of artificial intelligence, big data and analytics applications in exploration and production operations. In *International Petroleum Technology Conference* (p. D101S043R001). IPTC.

[8] Amaechi, C.V., Reda, A., Kgosiemang, I.M., Ja'e, I.A., Oyetunji, A.K., Olukolajo, M.A. and Igwe, I.B., 2022. Guidelines on asset management of offshore facilities for monitoring, sustainable maintenance, and safety practices. *Sensors*, *22*(19), p.7270.

[9] Amiri, N., Shaterabadi, M., Reza Kashyzadeh, K. and Chizari, M., 2021. A comprehensive review on design, monitoring, and failure in fixed offshore platforms. *Journal of Marine Science and Engineering*, *9*(12), p.1349.

[10] Ani, E.C., Olu-lawal, K.A., Olajiga, O.K., Montero, D.J.P. and Adeleke, A.K., 2024. Intelligent monitoring systems in manufacturing: current state and future perspectives. *Engineering Science & Technology Journal*, *5*(3), pp.750-759.

[11] Ayvaz, S. and Alpay, K., 2021. Predictive maintenance system for production lines in manufacturing: A machine learning approach using IoT data in real-time. *Expert Systems with Applications*, *173*, p.114598.

[12] Balakrishnan, G.K., Yaw, C.T., Koh, S.P., Abedin, T., Raj, A.A., Tiong, S.K. and Chen, C.P., 2022. A review of infrared thermography for condition-based monitoring in electrical energy: Applications and recommendations. *Energies*, *15*(16), p.6000.

[13] Bharadiya, J.P., 2023. Machine learning and AI in business intelligence: Trends and opportunities. *International Journal of Computer (IJC)*, *48*(1), pp.123-134.

[14] Campbell, C., Sands, S., Ferraro, C., Tsao, H.Y.J. and Mavrommatis, A., 2020. From data to action: How marketers can leverage AI. *Business horizons*, *63*(2), pp.227-243.

[15] Chelliah, P.R., Jayasankar, V., Agerstam, M., Sundaravadivazhagan, B. and Cyriac, R., 2023. *The Power of Artificial Intelligence for the Next-Generation Oil and Gas Industry: Envisaging AI-inspired Intelligent Energy Systems and Environments*. John Wiley & Sons.

[16] Chou, S.Y. and Yu, T.H.K., 2022. Developing an exhaustive optimal maintenance schedule for offshore wind turbines based on risk-assessment, technical factors and cost-effective evaluation. *Energy*, *249*, p.123613.

[17] Chowdhury, S., Dey, P., Joel-Edgar, S., Bhattacharya, S., Rodriguez-Espindola, O., Abadie, A. and Truong, L., 2023. Unlocking the value of artificial intelligence in human resource management through AI capability framework. *Human Resource Management Review*, *33*(1), p.100899.

[18] Chukwurah, E.G. and Aderemi, S., 2024. HARMONIZING TEAMS AND REGULATIONS: STRATEGIES FOR DATA PROTECTION COMPLIANCE IN US TECHNOLOGY COMPANIES. *Computer Science & IT Research Journal*, *5*(4), pp.824-838.

[19] Çınar, Z.M., Abdussalam Nuhu, A., Zeeshan, Q., Korhan, O., Asmael, M. and Safaei, B., 2020. Machine learning in predictive maintenance towards sustainable smart manufacturing in industry 4.0. *Sustainability*, *12*(19), p.8211.

[20] Dalzochio, J., Kunst, R., Pignaton, E., Binotto, A., Sanyal, S., Favilla, J. and Barbosa, J., 2020. Machine learning and reasoning for predictive maintenance in Industry 4.0: Current status and challenges. *Computers in Industry*, *123*, p.103298.

[21] Diène, B., Rodrigues, J.J., Diallo, O., Ndoye, E.H.M. and Korotaev, V.V., 2020. Data management techniques for Internet of Things. *Mechanical Systems and Signal Processing*, *138*, p.106564.

[22] Duggal, A. and Minnebo, J., 2020, May. The Floating Production, Storage and Offloading system–past, present and future. In *Offshore Technology Conference* (p. D021S017R005). OTC.

[23] Fox, H., Pillai, A.C., Friedrich, D., Collu, M., Dawood, T. and Johanning, L., 2022. A review of predictive and prescriptive offshore wind farm operation and maintenance. *Energies*, *15*(2), p.504.

[24] Gupta, D. and Shah, M., 2022. A comprehensive study on artificial intelligence in oil and gas sector. *Environmental Science and Pollution Research*, *29*(34), pp.50984-50997.

[25] Hajej, Z., Rezg, N. and Gharbi, A., 2021. Joint production preventive maintenance and dynamic inspection for a degrading manufacturing system. *The International Journal of Advanced Manufacturing Technology*, *112*, pp.221-239.

[26] Hussain, M., Alamri, A., Zhang, T. and Jamil, I., 2024. Application of Artificial Intelligence in the Oil and Gas Industry. In *Engineering Applications of Artificial Intelligence* (pp. 341-373). Cham: Springer Nature Switzerland.

[27] Jan, Z., Ahamed, F., Mayer, W., Patel, N., Grossmann, G., Stumptner, M. and Kuusk, A., 2023. Artificial intelligence for industry 4.0: Systematic review of applications, challenges, and opportunities. *Expert Systems with Applications*, *216*, p.119456.

[28] Jimenez, V.J., Bouhmala, N. and Gausdal, A.H., 2020. Developing a predictive maintenance model for vessel machinery. *Journal of Ocean Engineering and Science*, *5*(4), pp.358-386.

[29] Kamat, P. and Sugandhi, R., 2020. Anomaly detection for predictive maintenance in industry 4.0-A survey. In *E3S web of conferences* (Vol. 170, p. 02007). EDP Sciences.

[30] Kirschbaum, L., Roman, D., Singh, G., Bruns, J., Robu, V. and Flynn, D., 2020. AI-driven maintenance support for downhole tools and electronics operated in dynamic drilling environments. *IEEE Access*, *8*, pp.78683-78701.

[31] Liu, H., Liu, H., Zhu, C. and Parker, R.G., 2020. Effects of lubrication on gear performance: A review. *Mechanism and Machine Theory*, *145*, p.103701.

[32] Martins, L., Silva, F.J., Pimentel, C., Casais, R.B. and Campilho, R.D.S.G., 2020. Improving preventive maintenance management in an energy solutions company. *Procedia Manufacturing*, *51*, pp.1551-1558.

[33] Mathew, D., Brintha, N.C. and Jappes, J.W., 2023. Artificial intelligence powered automation for industry 4.0. In *New Horizons for Industry 4.0 in Modern Business* (pp. 1-28). Cham: Springer International Publishing.

[34] Mitchell, D., Blanche, J., Harper, S., Lim, T., Gupta, R., Zaki, O., Tang, W., Robu, V., Watson, S. and Flynn, D., 2022. A review: Challenges and opportunities for artificial intelligence and robotics in the offshore wind sector. *Energy and AI*, *8*, p.100146.

[35] Mohammed, A.S., Reinecke, P., Burnap, P., Rana, O. and Anthi, E., 2022. Cybersecurity challenges in the offshore oil and gas industry: an Industrial Cyber-Physical Systems (ICPS) perspective. *ACM Transactions on Cyber-Physical Systems (TCPS)*, *6*(3), pp.1-27.

[36] Monk, S.D., Grievson, A., Bandala, M., West, C., Montazeri, A. and Taylor, C.J., 2021. Implementation and evaluation of a semi-autonomous hydraulic dual manipulator for cutting pipework in radiologically active environments. *Robotics*, *10*(2), p.62.

[37] Munoko, I., Brown-Liburd, H.L. and Vasarhelyi, M., 2020. The ethical implications of using artificial intelligence in auditing. *Journal of business ethics*, *167*(2), pp.209-234.

[38] Nguyen, T., Gosine, R.G. and Warrian, P., 2020. A systematic review of big data analytics for oil and gas industry 4.0. *IEEE access*, *8*, pp.61183-61201.

[39] Nunes, P., Santos, J. and Rocha, E., 2023. Challenges in predictive maintenance–A review. *CIRP Journal of Manufacturing Science and Technology*, *40*, pp.53-67.

[40] Olatunde, T.M., Adelani, F.A. and Sikhakhane, Z.Q., 2024. A REVIEW OF SMART WATER MANAGEMENT SYSTEMS FROM AFRICA AND THE UNITED STATES. *Engineering Science & Technology Journal*, *5*(4), pp.1231-1242.

[41] Olowe, K.O. and Kumarasamy, M., 2017. Development of the hybrid cells in series model to simulate ammonia nutrient pollutant transport along the Umgeni River. *Environmental Science and Pollution Research*, *24*, pp.22967-22979.

[42] Olowe, K.O. and Kumarasamy, M., 2021. A Mathematical Model Development for Simulating Nitrate Pollutant Transport Along a River. *International Journal of Engineering Research in Africa*, *57*, pp.149-168.

[43] Olowe, K.O., 2018. Assessment of Some Existing Water Quality Models. *Nature Environment & Pollution Technology*, *17*(3).

[44] OLOWE, K.O., WASIU, J. and ADEBAYO, V.B., 2019. Effectiveness of Palm Kernel Shell Ash Concrete Reinforced with Steel Fibres. *ABUAD Journal of Engineering Research and Development (AJERD)*, *2*(2), pp.1-9.

[45] Olugu, E.U., Wong, K.Y., Chung Ee, J.Y. and Mammedov, Y.D., 2022. Incorporating sustainability and maintenance for performance assessment of offshore oil and gas platforms: a perspective. *Sustainability*, *14*(2), p.807.

[46] Omole, F.O., Olajiga, O.K. and Olatunde, T.M., 2024. SUSTAINABLE URBAN DESIGN: A REVIEW OF ECO-FRIENDLY BUILDING PRACTICES AND COMMUNITY IMPACT. *Engineering Science & Technology Journal*, *5*(3), pp.1020-1030.

[47] Paganelli, A.I., Mondéjar, A.G., da Silva, A.C., Silva-Calpa, G., Teixeira, M.F., Carvalho, F., Raposo, A. and Endler, M., 2022. Real-time data analysis in health monitoring systems: A comprehensive systematic literature review. *Journal of Biomedical Informatics*, *127*, p.104009.

[48] Paul, S., Poudyal, A., Poudel, S., Dubey, A. and Wang, Z., 2024. Resilience assessment and planning in power distribution systems: Past and future considerations. *Renewable and Sustainable Energy Reviews*, *189*, p.113991.

[49] Qin, Y., Zhang, J.H., Chan, F.T., Chung, S.H., Niu, B. and Qu, T., 2020. A two-stage optimization approach for aircraft hangar maintenance planning and staff assignment problems under MRO outsourcing mode. *Computers & Industrial Engineering*, *146*, p.106607.

[50] Ren, Z., Verma, A.S., Li, Y., Teuwen, J.J. and Jiang, Z., 2021. Offshore wind turbine operations and maintenance: A state-of-the-art review. *Renewable and Sustainable Energy Reviews*, *144*, p.110886.

[51] Rinaldi, G., Thies, P.R. and Johanning, L., 2021. Current status and future trends in the operation and maintenance of offshore wind turbines: A review. *Energies*, *14*(9), p.2484.

[52] Sarker, I.H., 2022. AI-based modeling: techniques, applications and research issues towards automation, intelligent and smart systems. *SN Computer Science*, *3*(2), p.158.

[53] Sharapov, D., 2023, November. Offshore Platforms in Arctic Icy Environment. In *International Conference on Advanced Civil Engineering and Smart Structures* (pp. 120-130). Singapore: Springer Nature Singapore.

[54] Singh, H., Bhardwaj, N., Arya, S.K. and Khatri, M., 2020. Environmental impacts of oil spills and their remediation by magnetic nanomaterials. *Environmental nanotechnology, monitoring & management*, *14*, p.100305.

[55] Sjödin, D., Parida, V., Palmié, M. and Wincent, J., 2021. How AI capabilities enable business model innovation: Scaling AI through co-evolutionary processes and feedback loops. *Journal of Business Research*, *134*, pp.574-587.

[56] Sonko, S., Ibekwe, K.I., Ilojianya, V.I., Etukudoh, E.A. and Fabuyide, A., 2024. QUANTUM CRYPTOGRAPHY AND US DIGITAL SECURITY: A COMPREHENSIVE REVIEW: INVESTIGATING THE POTENTIAL OF QUANTUM TECHNOLOGIES IN CREATING UNBREAKABLE ENCRYPTION AND THEIR FUTURE IN NATIONAL SECURITY. *Computer Science & IT Research Journal*, *5*(2), pp.390-414.

[57] Stroykov, G., Vasilev, Y.N. and Zhukov, O.V., 2021. Basic principles (indicators) for assessing the technical and economic potential of developing arctic offshore oil and gas fields. *Journal of Marine Science and Engineering*, *9*(12), p.1400.

[58] Subrat, N., 2020, November. Using Data Science to Enable Condition Based Maintenance and Classification for Offshore Assets. In *Abu Dhabi International Petroleum Exhibition and Conference* (p. D012S116R021). SPE.

[59] Tan, J.H., Roberts, B., Sundararaju, P., Sintive, C., Facheris, L., Vanden Bosch, J., Lehning, V. and Pegg, M., 2020, October. Transforming offshore oil and gas production platforms into smart unmanned installations. In *Offshore Technology Conference Asia* (p. D031S026R001). OTC.

[60] Thapa, S. and Mailewa, A., 2020, April. The role of intrusion detection/prevention systems in modern computer networks: A review. In *Conference: Midwest Instruction and Computing Symposium (MICS)* (Vol. 53, pp. 1-14).

[61] Tschang, F.T. and Almirall, E., 2021. Artificial intelligence as augmenting automation: Implications for employment. *Academy of Management Perspectives*, *35*(4), pp.642-659.

[62] Usman, F.O., Ani, E.C., Ebirim, W., Montero, D.J.P., Olu-lawal, K.A. and Ninduwezuor-Ehiobu, N., 2024. Integrating renewable energy solutions in the manufacturing INDUSTRY: CHALLENGES AND OPPORTUNITIES: A REVIEW. *Engineering Science & Technology Journal*, *5*(3), pp.674-703.

[63] Wanasinghe, T.R., Trinh, T., Nguyen, T., Gosine, R.G., James, L.A. and Warrian, P.J., 2021. Human centric digital transformation and operator 4.0 for the oil and gas industry. *Ieee Access*, *9*, pp.113270-113291.

[64] Wang, Z., Guo, Y. and Wang, H., 2022. Review on monitoring and operation-maintenance technology of far-reaching sea smart wind farms. *Journal of Marine Science and Engineering*, *10*(6), p.820.

[65] Zaki, O., Dunnigan, M., Robu, V. and Flynn, D., 2021. Reliability and safety of autonomous systems based on semantic modelling for self-certification. *Robotics*, *10*(1), p.10.