Hazard Identification in Offshore Rigs Operation

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المستخلص

تُعدّ صناعة النفط والغاز أساسيةً لنمو الاقتصاد العالمي. ومع ذلك، تُواجه هذه الصناعة مخـاطر جسيمة تُهدد الحياة. فعلى مر السنين، أُبلغ عن العديد من الحوادث والوفيات في مواقع الحفر البريـة والبحريـة، ويعـود ذلك إلى حد كبير إلى عدم كفاية لوائح الصحة والسلامة وتدابير الوقاية. وعلى الرغم من بعض التقدم المحـرز فـي السيطرة على نسبة ضئيلة من هذه المخاطر في السنوات الأخيرة، إلا أن طبيعة مهنـة الحفـر، التـي تتسـم بعـدم القدرة على التنبؤ بها، لا تزال تُشكّل تحديات كبيرة لضمان السلامة. تقتصر الدراسة الحالية على تحديد مخاطر تشغيل منصات الحفر البحرية، استنادًا إلى تقارير الحوادث التي وقعت فـي جميـع أنحـاء العـالم، خـلال الفترة الزمنية مـن عـام ٢٠١٠ إلـى عـام ٢٠٢٤. ويهدف هـذا البحث إلـى تحديد وتصـنيف سيناريوهات المخـاطر المرتبطة بتشغيل هذه المنصات، وترتيبها وفقًا لقيمـة مخاطرهـا باستخدام نمـوذج رياضـي مناسب. كمـا حـدد البحث أساليب للحد من عوامل الخطر المتعلقة بالسلامة والصحة التي تواجه هذه المنصات. استُخدمت المنهجية الوصفية التحليلية لتحقيق الهدف المذكور، واستُخدمت حزمة برمجيات مناسبة لتحليل هـذه البيانـات إحصـائيًا، ونموذج مناسب لاتخاذ القرارات متعدد المعايير (MCDM) لتصنيف سيناريوهات المخاطر. وُضعت وناقشت عوامل الارتباط بين عناصر عوامل الخطر.

الكلمات الرئيسية : عمل الحفارات البحرية، سيناريوهات المخاطر، عوامل الخطر، إدارة المخاطر، AHP.

Abstract

The oil and gas industry are crucial to the growth of the global economy. However, this industry is fraught with significant life-threatening risks. Over the years, numerous accidents and fatalities have been reported at both onshore and offshore drilling sites, largely due to insufficient health and safety regulations and prevention measures. Despite some progress in controlling a small percentage of these risks in recent years, the inherently unpredictable nature of the drilling profession continues to pose substantial challenges to ensuring safety.

Where Hazard: something that can cause harm. And Risk: the chance that harm will occur and how bad it could be.

The current study is limited to hazard identification of offshore rigs operation, based on reports on accidents that occurred all over the world, within the time span from 2010 to 2024.

The aim of this research was to identify and classify the hazard scenarios associated with operating these platforms and to arrange the scenarios according to their risk value by using an appropriate

mathematical model. It also identified methods to reduce the safety and health risk factors which face these rigs. The analytic descriptive methodology was used to achieve the aforementioned aim, a suitable software package was used to statistically analyze this data and a suitable Multi-Criteria Decision-Making (MCDM) model was used to rank the hazard scenarios. Ranking correlation factors between elements of risk factors were developed and discussed.

Keywords-Offshore Rigs Operation, Hazard Scenarios, Risk Factors, Risk Management, AHP.

1- Background

Oil and gas projects are prime examples of industrial ventures that stand out due to their unique nature. These projects require highly qualified, specialized, and experienced contractors who must possess advanced technological and technical expertise. (Noort et al., 2019)

Additionally, contractors must have a thorough awareness, understanding, and the capability to evaluate all types of risks associated with such complex operations. However, this operation is closely linked to life-threatening risk for drilling crew. (Niven & McLeod, 2009) Over the decades, hundreds of accidents and fatalities have been recorded at onshore and offshore drilling sites, primarily due to insufficient health and safety regulations and preventive measures. (Duvillard, et al., 2021) Despite some progress, the unpredictable nature of the drilling profession has allowed only a small percentage of risk factors to be controlled in recent years. To address this, an extensive and systematic literature review will be conducted to identify the most significant safety and health risks and the root causes of accidents and injuries in offshore drilling over the past 14 years, from 2010 to 2024. Previous studies have shown that Blowout, Fire, Explosion, Oil spill, Helicopter, Structure safety, Marine accident, Natural hazards, Structural failure and Mechanical accidents. In the current research a field survey was conducted through a structured questionnaire to pinpoint the most significant safety and health risk factors and the primary causes of fatalities in offshore drilling sites over the past two decades, in addition to conducting a comprehensive and systematic literature review for the same purpose. (Sandell, 2025 & Bahr, 2014)

This review aimed to highlight the key underlying causes of accidents and injuries during drilling operations. It was intended to serve as a guide for safety and health professionals and researchers, enabling them to focus on the most hazardous drilling activities and effectively reduce associated health and safety risk factors. (Bobbio, et al.,2019)

An exhaustive review of previous work covering the period from 2010 to 2024 on risk assessment of offshore rig operation has singled out blowout, fire, explosion, oil spill, helicopter, structure safety, marine accident, natural hazards, structural failure and mechanical accidents, as the most hazardous scenarios is fires and explosions. (Ashraf, 2025) However, the current research involves identification, classification and ranking of hazard scenarios according to their risk factor. In addition, it singled out some risk control options to eliminate/reduce risk associated with the most hazardous scenarios.

2- Methodology

The risk assessment process essentially provides a systematic approach to identify, analyze, evaluate and treat risk, as shown in Figure 1(ISO, 2018). Hazard identification involves pinpointing potential sources of hazardous events or scenarios, understanding their causes, and assessing their possible outcomes. (Khan, et al., 2014) Risk analysis involves evaluating the likelihood and potential outcomes of a hazardous event. Since a single hazardous event can lead to multiple consequences, the analysis must account for all possible impacts.

Risk evaluation involves using the outcomes of the risk analysis to compare these results against established risk acceptance criteria. (Abimbola, et al., 2016) Risk treatment refers to the process of choosing and applying one or more strategies to address and modify risks. Accordingly, the research design used in this study is based on descriptive and analytic approaches where available databases on hazard identification in offshore rigs operation are analyzed and main factors contributing to these accidents are singled out. A systematic procedure of hazard identification in offshore rigs operation was followed, which consisted of the following steps:

   i) An analytic descriptive methodology is used in reviewing the literature.
   ii) A specially designed questionnaire is used to collect primary data from experts in the field.
   iii) A suitable software package is used to analyze these data.
   iv) A suitable model is used to rank the hazard scenarios.
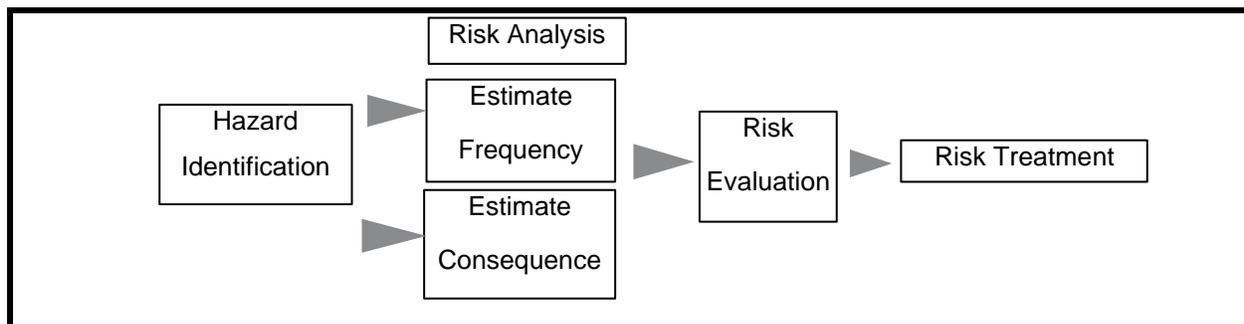

Figure 1: Risk assessment four main steps (ISO, 2018)

On the other hand, IMO-FSA (2018) is a structured and systematic approach designed to improve maritime safety, encompassing the protection of life, health, marine environment, and property through risk analysis and cost-benefit evaluation. (Khan et al., 2018) It serves as a tool to assess new regulations for maritime safety and marine environmental protection or to compare existing regulations with potential enhancements. (Tabassum et al., 2019) The goal is to strike a balance between maritime safety or environmental protection and associated costs. (Khakzad et al., 2013) The FSA is structured into five key steps:
i) hazard identification (a list of all potential accident scenarios, including their possible causes).
ii) risk analysis and evaluation (evaluation of risk factors).
iii) risk control options (regulatory measures are developed to mitigate risks have been identified).
iv) cost benefit analysis (involve evaluating the cost-effectiveness of each proposed risk control option).

v) decision-making recommendations (detailed information about the hazards, their associated risks and the cost effectiveness of alternative risk control options is provided).

FSA promotes a proactive approach by identifying and addressing potential hazards before leading to serious accidents. (Duvillard et al., 2021) FSA marks a significant shift from the previously fragmented and reactive regulatory approach to one that is proactive, integrated, and grounded in risk evaluation and management. This transparent and justifiable methodology encourages greater compliance with maritime regulations, ultimately enhancing safety and environmental protection. (Dudek et al., 2020)

In this research the first three steps of the FSA frame work are covered. The fourth and fifth steps are beyond the capabilities of the researcher, since they need a budget among other considerations such as time, data, and special instruments. Multi Criterion Decision-Making (MCDM) is a decision making methodology that aims to analyze and evaluate alternative solutions based on multiple criteria or objectives. It is useful in complex decision making scenarios where there are various conflicting factors to consider. (Eklund et al., 2019) In the realm of risk assessment and arrangement of hazards scenarios, it can be effectively employed to assist decision makers in selecting the most appropriate risk management strategies. It allows decision maker to make well informed and balanced decision and provide a systematic framework for evaluating and ranking potential hazard scenarios. The AHP is a mathematical framework designed to assist in structuring and supporting the decision-making process. It is a particularly useful for addressing complex and unstructured decision problems, by integrating quantitative with qualitative methods together (Triantaphyllou, 1995). AHP aids decision-makers in identifying the most suitable solution that aligns with their objectives and their comprehension of the issue at hand. AHP offers a valuable mechanism for assessing the consistency of these measures and alternatives, under consideration, thereby minimizing bias in decision-making process. (Hsu et al., 2012) The AHP method also enhances group decision-making by promoting consensus, achieved through the calculation of the geometric mean of the individual pairwise comparisons (Zahir, 1999).

AHP is particularly well suited for modeling scenarios involving uncertainty and risk, as it can generate scales in situations where traditional measures are absent (Millet & Wedley, 2002).

This unique capability makes it a powerful tool for addressing complex and uncertain decision problems. (Tabassum et al., 2019)

Sampling: The sample size of the research consisted of 80 questionnaires which were sent out to experts working in the shipping industry, with enough expertise to pass judgments through pairwise comparisons of seven criteria and thirty-seven alternative hazards affecting offshore rigs, using a five-point Likert scale. 75 questionnaires were returned representing a response ratio of 93.75%. Only of 51 of them were accepted and included in the analysis, while the remaining 24 were rejected due to inaccuracy and incompletion, thus yielding a ratio of 68% of the participants.

Participants with accepted questionnaires included experts working in liner shipping companies, port authorities, terminal operators, logistics managers, operation managers, freight forwarders, worker on offshore rigs and academic researchers. Completed questionnaires have been

subsequently used to prioritize the hazards affecting offshore rigs. It is worthy to mention at this point that these hazard scenarios were selected from a much greater set of hazard scenarios related to offshore rigs based on the analysis of relevant accidents. The scenarios were divided into five groups: i) eight heat scenarios, ii) seven natural phenomena scenarios, iii) six helicopter scenarios, iv) ten handling error of rigs scenarios, and v) six miscellaneous scenarios, as shown in Table 1. Each expert was asked to fill in the first row of all the tables in the questionnaire and the remaining cells in each table were completed by the researchers, using the properties of the AHP matrices. Further details can be found elsewhere. (Ashraf.2025)

Method of analysis: The aggregated matrices were obtained by taking the geometric mean of individual enteries, using descriptive statistics. This approach enabled the results to be presented in tables, graphs and other forms, as suggested by (Cox, 2017). Analysis was conducted using Microsoft office Excel, 2010.

Statistical data analysis: This was done by using the Statistical Package for Social Sciences (SPSS), by taking the geometric mean ($a_{ij}* = \sqrt[n]{\prod_{k=1}^{n} (a_{ij})}$ $_k$ where: $(a_{ij})k$ is the judgment a_{ij} of the kth expert, and k changes from 1 to n, where n is the number of returned, accepted questionnaires, n= 51.

3- Results and Discussion
Table 1 illustrates the risk assessment matrix computed from the aggregated matrices based on the individual pairwise comparisons of criteria and scenarios provided by the participants. Weights of criteria are provided at the top of the table, whereas weights of scenarios with respect to individual criteria are listed under respective criteria. Then the total weight of each scenario is computed and listed as Wt* (%), and, finally, the scenarios are ranked accordingly.

Total weight of scenarios are also illustrated in Figure 2 for ease of comparison and to give a panoramic picture of the risk level of individual scenarios.

It is clear from Table 1 and Figure 2 that the five top hazardous scenarios, in descending order, are explosion, helicopter crash, oil spill, natural phenomena tides and sea pollution. Unfortunately, no previous study including this relatively large number of scenarios is available to compare with. However, data collected from different sources, show that oil spill, explosion and fire, blowout, marine accidents, helicopter crash, natural hazards, mechanical accidents, structural failure and structural safety the most hazardous scenarios based on the aforementioned review of previous studies, consistent, to a great extent, with the current results.

More accurate comparisons between the current results and those reported in different databases should be made to further confirm the validity of current results, once appropriate data are found. However, it was felt necessary to find some way to compare the current results with those available in the open literature.

Experts in the field contacted and it was generally confirmed that both, current and previous data assure that the most hazardous scenarios are fire and explosion, oil spill and sea pollution, helicopter accidents, structure safety and blowout, with minor difference in ranks of both sets. Further effort is needed to gather enough data to compare with. Complementary research, therefore, should be directed towards achieving this goal.

4- Conclusions

This research discussed the hazard scenarios affecting the offshore oil rigs. It studied the importance of these scenarios based on their probability of occurrence and degree of severity. It relied on a field survey through a structured questionnaire directed to the experts working in the oil and gas field. Thirty-seven risk hazard scenarios were identified and combined into five major groups related to their sources, as has been mentioned earlier. The questionnaire developed collected respondents, and the second related to the respondent's judgement on probability of occurrence and degree of severity of the risk factors through pairwise comparisons of criteria and scenarios. All collected data were analyzed, risk evaluated and hazards scenarios ranked. Analysis and comparison of results has indicated that the top nine hazard scenarios affecting offshore rigs which are: a) explosion, b) helicopter crash, c) oil spill, d) natural phenomena tides, e) pollution to the sea, f) blowout, g) release of flammable hydrocarbons, and h) fire. Accepted agreement of current and previous results was generally obtained.

Table 1 Risk assessment matrix

Cr / Sc	C_1	C_2	C_3	C_4	C_5	C_6	C_7	Wt* (%)	Rank
	0.233	0.155	0.116	0.155	0.077	0.146	0.117		
S_1	0.065	0.075	0.082	0.092	0.101	0.082	0.078	7.920	1
S_2	0.043	0.030	0.040	0.046	0.036	0.027	0.052	3.922	9
S_3	0.040	0.038	0.055	0.031	0.050	0.041	0.055	4.26	6
S_4	0.043	0.050	0.027	0.018	0.020	0.020	0.039	3.287	14
S_5	0.032	0.047	0.040	0.046	0.034	0.054	0.026	4.014	8
S_6	0.043	0.030	0.051	0.023	0.025	0.041	0.039	3.659	10
S_7	0.041	0.025	0.020	0.031	0.020	0.027	0.019	2.821	17
S_8	0.026	0.038	0.016	0.046	0.050	0.041	0.026	3.376	13
S_9	0.047	0.046	0.040	0.037	0.045	0.040	0.050	4.324	4
S_{10}	0.023	0.030	0.026	0.029	0.032	0.032	0.025	2.774	18
S_{11}	0.012	0.011	0.013	0.025	0.011	0.008	0.010	1.298	29
S_{12}	0.016	0.015	0.020	0.012	0.009	0.009	0.012	1.357	28
S_{13}	0.031	0.023	0.022	0.031	0.030	0.027	0.020	2.482	20
S_{14}	0.023	0.018	0.020	0.018	0.018	0.020	0.033	2.154	22
S_{15}	0.016	0.023	0.026	0.015	0.022	0.032	0.017	2.076	23

Heat scenarios (G_1): S_1–S_8. Natural phenomena scenarios (G_2): S_9–S_{15}.

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Helicopter scenarios(G₃)	S₁₆	0.055	0.064	0.064	0.062	0.062	0.060	0.067	**6.088**	**2**
	S₁₇	0.027	0.051	0.022	0.031	0.025	0.020	0.017	**2.827**	**16**
	S₁₈	0.036	0.032	0.043	0.041	0.021	0.043	0.027	**3.568**	**12**
	S₁₉	0.039	0.042	0.052	0.044	0.031	0.040	0.045	**4.184**	**7**
	S₂₀	0.044	0.021	0.016	0.020	0.041	0.015	0.045	**2.905**	**15**
	S₂₁	0.022	0.013	0.026	0.025	0.044	0.043	0.022	**2.611**	**19**
Handling error of rigs scenarios(G₄)	S₂₂	0.033	0.017	0.012	0.009	0.014	0.014	0.020	**1.838**	**25**
	S₂₃	0.023	0.008	0.005	0.006	0.009	0.009	0.010	**1.145**	**31**
	S₂₄	0.016	0.011	0.004	0.006	0.005	0.003	0.004	**0.823**	**33**
	S₂₅	0.011	0.007	0.009	0.005	0.004	0.006	0.007	**0.727**	**34**
	S₂₆	0.008	0.006	0.080	0.043	0.057	0.005	0.005	**1.602**	**27**
	S₂₈	0.013	0.011	0.018	0.013	0.003	0.042	0.010	**1.629**	**26**
	S₂₉	0.021	0.033	0.003	0.043	0.005	0.007	0.005	**1.893**	**24**
	S₃₀	0.022	0.003	0.048	0.003	0.057	0.009	0.040	**2.202**	**21**
	S₃₁	0.013	0.067	0.036	0.004	0.005	0.068	0.061	**3.572**	**11**
Miscellaneous scenarios (G₅)	S₃₂	0.010	0.012	0.010	0.013	0.010	0.011	0.010	**1.081**	**32**
	S₃₃	0.004	0.006	0.003	0.004	0.003	0.004	0.002	**0.396**	**37**
	S₃₄	0.005	0.008	0.002	0.003	0.002	0.004	0.003	**0.407**	**36**
	S₃₅	0.003	0.003	0.004	0.004	0.003	0.004	0.010	**0.440**	**35**
	S₃₆	0.049	0.047	0.051	0.037	0.052	0.033	0.050	**4.512**	**3**
	S₃₇	0.039	0.035	0.041	0.050	0.041	0.055	0.040	**4.299**	**5**
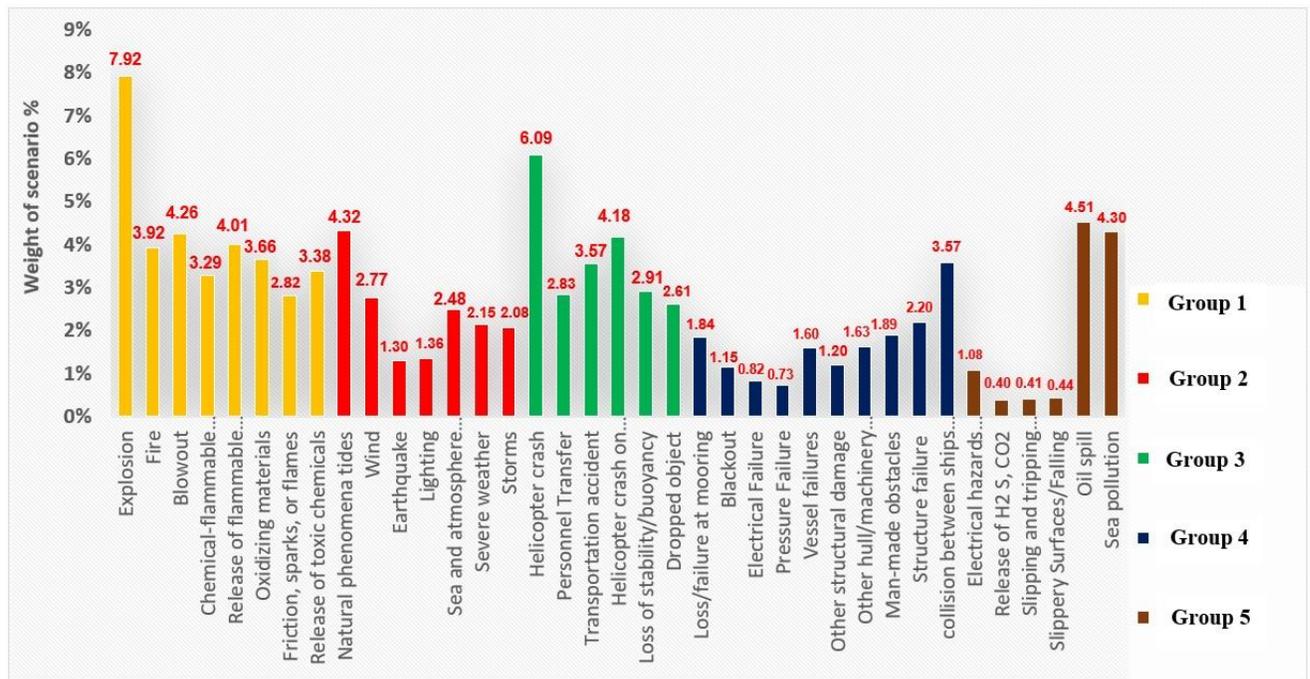
Figure 2 Total weights of scenarios

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