Exploring the Objectives Behind Digital Twin Implementations in the Oil & Gas Industry

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Abstract. A Digital Twin is defined as a digital representation of physical entities and processes, synchronized with the real world at a specific rate and level of detail. It represents either a conceptual or an existing physical entity, system, or process, acting as its digital counterpart. Designed to closely mirror a physical object, a digital twin integrates both real-time and historical data to depict its history, current state, and predicted behavior [1]. By leveraging data, digital twins mimic and integrate every characteristic of a physical object, person, or process in a virtual space, enabling superior decision-making and efficient action. Capable of replicating a wide range of real-world entities, from individual devices to entire urban areas, digital twins are applied in various sectors such as manufacturing, energy, and architecture [2]. In the Oil and Gas sector, digital twins are highly valuable for enhancing operational activities and providing insights into procedural workings. They offer a live, virtual model of physical assets or systems, built upon static and dynamic data, which allows for the emulation of real-world operations within a digital framework, thereby supporting faster and more informed decisions. This technology is crucial in optimizing output, advancing intelligent asset control, and integrating data from diverse sources, thus significantly enhancing operational effectiveness and productivity. With the Oil and Gas industry adopting advanced technologies like AI, IoT, Big Data, and cloud computing, digital twins emerge as a transformative technology that can refine processes and provide a comprehensive understanding of assets [3, 4].

This research aims to identify the main objectives behind the adoption of DTs in the O&G sector, using a systematic literature review that adopts the PRISMA framework; We screened studies to extract relevant data on DT implementations. Our focus was on articles that explicitly discuss the objectives of DT applications in the O&G industry, analyzing the content to categorize these objectives into three main themes. After reviewing a sample of 31 articles that develop case studies on the utilization of DTs in O&G, we observe three major groups of objectives. Although other studies have addressed the primary objectives of digital twin implementation, to the best of our knowledge, none have specifically focused on the oil and gas sector.

The first objective, Monitoring, Control, and Management, encompasses the use of DTs for the continuous surveillance, oversight, and administration of O&G operations and assets. It involves the integration of real-time data with geometric or procedural projections to enhance the precision and efficiency of data processing. The goal is to maintain an up-to-date representation of physical assets or processes, allowing for real-

time management and decision-making based on current data. This category underscores the vital role of digitization in planning and executing directional drilling, managing drilling operations, production, and the maintenance of equipment and infrastructure. Monitoring, Control, and Management are the main goals of 29% of the analyzed papers.

The second objective, Optimization, involves DTs in improving pipeline design, energy efficiency, and drilling operations using AI and real-time data analysis. This includes strategic planning for Field Development Planning (FDP) to maximize returns, enhancing drilling efficiency, optimizing natural gas treatment stations for hydrocarbon recovery, reducing energy consumption, and employing automation technology for operational efficiency and tool longevity. Optimization of outcomes and resources is the main goal of 38% of the analyzed papers.

The third objective, Prediction, underscores DTs' critical role in maintaining operational integrity by diagnosing failures in subsea production control systems, providing maintenance forecasts to prevent failures, and supporting proactive interventions. DTs enable continuous monitoring for effective asset management, utilize hybrid data analysis for real-time condition monitoring, and facilitate risk-based inspection strategies. They are also key in identifying leaks and diagnosing failures in challenging operational environments, thereby ensuring process reliability and safety. Prediction and Anomaly Detection are the main goals of 33% of the analyzed papers. Figure 1 summarizes the main objectives in O&G and their frequency in the literature.

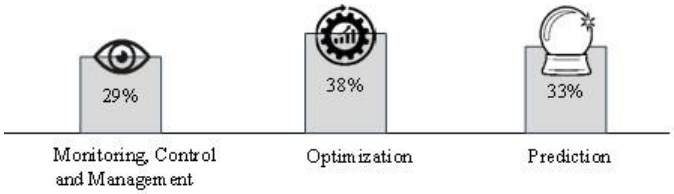

Figure 1 – Objetives in O&G and their relative frequency.

We observed that the main objectives of the research papers are also related to the maturity level of the Digital Twin. Thus, more sophisticated Digital Twins tend to aim at Optimization, while Monitoring, Control, and Management are initial objectives for many developing their Digital Twins. These findings are similar to those described by authors that classify Digital Twins in a sequence that shows Descriptive, Predictive, and Prescriptive models in this order of importance. As this study continues, it promises to shed light on the practical implications and benefits of DT implementation, offering a grounded perspective on its transformative potential in the O&G industry.

K**eywords:** Digital Twin; Decision Support Systems; Industry 4.0; Oil & Gas.

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