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Article

The Offshore Oil & Gas Industry and Additive Manufacturing: A Competitiveness Analysis

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Abstract. This study examines the impact of Additive Manufacturing (AM) on the Offshore Oil and Gas Industry, focusing on its role in enhancing competitiveness, operational efficiency, and sustainability. Using strategic frameworks such as PESTEL, Porter's Five Forces, and SWOT, the research highlights AM's potential to optimize supply chains, reduce downtime, and support on-demand production. Key findings suggest that AM offers significant benefits, including cost reduction, supply chain flexibility, and environmental advantages through waste minimization. However, challenges remain, such as high initial investment costs, technical limitations, and the need for workforce upskilling. Additionally, regulatory and standardization issues hinder broader AM adoption. The study emphasizes that overcoming these challenges requires strategic investments, workforce development, and collaboration across sectors. Future research should focus on assessing the long-term economic benefits of AM through lifecycle cost analyses, as well as exploring its integration with emerging technologies like artificial intelligence and digital twins. Additionally, harmonizing international standards for AM and investigating its environmental impacts will be crucial for enabling widespread adoption in the offshore sector. This paper provides valuable insights for industry stakeholders, demonstrating that AM has the potential to drive innovation and sustainability in the Offshore Oil and Gas Industry, positioning companies for long-term competitive advantage.

Keywords: Additive Manufacturing; Strategy; Competitiveness

1. Introduction

Examining the dynamic interplay between the Offshore Oil and Gas Industry and the transformative potential of Additive Manufacturing (AM) is crucial when it comes to establishing entrepreneurial strategies which might result in a positive financial impact.

Historically, the Offshore Oil and Gas Industry has been characterized by capital-intensive operations influenced by market forces, regulatory requirements, and technological advancements (Yan et al., 2023). Recent events, such as the COVID-19 pandemic and the Russia-Ukraine conflict, have further disrupted the industry, prompting a reevaluation of operational strategies (Guo et al., 2024). Companies are increasingly integrating AM technologies to enhance production processes, reduce waste, and improve supply chain dynamics, this aligning with sustainability goals (Egon et al., 2024).

Additionally, it's important to state that the adoption of AM allows for on-demand production and customization, significantly impacting competitiveness and operational efficiency in this high-stakes environment (Naghshineh, 2024). Entrepreneurs in the industry face high barriers to entry, necessitating tailored strategies that encompass financial resources, compliance with environmental regulations, and the integration of innovative technologies (Jafar et al., 2024). Building strategic

partnerships and fostering a culture of continuous improvement are essential for navigating these complexities and seizing emerging opportunities in a rapidly evolving market landscape.

Moreover, the industry's shift towards cleaner energy sources has prompted companies to leverage their expertise in large-scale offshore projects, positioning themselves as leaders in the transition to sustainable energy solutions (Bhattacharya & Kammen, 2024). Despite the potential benefits of Additive Manufacturing, challenges remain, including the need for standardized practices and regulatory compliance to ensure the safe use of 3D-printed components (Jin et al., 2022).

As companies prioritize innovation and technological integration, the interplay between traditional operational practices and advanced manufacturing techniques will play a crucial role in enhancing competitiveness in the Offshore Oil and Gas Industry. By effectively addressing these challenges and capitalizing on available opportunities, entrepreneurs can navigate the complexities of the industry and achieve sustainable growth.

1.1. Objective

The primary objective of this study is to evaluate the competitive dynamics of companies integrating AM technologies into their production processes, with a focus on high-stakes industries such as Offshore Oil and Gas.

By applying strategic analytical frameworks such as Porter's Five Forces, the study aims to identify how AM adoption influences factors like operational efficiency, market positioning, and industry competitiveness.

This research seeks to provide actionable insights into how AM-enabled companies can leverage technological advancements to overcome market challenges, optimize supply chains, and align with sustainability goals.

1.2. Research Questions

This section outlines the critical inquiries that guide the study, focusing on the integration of AM within high-stakes industries.

By addressing these questions, the research seeks to uncover insights into the transformative potential of AM in complex industrial environments.

- *How does the adoption of AM influence the competitive positioning of companies in high-stakes industries such as the Offshore Oil and Gas industry?*
- *How does AM impact operational efficiency and supply chain dynamics in industries with complex logistics, such as offshore operations?*

1.3. Research Gap

Despite the growing adoption of AM in various industries, there remains a limited understanding of its specific impact on competitiveness and operational efficiency in high-stakes sectors such as offshore oil and gas. While AM's potential benefits - such as reduced production costs, enhanced customization, and sustainability improvements - are widely acknowledged, there is a gap in research that directly explores how these advantages affect market positioning and industry dynamics.

Furthermore, the challenges associated with AM adoption, including regulatory hurdles, standardization issues, and the integration of AM into existing manufacturing ecosystems, are not fully addressed within the context of offshore industries.

This research aims to bridge this gap by providing a comprehensive analysis of AM's role in shaping competitive strategies and operational practices within the offshore oil and gas sector.

1.4. Hypothesis

The hypothesis guiding this study is that the adoption of AM in Offshore Oil and Gas companies significantly enhances their competitiveness by improving operational efficiency, reducing costs, and enabling faster, on-demand production.

Additionally, it is hypothesized that AM adoption helps companies navigate industry challenges, such as inventory management and supply chain disruptions, while contributing to sustainability goals.

2. Literature Review

2.1. Conventional Strategies in the Offshore Oil and Gas Industry

A firm's strategy is generally shaped by its standing within its industry or market environment and by the competitive edge it holds in that context. (Dirani & Ponomarenko, 2021; Garcia et al., 2014)

Thus, it's imperative to affirm that the Offshore Oil and Gas Industry requires distinct strategies to stay competitive, especially given its reliance on high-risk environments, extensive supply chains, and specialized technological needs. (Amaechi et al., 2022; Olugu et al., 2022)

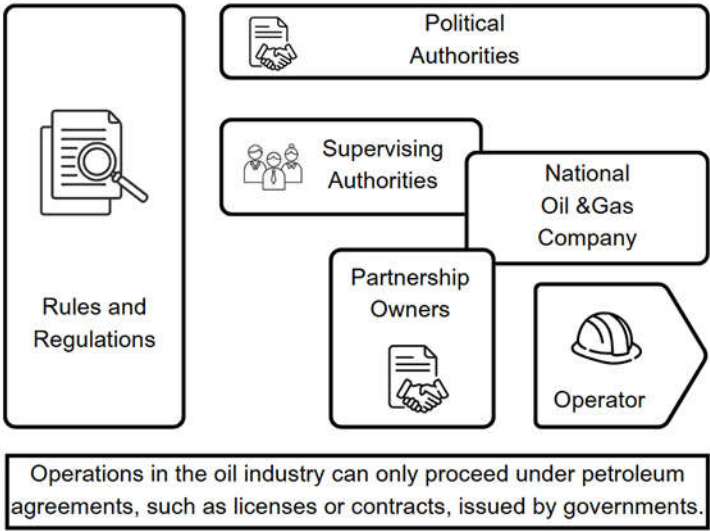


Figure 1. Structure of Offshore Oil and Gas Licensing (Concessionary Systems).

One of these strategies stems from the procurement of concessionary licensing systems, primary Offshore fiscal frameworks employed globally, where governments permit private companies to explore, develop, and produce resources, retaining ownership of natural resources but transferring the right to produce them to a private company, which then pays royalties and taxes based on production. (Dirani & Ponomarenko, 2021)

This system contrasts with contractual approaches like production sharing agreements, where the state shares directly in production or revenue rather than transferring title to resources at the production site. Concessionary systems are commonly used in countries such as Norway, the UK, and Australia, and often emphasize maximizing state revenue through royalties and taxation while encouraging investment by allowing companies to own produced oil and gas at the export point rather than the wellhead. (Olleik et al., 2021; Singh et al., 2023)

Strategic Partnerships and Value Creation

Building strategic partnerships is another essential strategy for entrepreneurs in the Offshore Oil and Gas Industry. Collaborations can provide access to unique capabilities and resources, allowing companies to undertake large-scale projects.

By leveraging their existing experience and relationships with energy stakeholders, oil and gas companies can position themselves as leaders in the energy transition, offering distinctive value propositions to their customers. (Kienzler et al., 2023)

2.2. Metal Additive Manufacturing and On-Demand Production

The process of Additive Manufacturing (AM) is based on the direct conversion of 3D data from a CAD file into a physical object by sequentially building layers of material (Frazier, 2014).

It's noteworthy that AM enables the production of complex or customized parts without additional tools, reducing conventional processing steps and spare part inventories through on-demand manufacturing, while also allowing changes in production without extra costs or the need to alter tools or molds (DebRoy et al., 2018; Vafadar et al., 2021).

According to Vafadar et al. (2021), AM has been implemented and used in a wide range of industries as presented in Figure 2.

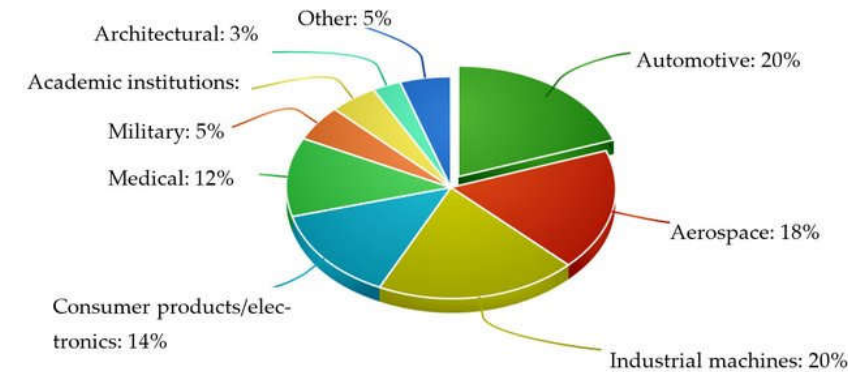


Figure 2. Industrial Adoption of AM (Vafadar et al., 2021).

Regarding metal AM, three primary systems are employed to produce metal parts: powder bed systems, powder feed systems, and wire feed systems (Frazier, 2014).

In the context of the Offshore sector, the most commonly utilized technologies are Direct Metal Laser Sintering (DMLS), Selective Laser Melting (SLM), and Electron Beam Melting (EBM) (Deja et al., 2020).

ADDITIVE TECHNOLOGY	METHOD USED TO CREATE AN OBJECT	ENERGY SOURCE	AREAS OF POSSIBLE APPLICATION
DIRECT METAL LASER SINTERING	JOINING PARTICLESOF METALLIC POWDER BY SINTERING	LASER BEAM	AIRCRAFT AND AEROSPACE, AUTOMOTIVE, TOOL MAKING, MARITIME, MEDICAL, MILITARY
SELECTIVE LASER MELTING	JOINING PARTICLES OF METALLIC POWDER BY FULL MELTING		
ELECTROON BEAM MELTING	JOINING PARTICLES OF METALLIC POWDER BY FULL MELTING	ELECTRON BEAM	AIRCRAFT, MARITIME, AEROSPACE, AUTOMOTIVE

Figure 3. Metal AM Technologies (Deja et al., 2020).

3. Unplanned Downtime

In the Offshore Oil and Gas Industry, where Lead Time requirements are stringent, the financial consequences of Unplanned Downtime can be severe. When equipment failures or breakdowns occur, necessitating part replacements, the annual cost impact could reach as high as \$88 million. This figure encompasses both the expenses associated with repairs and the financial losses resulting from production delays or interruptions. (Kimberlite International Oilfield Research et al., 2016)

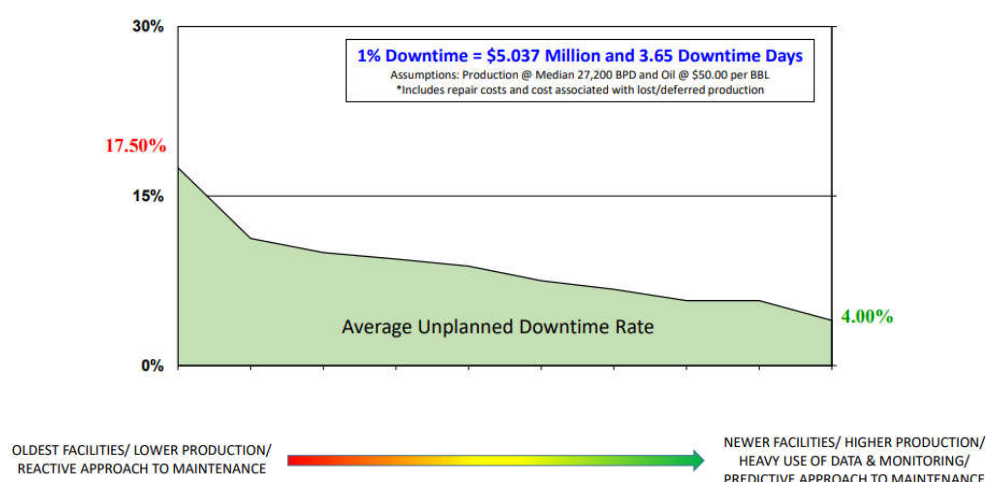


Figure 4. Cost of Downtime regarding Offshore platform conditions (Kimberlite International Oilfield Research et al., 2016).

According to GE Oil & Gas (2016), offshore unplanned Downtime contributes with 37% of the major expenses, a notable factor regarding the economic burden associated with Offshore Downtime pertains to the substantial logistics expenses incurred in transportation to the remote Offshore sites of Original Equipment Manufacturer (OEM) components (Md Sapry, 2020). It is significant to observe that in most cases, Subtractive Manufacturing techniques are employed to produce OEM parts, which play a crucial role in maintaining the efficient functioning of Offshore installations (Deja et al., 2020).

These components are typically procured from diverse suppliers, occasionally spanning multiple continents. Subsequently, they are transported to offshore locations, requiring intricate coordination to ensure the timely and precise delivery of the requisite components, encompassing customs clearance, compliance with import regulations, mitigation of weather-related delays, and synchronized scheduling with maintenance interventions. (Alan E. Branch, 2008)

Bearing this in mind, the implementation of AM as an on-demand manufacturing process can help optimize the supply chains and, in turn, reduce logistical costs.

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