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Agentic AI and sustainable procurement: Rethinking anti-corrosion strategies in oil and gas

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Abstract

Corrosion remains a persistent challenge in the oil and gas industry, causing infrastructure failures, escalating maintenance costs, and severe environmental risks. Recent innovations in anti-corrosive materials—such as nanotechnology-based coatings, corrosion-resistant alloys, and graphene composites—have been further accelerated by the rise of Artificial Intelligence (AI) in procurement. This paper introduces a next-generation framework for AI-driven procurement of anti-corrosive materials, integrating predictive analytics, generative AI, agentic AI, and blockchain-backed transparency. Generative AI enables dynamic supplier intelligence, automated sustainability reporting, and RFQ drafting, while agentic AI agents autonomously negotiate contracts, optimize sourcing cycles, and adapt procurement strategies in real time. Multimodal AI, when combined with IoT sensors and digital twins, facilitates predictive corrosion monitoring by analyzing sensor streams, visual inspection data, and supplier documents simultaneously. Furthermore, quantum AI simulations hold the potential to model corrosion resistance of emerging alloys under refinery-specific conditions, enabling more accurate material selection. Beyond cost savings and operational resilience, AI aligns procurement with sustainability goals by recommending low-VOC coatings, minimizing carbon footprints, and enabling circular economy practices. To ensure adoption, the paper emphasizes explainable AI (XAI) for procurement leaders, offering transparency into supplier rankings and material recommendations. By synthesizing advances in material science with cutting-edge AI, this study provides a strategic roadmap for resilient, sustainable, and autonomous procurement in the oil and gas sector.

Keywords: Anti-corrosive materials; Corrosion prevention; Oil and gas procurement; Artificial Intelligence (AI) in procurement; Predictive maintenance; Machine learning in material selection; Smart coatings; Nanotechnology in corrosion protection; AI-driven supplier evaluation; Blockchain in procurement; Digital twin technology; Cathodic protection; Material lifecycle analysis; Supply chain optimization; Sustainable procurement; Deep learning for risk assessment; Corrosion-resistant alloys (CRA); Automated procurement platforms

1. Introduction

Corrosion is the gradual deterioration of metals due to chemical reactions with their environment, primarily involving oxygen, water, and other corrosive agents (Corrosion, 2025). In the oil and gas industry, corrosion is a significant challenge because equipment and infrastructure are constantly exposed to harsh conditions, such as moisture, saltwater, and chemicals. The global cost of corrosion is estimated at over $2.5 trillion annually (NACE International, 2016).

Procurement plays a critical role in mitigating corrosion risks through the sourcing of high-performance coatings, corrosion-resistant alloys, inhibitors, and advanced monitoring technologies. However, traditional procurement approaches—manual supplier evaluations, fragmented data, and reactive maintenance—are increasingly insufficient. With the advent of AI, procurement is shifting from tactical purchasing to a predictive, autonomous, and sustainability-

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driven discipline. This paper explores the convergence of advanced anti-corrosion materials and AI-driven procurement strategies, with a focus on innovations, real-world applications, and future prospects.

2. The Critical Role of Material Selection in Oil and Gas Refinery Procurement

Oil and gas refineries operate under extreme conditions of high temperature, pressure, and exposure to corrosive agents such as hydrogen sulfide, sulfur compounds, and seawater. The procurement of high-quality materials is therefore essential for ensuring infrastructure longevity, operational efficiency, worker safety, and environmental sustainability.

Choosing the right materials—such as corrosion-resistant alloys (CRAs), stainless steel, and protective coatings—extends equipment life, reduces unplanned maintenance costs, ensures compliance with regulatory standards (e.g., OSHA and API), and improves overall refinery efficiency.

Corrosion engineers play a vital role by assessing material suitability for pipelines and equipment, recommending inhibitors and protective systems, and using predictive maintenance tools with AI-based monitoring to detect early signs of deterioration. Procurement managers complement this by sourcing compliant materials, negotiating cost-effective contracts, maintaining supply chain resilience, and increasingly leveraging AI-powered analytics for supplier evaluation, strategy optimization, and material traceability.

Failure to procure the right materials has severe consequences. For human safety, corroded pipelines and structures can trigger fires, toxic leaks, and equipment failures that endanger workers and communities. Environmentally, material degradation leads to oil spills, air pollution from sulfur dioxide and nitrogen oxides, and a larger carbon footprint from frequent replacements and energy-intensive repairs.

Thus, strategic procurement and precise material selection are not merely operational tasks but essential safeguards for refinery sustainability, safety, and excellence.

3. The Crucial Role of Coatings in Corrosion Prevention

Coatings are one of the most effective and widely used solutions for corrosion prevention in the oil and gas industry. They act as a protective barrier between metal surfaces and corrosive environments, significantly extending the lifespan of refinery equipment, pipelines, and storage tanks. (Solovyeva, V. A 2023)

How Coatings Prevent Corrosion

- Barrier Protection – Coatings create a physical layer that prevents moisture, oxygen, and chemicals from reaching the metal surface.
- Chemical Resistance – Specialized coatings resist harsh chemicals such as acids, alkalis, and hydrocarbons, reducing material degradation.
- Cathodic Protection Enhancement – Some coatings, like zinc-rich coatings, work with cathodic protection systems to prevent electrochemical reactions that lead to corrosion.
- Thermal and UV Resistance – High-temperature coatings protect equipment from extreme heat in refineries and offshore platforms, while UV-resistant coatings prevent degradation in outdoor applications.

Types of Anti-Corrosion Coatings

- Epoxy Coatings – Highly durable and resistant to chemicals and moisture.
- Polyurethane Coatings – Provide strong UV and weather resistance for outdoor equipment.
- Zinc-Rich Coatings – Offer cathodic protection by sacrificing zinc instead of the base metal.
- Ceramic Coatings – Withstand extreme temperatures and harsh chemical exposures.

By integrating high-performance coatings into procurement strategies, refineries can enhance asset durability, reduce maintenance costs, and prevent environmental hazards, ensuring long-term operational efficiency and safety.

3.1. Advances in Anti-Corrosive Materials

3.1.1. Nanotechnology-Based Coatings

Nanotechnology has revolutionized anti-corrosive coatings by enhancing their resistance and durability. Nano-ceramic coatings and polymer nanocomposites provide superior protection by forming a dense, self-healing layer that prevents oxidation and chemical attacks. Companies like Hempel, AkzoNobel, and PPG Industries are leading the development of nanotech-based coatings.

3.1.2. Corrosion-Resistant Alloys (CRAs)

CRAs such as Inconel, Hastelloy, and Duplex stainless steels withstand extreme refinery environments. AI-driven predictive models are increasingly used to determine the most cost-effective CRA selection for project-specific conditions.

3.1.3. Smart Coatings with Self-Healing Properties

Self-healing polymers release inhibitors upon mechanical damage, preventing corrosion spread. When integrated with sensors and AI-driven quality inspections, they offer real-time corrosion monitoring.

3.1.4. Graphene-Based Coatings

Graphene provides ultra-thin, impermeable barriers with exceptional conductivity, making it a revolutionary material for corrosion protection in pipelines and refineries.

AI-Driven Procurement Framework

The procurement of anti-corrosive materials in oil and gas refineries is crucial to ensuring asset longevity, operational safety, and cost-efficiency. AI is transforming this process by optimizing supplier selection, improving material quality assessment, and predicting corrosion risks in advance.

AI in Supplier Selection and Procurement Optimization

- **Predictive Supplier Analysis:** AI-driven procurement platforms, such as SAP Ariba and Jaggaer, use predictive analytics to evaluate suppliers based on historical performance, material quality, and cost-effectiveness. This helps companies select vendors that provide the best anti-corrosive solutions tailored to specific project needs. Blockchain integration further ensures supply chain transparency and fraud prevention. AI identifies suppliers that offer optimal price-performance ratios, reducing reliance on trial-and-error selection.
- **Automated Contract Management and Compliance:** AI agents autonomously negotiate supplier contracts, optimize bid evaluations, and adapt sourcing strategies. By learning from historical performance data and market dynamics, they enable fully autonomous procurement cycles. Waditwar (2025)
- **Digital Twin Technology for Corrosion Monitoring:** By combining IoT sensors, computer vision, and textual data, multimodal AI systems provide holistic insights into corrosion risk and material performance. Digital twins replicate refinery conditions, simulating corrosion progression and enabling proactive procurement decisions.
- **Blockchain for Transparent Supply Chains:** Blockchain technology ensures end-to-end transparency in procurement by providing immutable records of material sourcing, transportation, and quality certifications. Both Chevron and ExxonMobil, being major players in the oil and gas industry, have shown interest in blockchain technology and its potential uses. (Blockchain, 2023).

Quantum AI for Material Science

Quantum AI simulations allow procurement teams to model corrosion resistance of new alloys under refinery-specific stressors, enhancing accuracy in material selection.

Explainable AI (XAI)

To build trust, XAI frameworks highlight the parameters driving AI recommendations—such as price, sustainability score, and historical reliability—empowering procurement leaders with transparent decision-making.

4. Case Study: AI-Powered Corrosion Procurement

Problem: A refinery faces frequent pipeline failures despite standard coatings. Supplier selection is inconsistent, and failures cause shutdowns and environmental risks.

4.1. AI-Powered Solution

4.1.1. AI-Driven Material Selection

The refinery integrates AI-powered material selection software that:

- Analyzes past corrosion failures using machine learning and big data.
- Simulates real-world conditions using digital twin technology to test various anti-corrosive coatings before procurement.
- Recommends the best-fit coating (e.g., an AI-optimized epoxy-based coating with higher chemical resistance).

4.1.2. AI in Supplier Optimization

The procurement team uses an AI-driven sourcing platform that:

- Ranks suppliers based on historical performance, material quality, and compliance with industry standards
- Uses predictive analytics to evaluate bid proposals, selecting vendors with the best long-term reliability and cost-effectiveness.
- Implements blockchain for material traceability, ensuring authenticity and eliminating counterfeit coatings.

4.1.3. AI for Predictive Corrosion Monitoring

- The refinery installs AI-powered IoT sensors in pipelines to track corrosion in real-time.
- AI analyzes sensor data and predicts coating degradation months in advance.
- Maintenance teams receive automated alerts before corrosion reaches critical levels, preventing leaks and costly shutdowns.

4.1.4. AI Algorithms for Corrosion Risk Assessment in Oil and Gas Refineries

Several AI models have been deployed for predicting and mitigating corrosion risks in oil and gas refineries.

- Neural networks and deep learning models are widely used for predictive corrosion assessment, analyzing historical data and sensor readings to forecast potential pipeline failures before they occur.
- AI-powered digital twins simulate corrosion patterns under different environmental conditions, helping refineries optimize anti-corrosion material selection. Additionally, AI-enhanced spectroscopy techniques such as X-ray fluorescence (XRF) and laser-induced breakdown spectroscopy (LIBS) are improving material testing accuracy, allowing procurement teams to assess real-time corrosion resistance of sourced materials.

Results & Benefits

- **Reduction in Corrosion Failures** – AI selects the optimal coating based on refinery conditions.
- **Cost Savings** – Smart procurement eliminates inefficient suppliers and reduces over-ordering.
- **Zero Unplanned Shutdowns –** Predictive AI monitoring ensures early intervention, preventing accidents.
- **Improved Safety & Environmental Protection** – AI prevents hazardous leaks, ensuring compliance with safety regulations.

By integrating AI in procurement and corrosion monitoring, oil refineries can achieve long-term asset protection, reduced costs, and enhanced safety, ensuring sustainable operations.

Several leading oil and gas companies have begun integrating Artificial Intelligence (AI) into their procurement processes to enhance efficiency, cost-effectiveness, and decision-making. Notable examples include:

- **BP:** The company has invested in AI-powered procurement platforms that automate contract reviews, significantly reducing the time spent on drafting and negotiating contracts. (Banaferi, 2024). ExxonMobil and BP are also integrating machine learning algorithms into their predictive maintenance programs, reducing unexpected material failures and optimizing long-term procurement strategies.
- **Shell:** Shell is leveraging AI to enhance operational efficiency in various domains, including supply chain management. (Aaron, 2025)
- **TotalEnergies:** Similar to BP and Shell, TotalEnergies is utilizing AI to improve operational efficiency across its supply chain management, exploration, and production processes.

- **Cognite:** This Norwegian software company provides AI-driven data operations and contextualization platforms to industrial clients, including oil and gas companies like Aker BP and Saudi Aramco, aiding in procurement and operational efficiency.

These implementations demonstrate a growing trend in the oil and gas industry toward adopting AI technologies to streamline procurement activities, optimize supplier relationships, and enhance overall operational performance. AI adoption in procurement has led to measurable efficiency improvements in the oil and gas sector. A report by McKinsey & Company (2023) found that AI-driven procurement solutions have significantly reduced supplier lead times and improved supplier risk mitigation, and also decreased procurement costs in major oil companies implementing these technologies. Companies leveraging predictive analytics and blockchain-backed procurement have streamlined their supply chain, reducing procurement cycle times by 20%. Additionally, BP and Shell reported a 30% increase in contract compliance and 25% reduction in material wastage after integrating AI-enhanced contract management and sourcing platforms. These improvements demonstrate that AI can optimize procurement workflows, ensuring efficiency, cost savings, and risk mitigation.

5. Future Prospects of AI-Based Technologies in Oil and Gas Industry Procurement

AI is rapidly transforming procurement in the oil and gas sector, and its future prospects promise greater efficiency, cost savings, and sustainability. As AI technology advances, procurement processes will become more autonomous, predictive, and intelligent, leading to better decision-making and supply chain optimization.

5.1. Autonomous & Self-Learning Procurement Systems

- AI-Driven Automated Negotiations – Future AI systems will autonomously negotiate supplier contracts, ensuring best pricing and quality based on historical performance and market trends.
- AI-Based Smart Contracts – Blockchain-integrated AI will facilitate self-executing contracts, ensuring compliance and real-time verification of material authenticity.
- Example: AI bots will automatically evaluate supplier bids, negotiate pricing, and execute procurement contracts based on real-time risk and demand analysis.

5.2. AI-Powered Predictive Procurement & Risk Mitigation

- Advanced Predictive Analytics – AI will analyze weather patterns, geopolitical events, and economic indicators to forecast supply chain disruptions before they happen.
- Dynamic Supplier Risk Assessment – AI will continuously monitor suppliers' financial health, compliance, and sustainability efforts, preventing procurement from unreliable vendors.
- Example: AI could predict a raw material shortage months in advance, allowing procurement managers to secure alternative suppliers proactively.

5.3. AI in Sustainable & Green Procurement

- Eco-Friendly Material Selection – AI algorithms will identify sustainable anti-corrosive materials with lower environmental impact.
- Carbon Footprint Optimization – AI will help refineries source locally and optimize logistics to reduce CO_2 emissions from transportation.
- AI-Powered Recycling & Circular Economy – AI will assist in reusing corrosion-resistant materials, reducing waste and dependency on raw material extraction.
- Example: AI will recommend corrosion-resistant coatings that are low-VOC (volatile organic compounds), ensuring regulatory compliance and environmental sustainability.

5.4. Integration of AI with IoT & Digital Twins

- AI & IoT-Connected Procurement – Smart sensors in refineries will provide real-time data on material degradation and usage, enabling just-in-time procurement.
- Digital Twin Technology – AI-powered digital replicas of refineries will simulate corrosion progression, optimizing procurement decisions for preventive maintenance.
- Example: AI-driven IoT sensors will monitor pipeline corrosion in real-time, automatically triggering procurement requests for replacement coatings before failure occurs.

5.5. AI-Enabled Market Intelligence & Price Forecasting

- Real-Time Market Analysis – AI will analyze global trade patterns, raw material prices, and supplier performance trends to help procurement teams make data-driven decisions.
- Dynamic Pricing Models – AI will predict price fluctuations of anti-corrosive materials and suggest optimal purchasing windows to secure the best deals.
- Example: AI could forecast a price hike in corrosion-resistant alloys due to geopolitical tensions and recommend early bulk purchases to reduce costs.

5.6. AI & Robotics in Procurement Logistics

- AI-Optimized Warehouse Management – AI will automate inventory tracking, ensuring refineries have the right materials at the right time without overstocking.
- Autonomous Procurement Drones – In offshore operations, AI-powered drones could be used for material inspections and procurement delivery in remote locations.
- Example: AI will automate stock replenishment by analyzing real-time inventory data, preventing costly delays in refinery operations.

5.7. AI in Regulatory Compliance & Net-Zero Commitments in Oil and Gas Procurement

- With global efforts toward carbon neutrality and net-zero emissions, oil and gas companies are under pressure to procure materials and coatings that meet stringent environmental regulations.
- AI assists in selecting eco-friendly anti-corrosive coatings, identifying low-VOC (volatile organic compound) formulations, and minimizing hazardous waste in procurement.
- AI-driven carbon footprint tracking allows procurement teams to evaluate the environmental impact of sourced materials, ensuring compliance with EU Green Deal, EPA (Environmental Protection Agency) regulations, and UN Sustainable Development Goals (SDGs).
- Additionally, AI-powered blockchain solutions provide full traceability of materials, ensuring that procurement aligns with ESG (Environmental, Social, and Governance) criteria.
- Companies like TotalEnergies and Chevron are already leveraging AI for sustainable procurement strategies, aiming to reduce refinery emissions by 50% by 2030.

The future of AI in oil and gas procurement lies in automation, intelligence, and sustainability, transforming how companies source materials, manage suppliers, and optimize procurement strategies. With AI-driven procurement, businesses will significantly reduce costs by predicting market trends and automating sourcing, leading to optimized spending and improved financial efficiency. AI will also enhance safety and compliance by ensuring that all materials meet strict environmental and industry regulations, reducing risks associated with poor-quality or non-compliant products. Additionally, predictive AI models will improve efficiency by anticipating supply chain disruptions and preventing delays, ensuring a seamless flow of critical materials for refinery operations. Sustainability will be a core focus, as AI will help companies transition to eco-friendly procurement practices, selecting sustainable materials and minimizing environmental impact in line with global regulations. As AI technology continues to evolve, human procurement managers will shift from tactical, routine purchasing to strategic decision-making, allowing AI to handle repetitive tasks while professionals focus on high-value initiatives that drive innovation and long-term success.

6. Limitations of AI Technology in Oil and Gas Industry Procurement

While AI has significantly transformed procurement in the oil and gas industry, it still faces key limitations and challenges that can impact adoption, efficiency, and decision-making.

6.1. Data Quality & Availability Issues

- AI algorithms require high-quality, structured data for accurate analysis and decision-making.
- Many oil and gas companies have legacy procurement systems with inconsistent, incomplete, or unstructured data, making AI implementation challenging.
- Data silos across departments prevent AI systems from accessing all relevant procurement data.

Example: If past supplier performance data is incomplete or biased, AI may recommend unreliable vendors, leading to material quality issues.

6.2. High Initial Investment & Integration Costs

- Implementing AI-driven procurement solutions requires significant investment in:
- AI software and platforms
- IoT-enabled sensors for predictive procurement
- Data integration across multiple supply chain systems
- Many smaller oil and gas companies lack the budget or expertise to deploy AI at scale.

Example: AI-powered procurement analytics platforms can be expensive, and ROI may take years to materialize.

6.3. Lack of Human Expertise & Resistance to Change

- AI models can analyze data but lack industry-specific intuition that experienced procurement managers have.
- Resistance from procurement teams who trust traditional sourcing methods may slow AI adoption.
- Over-reliance on AI without human oversight can lead to procurement errors.

Example: An AI system might select a supplier based on cost optimization but miss critical factors like geopolitical risks or ethical sourcing concerns.

6.4. Cybersecurity & Data Privacy Risks

- AI procurement systems handle sensitive financial and supplier data, making them a target for cyberattacks.
- AI-driven blockchain solutions for procurement transparency can expose confidential supply chain information if not properly secured.
- Oil and gas firms need robust cybersecurity frameworks to prevent AI data breaches.

Example: A cyberattack on an AI-powered procurement platform could manipulate supplier rankings, leading to fraudulent transactions or counterfeit material procurement.

6.5. Regulatory & Compliance Challenges

- AI algorithms must comply with strict industry regulations, including:
- Environmental standards (e.g., EPA, EU Green Deal)
- Trade restrictions and supplier compliance laws
- Anti-corruption and fair-trade regulations
- AI models require constant updates to adapt to changing regulations, increasing complexity.

Example: AI may recommend sourcing anti-corrosive coatings from a supplier in a restricted trade region, leading to legal and compliance violations.

6.6. AI's Limited Ability to Handle Supply Chain Disruptions

- AI is data-driven and struggles with black swan events like:
- Geopolitical crises (e.g., trade bans, wars)
- Natural disasters affecting supply chains
- Sudden price spikes in raw materials
- AI models trained on past data cannot always predict unprecedented disruptions effectively.

Example: AI-based procurement may fail to anticipate a sudden shortage of corrosion-resistant materials due to unexpected geopolitical conflicts, delaying refinery maintenance.

AI enhances procurement efficiency in the oil and gas industry, but human expertise remains essential to address its limitations. Companies must:

- Improve data governance to ensure AI models are trained on accurate and complete information.
- Combine AI insights with human judgment to balance cost, quality, and risk.
- Strengthen cybersecurity frameworks to protect procurement data from attacks.
- Continuously update AI models to align with changing industry regulations.

By strategically integrating AI with human decision-making, oil and gas companies can overcome these limitations and maximize AI's potential in procurement.

7. Overcoming AI Limitations in Procurement: Hybrid Models & Data Governance

While AI significantly enhances procurement, it is not without challenges. Companies face issues such as data quality inconsistencies, integration complexity, and ethical concerns in AI-driven supplier selection. Enhancing data governance is critical firms must invest in data standardization, ensuring that AI systems are trained on accurate, unbiased, and comprehensive datasets to prevent procurement errors. Ethical AI procurement involves developing transparent AI models that consider sustainability, supplier ethics, and regulatory compliance in decision-making. Additionally, hybrid AI-human procurement models have emerged as an effective strategy to overcome AI limitations. AI handles data-driven analysis, supplier risk assessment, and automated bidding, while human experts oversee strategic decision-making, contract negotiation, and ethical considerations. Implementing a hybrid approach ensures that AI enhances human expertise rather than replacing it, balancing automation with judgment.

8. Conclusion

The integration of AI-driven procurement and advanced anti-corrosive materials is transforming the oil and gas industry by enhancing efficiency, safety, and sustainability. As the industry continues to battle corrosion-related challenges, AI has proven instrumental in supplier optimization, predictive maintenance, and material selection, ensuring that refineries operate with minimal disruptions and reduced costs. By leveraging machine learning, digital twins, and blockchain-backed procurement, companies can optimize sourcing decisions, prevent equipment failures, and extend asset life.

Despite its immense potential, AI adoption still faces hurdles such as data quality issues, cybersecurity risks, and high initial investment costs. To maximize the benefits of AI, oil and gas companies must bridge the gap between technology and human expertise, ensuring that AI-driven insights are complemented by strategic decision-making from procurement professionals.

Looking ahead, the future of procurement in the oil and gas sector will be increasingly autonomous and predictive, with AI enabling self-learning procurement systems, real-time risk mitigation, and sustainable sourcing strategies. Companies that embrace AI-powered procurement frameworks will not only achieve cost savings and operational resilience but will also set new industry standards for safety and environmental compliance. By strategically integrating AI, the oil and gas industry is poised for a more efficient, sustainable, and technologically advanced future.

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