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Subsea Equipment Reliability: Critical Analysis Of Existing Literature

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Subsea layouts, vital for oil and gas exploration, endure harsh conditions, such as high pressure, corrosion, and erosion. Reliable equipment is crucial for uninterrupted functionality. Various tools assess components, failure modes, and consequences. This work reviews the published literature to identify the current approaches, challenges, and opportunities in the research field dedicated to the reliability analysis of subsea equipment. The review covers basic reliability concepts and more advanced modeling and analysis techniques. By identifying key approaches, challenges, and opportunities in the field, this review aims to advance knowledge in effectively managing the reliability of subsea architectures.

We performed a systematic review utilizing the Web of Science (WoS) platform for data retrieval. The search strategy employed a combination of keywords to ensure a thorough exploration of relevant literature, specifically focusing on the intersection of (i) “Subsea” AND “Oil and Gas” AND “Reliability”; (ii) “Subsea Equipment” AND “Reliability”; (iii) “Subsea Layout” AND “Reliability”; (iv) “Marine Equipment” AND “Oil and Gas” AND “Reliability”. The inclusion criteria involved selecting articles published in English and available in journals, resulting in an initial pool of 181 articles. Then, during the selection process, we excluded 9 articles identified as conference proceedings, resulting in a refined dataset of 172 articles for further analysis.

Next, we conducted a preliminary screening of titles and abstracts to assess the relevance of each article to the study’s focus. As a result, 127 articles were excluded due to a lack of alignment with the primary objective of evaluating the reliability of subsea equipment. The next phase involved an in-depth examination of the remaining 45 articles through a comprehensive reading of their full manuscripts. A team of four experts with different backgrounds carried out this detailed analysis. The primary goal during this phase was to identify articles that conducted reliability assessments of subsea equipment and addressed the reliability of subsea layouts (set of equipment), considering the interactions within a set of subsea equipment. Following this rigorous evaluation, 10 articles emerged as meeting the specified criteria and were chosen for further analysis in this study (Table 1). These selected articles are poised to provide valuable insights into the nuanced aspects of subsea equipment reliability and its broader implications on subsea system integrity.

Based on the literature review on reliability analysis of subsea equipment, we identified several gaps and potential areas for further exploration. While individual studies have addressed specific aspects of subsea equipment reliability, there is a need for approaches that consider the entire subsea system and its interactions for conducting comprehensive reliability assessments. Sales et al. (2023) focused on determining the optimal global design for synthetic fields. Extending this research to real-world subsea fields could provide valuable insights into optimizing the entire subsea systems to enhance reliability and operational efficiency. In addition, establishing standardized methodologies for reliability analysis and benchmarking could facilitate comparisons across different studies and improve the reproducibility of results. Future research could focus on developing industry-wide standards for subsea equipment reliability assessment, incorporating best practices from various

disciplines such as reliability engineering, system dynamics, and marine engineering. By addressing these gaps, future studies will contribute to understanding subsea equipment reliability, enhancing performance, and assuring the integrity of subsea systems in oil and gas offshore operations.

Table 1. Selected Studies on Reliability Analysis of Subsea Equipment: Methods and Application Scenarios.

Reference	Brief Description	Methods	Application Scenarios
(Pang et al., 2020)	Integrates reliability and statistical techniques to calculate more robust reliability	Fault tree, fuzzy comprehensive evaluation, and Markov method	Subsea subsystem of the wellhead
(Hokstad, 1988)	Contrasts analytical methods with simulations	Asymptotic formulas and Monte Carlo	Architecture filter
(Bhardwaj et al., 2022)	Models the uncertainty in expert assessments.	Failure Mode and Effect Analysis (FMEA), Development of Reliability Influence Diagrams, and Bayesian models	Subsea separation and compression systems
(Pang et al., 2021)	Investigate the time-dependent reliability	Fault tree and a dynamic Bayesian model	Christmas tree
(C. Wang et al., 2022)	Consider incomplete repair and various fault detection methods	Generalized stochastic Petri net, Self-diagnosis (SD) test, Functional test (FT), and Partial stroke test (PST)	Subsea High Integrity Pressure Protection System
(C. Wang et al., 2021)	Categorize the failure efficiency based on various fault detection types and distinct repair approaches.	Dynamic Bayesian network, SD test, FT, and Partial stroke test	Subsea High Integrity Pressure Protection System
(X. Wang et al., 2019)	Evaluate system reliability and safety based on effects of multiple factors	Markov processes and multiple beta factor model	Electrical Control System of the Subsea Control Module
(Deans, 2009)	Summarizes tests, reliability analysis, and extended life testing	Reliability Block Diagram (RBD), FMEA, Mean-Time Between Failure, Fault Tree Analysis, Qualitative tests, and Quantitative tests	Schlumberger Subsea Monitoring and Control
(Yasseri and Bahai, 2020)	Reliability evaluation employing a system engineering framework	Design Matrix, Mean time to failure, and RBD	Typical subsea field's functional architecture
(Sales et al., 2023)	Determine the optimal global design	Mixed-integer Nonlinear	Synthetic field

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