ANALYSIS OF ENVIRONMENTAL AND SAFETY RISK MANAGEMENT APPLIED TO OFFSHORE PROJECTS UNDER HPHT (HIGH PRESSURE AND HIGH TEMPERATURE) CONDITIONS

Ana Clara Moreira de Santana Santos [1], Ana Lúcia Barbosa de Souza [2], Antonio Jose Mendonça Ferreira [4], Hugo Gomes D'Amato Villardi [2], Fernando Luiz Pellegrini Pessoa [2,3] , Sara Marques Oliveira de Araújo Souza [4] , Reinaldo Coelho Mirrre [1,2] .

[1] PRH 27.1 ANP/FINEP – Human Resources Training Program applied to Exploration, Development and Production of Oil, Natural Gas and Biofuels, SENAI-CIMATEC, Brazil
[2] Manufacturing and Technology Integrated Center, Competence Center, Engineering for Intensification of Chemical and Biochemical Processes, SENAI-CIMATEC, Brazil.
[3]Manufacturing and Technology Integrated Center, Graduate Program in Computational Modeling and Industrial Technology, SENAI-CIMATEC, Brazil.
[4] LDP – Production Development Laboratory, SENAI-CIMATEC, Brazil.

Abstract: Risk management in offshore oil and gas projects is essential for guaranteeing the safety of operations and protecting the environment. By identifying and mitigating risks, companies reduce the occurrence of unwanted events and minimize their negative impacts. The aim of this article is to carry out a literature review using lens.org software of the methodologies used in risk management in offshore oil and gas projects. The methodology consisted of bibliographical research, based on the analysis of books and dissertations from periods after 2013. This resulted in the need to develop a model that can create an integrated system, from the initial identification of risks to the implementation of preventive and corrective measures.

Keywords: Risk Management, oil and gas, project management, oil industry.

ANÁLISE DA GESTÃO DE RISCOS DE MEIO AMBIENTE E DE SEGURANÇA APLICADA A PROJETOS OFFSHORE EM CONDIÇÕES HPHT (ALTA PRESSÃO E ALTA TEMPERATURA)

Resumo: A gestão de riscos em projetos offshore de óleo e gás é essencial para garantir a segurança das operações e proteger o meio ambiente. Ao identificar e mitigar os riscos, as empresas reduzem a ocorrência de eventos indesejados e minimiza seus impactos negativos. Este artigo tem como objetivo realizar uma revisão da literatura utilizando o software lens.org das metodologias utilizadas no Gerenciamento de Riscos em projetos offshore de petróleo e gás. A metodologia se constituiu na pesquisa bibliográfica, fundamentada na análise de livros, dissertações, em períodos posteriores a 2013. Resultando numa necessidade de desenvolver um modelo que possa criar um sistema integrado, que abrange desde a identificação inicial dos riscos até a implementação de medidas preventivas e corretivas.

Palavras-chave: Gerenciamento de riscos, óleo e gás, gerenciamento de projetos, indústria petrolífera

1. INTRODUCTION

The oil industry, through exploration and production processes, has the potential to cause significant impacts on the environment and safety. These impacts can be the result of routine activities, such as the emission of pollutants and waste, as well as operational accidents. In this context, the implementation of innovative industrial projects in the Oil and Gas (O&G) sector presents several risks arising from technological uncertainties and operational complexity. This is mainly due to the high pressures and flows involved, requiring greater control and safety. There are several types of risks common to industrial oil and gas projects, including geological, operational, environmental, technical, safety, regulatory and financial risks. To minimize these risks, it is crucial that these projects are guided by norms and standards that regulate the sector, establishing effective risk management processes focused on monitoring and preventing accidents [1].

Risk management in industrial oil and gas projects in the offshore field includes identifying potential uncertainties associated with activities such as drilling wells, installing platforms, transporting and storing oil and gas and assessing the impact of these risks on safety, environment, operations and project finance. Thus, risk mitigation measures are developed to minimize the negative impacts of the identified risks and ensure that the project is carried out safely. Risks related to environmental and safety accidents are significant due to the impact on life. Therefore, in order to mitigate such impasses, the risk management activity of operations in O&G industrial projects becomes extremely important for ensuring the competitiveness of companies, reducing potential asset losses and reducing environmental impacts [2].

According to the study proposed by this work, there are several risk analysis techniques that are used to administer and manage operations. The main tools for risk analysis are: FMEA (Failure Modes and Effect Analysis), FTA (Fault Tree Analysis), ETA (Event Tree Analysis), HAZOP (Hazards and Operability Study), ALARP (As Low As Reasonably Practicable), Diagram Bow-Tie et al. [4]. In addition, it is essential that risk management in offshore industrial projects is carried out in accordance with applicable national and international standards and regulations, such as ISO standards and regulations of the International Association of Drilling Contractors (IADC) and the American Petroleum Institute (API). These rules and regulations establish guidelines and standards that must be followed to ensure safety and environmental protection in offshore operations. By adhering to these standards, companies can adopt best practices, identify and assess risks more efficiently, implement appropriate preventive and corrective measures, and promote compliance with legal requirements.

The objective of this project is to carry out a comprehensive literature review in order to map the main Risk Management techniques in industrial Oil and Gas (O&G) projects, focusing on offshore applications in high pressure and high temperature (HPHT) conditions. Subsequently, based on the deficiencies found, it will be possible to develop a method to address the main difficulties in offshore industrial projects. The same will be applied to a real case study to evaluate the performance of the tool to manage environmental and safety risks.

2. METHODOLOGY

In this research, a Bibliographic Review was carried out on the Safety and Environment risk management methodology involving *offshore industrial projects* in

HPHT situations. The database used was Lens.org (online patent and academic literature search engine). The main keywords of this research were " *Risk Management AND Environment AND Safety AND Offshore Projects AND Innovation AND oil and gas* ", presenting the annual scientific production in the last 10 years, related to risk management in offshore projects.

3. RESULTS AND DISCUSSION

Risk management has the primary objective of identifying, evaluating, mitigating and controlling the potential risks associated with an offshore project, aiming to guarantee the safety of the people involved, environmental protection and the economic viability of the enterprise as a whole. In order to achieve these objectives, it is crucial to implement adequate practices and processes that allow an accurate identification and analysis of risks, as well as the establishment of efficient preventive and corrective measures. In addition, it is essential to continuously monitor risks throughout the project life cycle [5]. Within the oil and gas industry, there are several widely adopted methods for managing risks related to safety and the environment. Some of these methods include Event Tree Analysis (ETA), Hazard and Operability Study (HAZOP), Hazard Analysis (AR), Fault Tree Analysis (AAF), Failure Mode, Effects, and Criticality Analysis (FMECA), HAZID (Hazard Identification), Monte Carlo Analysis, Expected Monetary Value (EV) analysis, sensitivity analysis, and others. of oil and gas, these methods have some gaps and deficiencies that still need to be addressed and improved.

The ETA method (Event Tree Analysis) is a technique used in industrial oil and gas projects to assess risks and estimate the probability of occurrence of an undesired event, which can be both qualitative and quantitative, depending on the approach used in the analysis. While it is a useful technique for risk analysis, there are some disadvantages that should be considered: ETA can be complex and require specialist risk engineering knowledge. ETA analysis requires prior knowledge of initial conditions, assumptions, limitations, and logical relationships between events, which can make the analysis difficult to understand and interpret for those not experienced in the technique, in addition to requiring an accurate estimate of the probability of each branch of the event tree, which can be difficult to estimate, especially for specific events or without history of occurrence [6].

The HAZOP method is a technique based on qualitative analysis, which largely depends on the judgment and interpretation of analysts, as a result, there is a risk of errors or omissions in identifying and assessing risks. Although HAZOP can identify and assess risks, the technique does not take into account the economic, environmental or social impact of identified risks. This can be a limitation for processes that have a high potential for negative impact [7]. Implementing the recommendations resulting from a HAZOP study can be complex and expensive. Change management can be difficult to implement in a complex industry, especially if multiple parties are involved. In this sense, the disadvantages may include the time and cost required to carry out a study, the need for specialized technical knowledge, the risk of errors and omissions, the limitation in assessing risks and impacts and the complexity of implementing the resulting recommendations. In addition, the HAZOP process can be time consuming and expensive, especially for complex processes or processes with many variables.

Risk Analysis (RA), also used in offshore projects, uses techniques This method involves the identification, assessment and prioritization of risks associated with the project. It uses both quantitative and qualitative assessment techniques to assess risks and determine the best strategies to mitigate them. Performing RA can be expensive, especially if you need to hire outside experts or additional equipment to conduct the analysis. Even with an experienced team, identifying all risks is difficult and there may be unknown risks that go undetected. AR is a subjective process, based on assumptions, estimates and judgments. This can lead to different results from different teams and different analysts, making it difficult to compare results [8].

Failure Mode, Effects and Criticality Analysis, FMECA, is often used in offshore projects. FMECA is a systematic risk analysis methodology that identifies potential failure modes in a system, assesses the effects of those failures, and determines their criticality. By conducting the FMECA analysis in the context of environmental and safety risk management, organizations can identify key risks, prioritize corrective actions, and implement appropriate prevention, control, and response measures. This helps promote process compliance, reduce accidents and incidents, protect the environment, and ensure the safety of people and operations. The FMECA qualitative approach is more common and involves the subjective assessment of failure modes, effects and criticality. In this approach, failure modes are identified and classified based on their severity, probability of occurrence and detection. FMECA analysis, especially in the qualitative approach, can involve a certain amount of subjectivity. FMECA analysis requires reliable data on failure modes, probabilities of occurrence, effects and detection. In addition to the complexity of the quantitative analysis [9].

HAZID (Hazard Identification) can be used in the management of environmental and safety risks in offshore oil and gas projects. HAZID is a systematic and proactive technique that aims to identify and analyze potential hazards and risks in an operation or project. HAZID is a qualitative risk analysis technique. It focuses on identifying and analyzing hazards and risks without assigning numerical values to the probabilities of occurrence or consequences of events. Qualitative analysis is carried out through discussions and subjective assessments by members of the HAZID team. HAZID relies on the subjective assessment of team members, which can lead to differences of opinion and differing interpretations of hazards and risks. HAZID does not assign numerical values to the probabilities of occurrence or consequences of events. This makes it difficult to carry out quantitative analyzes and direct comparison between the identified risks [10].

Monte Carlo Analysis can also be applied in assessing safety and environmental risks in projects and operations related to oil, gas and other industries. The technique can help to quantify and manage uncertainties associated with these risks, allowing a better understanding of possible scenarios and assisting in decision making. However, it may have some disadvantages such as dependence on assumptions, data availability and model complexity [11].

The FMEA (Failure Mode and Effects Analysis) method is useful for identifying and evaluating potential failure modes in a system, product or process. However, it has some shortcomings, including reliance on experts, focus on known failure modes, difficulty in quantifying the effects of failures, lack of a dynamic approach, and emphasis on failure detection and mitigation. It is important to consider these limitations and complement the FMEA with other approaches for a more comprehensive risk analysis [12].

Sensitivity analysis is a useful tool for understanding the influence of input variables on the results of a model or system. However, it does have some limitations. Gaps in sensitivity analysis include model simplifications, assumptions of independence between variables, statistical limitations, simplifications of causal relationships, and lack of consideration for uncertainty in variable values. It is important to keep these shortcomings in mind and complement sensitivity analysis with other techniques to obtain a more complete understanding of the system under study [13].

Table 1 shows the main methodologies adopted in the oil and gas industry and their identified gaps that need to be addressed in a management plan.

Table 1- Comparison between methods

Methods	Gaps	Qualification	References	prospecting area
ETA	Complex, requires prior knowledge of Risk Engineering, requires accurate estimation of the probability of each branch of the event tree, Limitations in modeling complex interactions, Limitations in incorporating human factors.	Hybrid	(FERDOUS, 2009)	O&G
HAZOP	Subjectivity, Limited focus, Lack of quantitative analysis, Dependence on the team's experience, Limitation in identifying emerging risks, Expensive and complex implementation, Requirement of time and cost to carry out the process, Risks of omissions, can be time consuming and expensive.	Qualitative	(DUNJÓ, 2010; CIA, 1993; IEC 61882;HOEPFFNER, 1989)	O&G
FMECA	Subjective, Data may be missing, Complexity of quantitative analysis, Lack of consideration in complex analyzes.	Hybrid	(BOUTI, 1994; SPREAFICO, 2017; TIXIER, 2002)	O&G
HAZID	Subjective, Lack of numerical data, Absence of performance metrics, Depends on team experience.	Hybrid	(CHARTRES, 2019)	O&G
MONTE CARLO ANALYSIS	Dependency on assumptions, Availability and quality of data, Model complexity, Computational limitations, Uncertainty in modeling rare events	Qualitative	(FERSON, 1996; XINGZHI, 2016)	O&G
SENSITIVITY ANALYSIS	Oversimplification, Reliance on assumptions, Limitations in models, Uncertainties in input data	Hybrid	(BORGONOVO, 2016)	O&G
FMEA	Depends on specialists, Difficulty in quantifying the effects of failures, Lack of dynamic approach	Hybrid	(JAYAWEERA, 2021; HUANG, 2020)	O&G

Source - Created by the authors

In this sense, based on an analysis carried out previously with the main risk management methods, it can be seen that the existing methodologies have gaps, even though they are already consolidated in the oil and gas area. These gaps may include a lack of comprehensive consideration of risks specific to the offshore environment, the absence of a protected risk management model, limited collaboration and communication between stakeholders, observation in the consideration of environmental risks, and failures to in the implementation of preventive and corrective measures. Correcting these gaps is important to ensure the effectiveness and safety of offshore projects, involving the proper identification of risks, the implementation of effective mitigation measures and collaboration between all parties involved.

4. CONCLUSION

Offshore projects involve complex and innovative operations. Focused on the pre-salt environment, these projects are scoped for operations at high pressure and high temperature, in addition to being subject to significant environmental and safety risks. However, some existing methodologies have flaws that need to be corrected. Therefore, there is a need for a new risk management model specific to offshore projects to take a structured and comprehensive approach, providing guidelines and best practices for the identification, assessment and mitigation of risks at all stages of the project. model for risk management in offshore projects allows the creation of a consistent and integrated system, which ranges from the initial identification of risks to the implementation of preventive and corrective actions. This process will propose collaboration between all stakeholders involved, including operators, contractors, regulatory and local communities.

Acknowledgments

Thanks to SENAI CIMATEC and PRH 27.1 by ANP (National Petroleum Agency) for institutional support. In addition, to advisors Ana Lucia Barbosa, Fernando Luiz Pellegrini Pessoa, Sara O. Marques and Hugo Villardi for their help in building the project.

5. REFERENCES

[1] RAMOS, S.B.; VEIGA, H. **Risk factors in oil and gas industry returns: International evidence. Energy Economics** , v. 33, no. 3, p. 525-542, 2011.

[2] MARIANO, J. **Proposal for an integrated assessment of environmental risks and impacts methodology for strategic environmental assessment studies of the oil and natural gas sector in offshore areas.** 2007. 571 f. Thesis (Doctorate in Science in Energy Planning) - Energy Planning - COPPE, Federal University of Rio de Janeiro, Rio de Janeiro.

[3] SILVA, M., **Visualization of risk as a support means for decision making: an approach through the analysis of risk management tools.** 2016. 86 p. Dissertation (Master of Science) – Federal Faculty of Pernambuco, Caruaru.

[4] VORA, M.; SANNI, S.; FLAGE, R. **An environmental risk assessment framework for enhanced oil recovery solutions from the offshore oil and gas industry.** Journal of Cleaner Production, v. 88, p. 107-118, 2021. DOI: 10.1016/j.jclepro.2021.126964

[5] FERDOUS, R., KHAN, F. SADIQ, R., AMYOTTE, P., VEITCH, B. **Handling data uncertainties in event tree analysis.** Process Safety and Environmental Protection, v. 87, n. 5, 283-292, 2009.

[6] DUNJÓ, J, et al., **Hazard and operability (HAZOP) analysis. A literature review.** 2010. Journal of Hazardous Materials.Volume 173, Issues 1–3, 15 Jan. 2010, p. 19-32.

[7] TIXIER, J.; DUSSERRE, G.; SALVI, O.; GASTON, D. **Review of 62 risk analysis methods of industrial plants.** Journal of Loss Prevention in the Process Industries, v. 15, p. 291-303, 2002.

[8] BOUTI, A.; AIT KADI, D. **A state-of-the-art review of FMEA/FMECA.** International Journal of Quality & Reliability Management, v. 11, no. 9, p. 35-66, 1994.

[10] CHARTRES, N.; BERO, L.A.; NORRIS, S.L. **A review of methods used for hazard identification and risk assessment of environmental hazards.** Environment International, v. 123, p. 231-239, Feb. 2019.

[11] FERSON, S. **What Monte Carlo methods cannot do.** Reliability Engineering & System Safety, v. 55, no. 1, p. 1-7, Jan. 1997.

[12] JAYAWEERA, ALA; RUTTER, V.; SAMARANAYAKE, NR **Application of Failure Mode and Effect Analysis (FMEA) to improve medication safety: a systematic review.** Postgraduate Medical Journal, v. 97, no. 1145, p. 168-174, Mar. 2021

[13] BORGONOVO, E.; PLISCHKE, E. **Sensitivity analysis: a review of recent advances.** European Journal of Operational Research, v. 248, no. 3, p. 869-887, February 2016.

[14]CIA, **A guide to hazard and operability studies.** Chemical Industries Association, 1993.

[15]IEC, 61882 **- Guia de aplicação de estudos de perigos e operabilidade (estudos HAZOP),** Comissão Eletrotécnica Internacional, Genebra, 2016.

[16]HOEPFFNER-**Analysis of the HAZOP study and comparison with similar safety analysis systems-** Gas Separation & Purification. v. 3, n. 3, Sept. 1989, p. 148-151.

[17]SPREAFICO, C; RUSSO, D; RIZZI, C. **A state-of-the-art review of FMEA/FMECA including patents.** Computer Science Review. v. 25, Aug. 2017, p. 19-28.

[18]HUANG, J, et al. **Failure mode and effect analysis improvement: A systematic literature review and future research agenda.** Reliability Engineering & System Safety. v. 199, July 2020, 106885.

[19]XIENGZHI, HU, et al. **Review of improved Monte Carlo methods in uncertainty-based design optimization for aerospace vehicles.** Progress in Aerospace Sciences. v. 86, Oct. 2016, p. 20-27.