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HAZARD IDENTICATION OF WELL TEST OPERATION IN DRILLING AND PRODUCTION OFFSHORE PLATFORM BY HAZID

Nafiseh FARAJIRAD[1]*, Müge ENSARİ ÖZAY[1]

[1]*Uskudar University, Faculty of Health Sciences, Occupational Health and Safety Department, Istanbul, Türkiye*

Abstract: A significant portion of energy resources has been discovered in offshore sectors, leading to a steadily increase in the volume of activities and operations. Once a well is drilled and fluid extraction begins, all the reservoir parameters, start to change. well test operation is one of the most crucial tools for engineers to comprehend the behavior and parameters of hydrocarbon reservoirs. In this study, the hazards associated with the well test operations has been identified by using HAZID technique. A total of 189 risks were identified in the initial risk assessment, with 35 categorized as low risk, 88 as medium risk, and 66 as high risk. Following the implementation of protection layers in the secondary risk assessment, the number of low risks incidents increased, while medium and high-risk incidents saw a significant reduction. Most of the identified risks are associated with loading operations and sea transportation from the port to the drilling rig. Since loading and unloading operations are critical and frequently occurring tasks in well testing, they contribute significantly to the overall risk profile.

Keywords: Hazard identification, HAZID, Offshore, Risk, Well test

***Corresponding author:** Uskudar University, Faculty of Health Sciences, Occupational Health and Safety Department, Istanbul, Türkiye
E mail: n_farajirad@yahooo.com (N. FARAJIRAD)
Nafiseh FARAJIRAD https://orcid.org/0000-0002-1137-0600
Müge ENSARİ ÖZAY https://ocid.org/0000-0002-4785-5503

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1. Introduction

Every task carries some potential risk to health or injury. The only way to fully eliminate this risk is to refrain from performing the task entirely. However, this is rarely a practical solution. In many cases, it is reasonable to proceed with a hazardous task if the risk can be minimized. Risk management involves identifying hazards, assessing the level of risk, and implementing controls to reduce that risk to acceptable levels (Nardone, 2011). The importance of offshore drilling is clear, particularly given the growing demand for these resources. Offshore drilling in developing and underdeveloped countries is particularly associated with numerous hazards, which hinder the implementation and effectiveness of these operations. As a result, these hazards can negatively impact the economies of countries.it is crucial to implement measures and policies to mitigate these risks (Yu and Michael, 2019). Once a well is drilled and fluid extraction begins, key reservoir parameters such as pressure, fluid volume, fluid viscosity, and other vital characteristics of the well begin to change. Well testing is the analysis of reservoir and well behavior over time, and the results obtained from these tests can greatly impact the determination of the actual reservoir parameter values. Well test interpretation entails extracting insights about a reservoir by analyzing the pressure-transient response caused by a change in production rate. These insights are then used to support reservoir management decisions. (Spivey and Lee, 2013). The well's behavior is usually monitored over a relatively short time frame, depending on the test's objectives, compared to the reservoir's overall lifespan. For well evaluation, tests are often completed within two days or less. However, reservoir limit testing may require several months of pressure data to be gathered (Bourdet, 2002). In a well testing operation, surface equipment links an active, high-pressure, high-temperature hydrocarbon well to burners set up on a jack-up rig. This setup is used to produce gas at various flow rates (Nardone, 2011). A well test presents several challenges due to its complexity, involving a wide range of tasks carried out by a diverse group of contractors and employees. This operation requires precise coordination, expertise, and attention to detail to ensure its success and safety. Many of the tasks are inherently hazardous and relate to pressure, flammable liquids and gases, explosives, toxic chemicals, working at heights, confined spaces, noise, heat stress, lifting, trips and falls, and manual handling. The complexity of the operation necessitates a structured approach to safety management, ensuring that risks are systematically identified, evaluated, and mitigated throughout the entire process.

Despite its cruciality, numerous studies have pointed out that worker safety in the offshore drilling industry is frequently neglected (Durell and Neff, 2019).

As a primary step of safety management, comprehensive hazard identification plays a crucial role in ensuring safety by helping to recognize potential risks early in the operation, allowing for proactive measures to mitigate them. The objective of this study is to identify the hazards associated with clean-up and surface well testing equipment in an offshore gas development plan, utilizing the Hazard Identification (HAZID) methodology.

2. Materials and Methods

In this research, the HAZID methodology was employed to detect and assess hazards. This approach, created by SHELL International Company, is designed to identify risks in the offshore hydrocarbon sector (Shell international Exploration and Production, 1995). The HAZID study conducted is a combined approach, integrating both conceptual and detailed HAZID methods. The identification of hazards and risks related to the operation has been done in a qualitative way by using experts' opinion through brainstorming.

2.1. Research Area

The offshore platform in the Persian Gulf, comprising 12 wells, is capable of producing up to 56 million cubic meters of sour gas daily, both at maximum and sustained levels, from the offshore reserves of the shared gas field.

2.2. Hazard Identification Technique (HAZID)

The HAZID technique is a method for identifying hazards and threats, involving a meeting with a highly experienced, multidisciplinary team. The team utilizes a structured brainstorming approach, guided by a checklist of possible health and safety concerns, to evaluate the relevance of potential hazards. The primary advantage of HAZID is that the early detection and evaluation of significant health, safety, and environmental hazards offer crucial insights for project development decisions. This process helps ensure safer and more cost-effective design choices are implemented (Shell international Exploration and Production, 1995). HAZID is a widely and frequently used technique in the petroleum industry. It is often applied across a broad range of areas, projects, and operations (Crawley, 2020).

Prior to initiating the study, the research methodology was outlined in detail to clarify the work steps, as illustrated in Figure 1. The HAZID technique used in this study consists of 2 main steps which are as follow.

2.2.1. Step (1): Planning step

This step consists of team building, planning meetings and preparing required documentation.

The initial step is to assemble a team with the necessary expertise for the specific study. Choosing the right team is just as crucial as the framework itself. The key to a successful HAZID lies in achieving the right balance of breadth and depth in the team's experience. When forming the study team, all relevant and active expertise in well testing operations was selected. The team assembled for the HAZID Study is presented in Table 1. Once the HAZID team was formed, eight meetings (Table 2) were conducted to perform the research studies.

The total duration of these meetings exceeded 18 hours.

All the required documents for the HAZID studies were determined in the first meeting. These documents are generally: Surface clean-up and well testing operation procedure, last hazard identification and risk assessment, incident report (accident and near miss report), well testing equipment specification, safe operation procedures, certifications, layouts, hydrocarbon fluid composition report and so on.

In the following section, the well testing operation was meticulously divided into its component tasks, with the operation stages being separately outlined. Next, the operation details were discussed, and the scope of the studies was defined. In order to more accurately identify hazards and evaluate risks, the clean-up and surface well testing were treated as a single system, which was then broken down into key sub-systems. To identify and assess risks in the clean-up and well test operation, all operational processes were thoroughly examined. After discussions, reviews, and reaching a consensus, six study nodes were chosen based on the main stages of the operation to investigate and identify potential hazards. Subsequently, each of the selected nodes is divided into study subgroups, allowing for a more detailed and focused examination of the hazards associated with every aspect of the operation. Table 3 illustrates the study nodes. All phases of the operation, categorized into 18 study sub-nodes, were thoroughly analyzed using the brainstorming method. This involved the exchange of insights, opinions, and experiences from experts, along with the application of the HAZID checklist from Shell company's guidelines (Shell international Exploration and Production, 1995). The checklist is divided into four main sections as follow, enabling a comprehensive and systematic assessment of various types of risks.

1: External and Environmental Hazards Check list,
2: Facility Hazards Check List,
3: Health Hazards Check List,
4: Project Implementation Issues Check List.

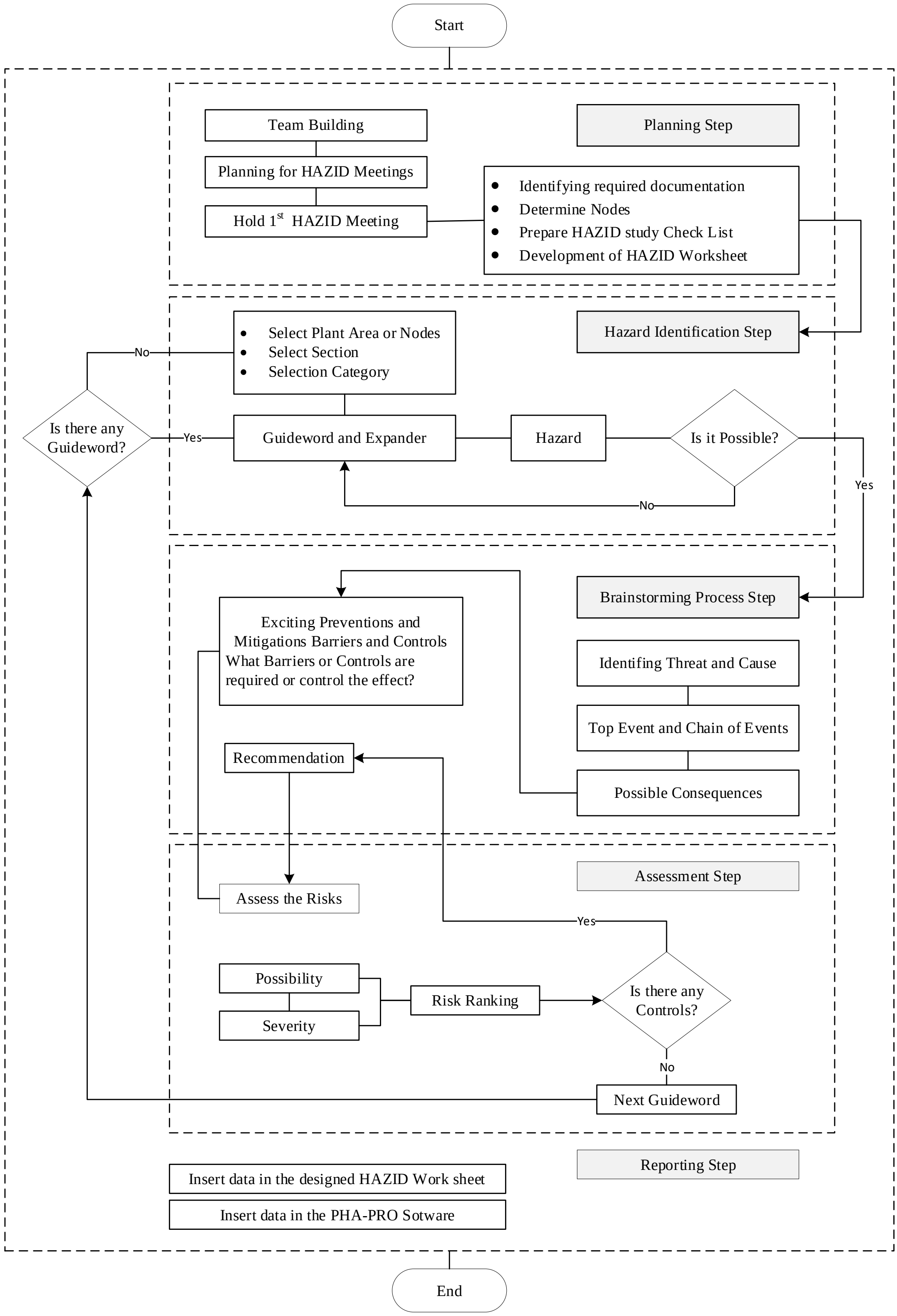


Figure 1. Research HAZID study methodology.

Table 1. Surface well test operation HAZID study assembling team

No.	Age	Experience	Educational Field Study	Education Degree	Organization Title	Rank
E1	42	20	Drilling Engineering	Master	Drilling Eng.	Manager
E2	38	15	Petroleum Engineer	Master	Company Man	Head
E3	45	22	HSE Management	Master	HSE Lead	Lead
E4	46	28	Petroleum Engineer	Bachelor	Offshore Installation Manager	Manager
E5	48	22	Mechanical Engineer	Master	Barge Master	Head
E6	48	22	Chemical Engineer	Master	Tool Pusher	Supervisor
E7	46	20	Petroleum Engineer	Bachelor	Field Supervisor	Manager
E8	35	15	Electrical Engineer	Bachelor	Well Test Dat Analysis Engineer	Operator
E9	43	18	Chemical Engineer	Master	Well Test Engineer	Supervisor
FS	25	3	HSE Management	PhD Student	-	-

Table 2. Planning for HAZID meetings

No.	Meeting Agenda	Meeting Minutes	Date	Duration
S-1	Opening Meeting	Discussion Scope of work	20.11.2023	4.30 hr
S-2	Brainstorming Meetings	Hazard Identification in Node No. 01	25.11.2023	2.00 hr
S-3		Hazard Identification in Node No. 02	28.11.2023	2.00 hr
S-4		Hazard Identification in Node No. 03	03.12.2023	2.00 hr
S-5		Hazard Identification in Node No. 04	06.12.2023	2.00 hr
S-6		Hazard Identification in Node No. 05	14.12.2023	2.00 hr
S-7		Hazard Identification in Node No. 06	16.12.2023	2.00 hr
S-8	Closing Meeting	Conclusion	20.12.2023	2.00 hr

Table 3. Node description

Node Number	Node Description
N1	Engineering
N2	Clean-up and Surface Well Test Equipment Logistic Package-Loading
N3	Clean-up and Surface Well Test Equipment Rig-Up (Assembling and installation)
N4	Clean-up and Surface Well Test Operation (Flow and Measurement)
N5	Clean-up and Surface Well Test Equipment Rig Down (De-assembling)
N6	Clean-up and Surface Well Test Equipment Logistic Package-Back Load

2.2.2. Step (2): Hazard identification step

Holding brainstorming meetings, HAZID study team members discussed about identifying hazards in each node as below steps:

•Select the node
•Determine subsystem, main equipment, tools, machinery, software, documents, operation parameters
•Select the section.
•Select category for each section from the check list.
•Select the guideword from the check list.
•Select the expander from the check list.
•Determine top events related to each hazard and chain of events.
•Determine the potential threats and causes.
•Determine the consequences of each cause.
•Determine the protection layers which is exciting against the causes and its consequences.
•Assess the risk ranking (primary stage) using risk matrix as shown in Table 4.
•Agree a recommendation for action or further consideration of the problem.
•Assess the risk ranking (secondary stage).
•Apply the next guideword (relevant to the selected categories).
•Apply the next section until they have all been considered.

Finally, all data and finding information collected and categorized in designed worksheets.

3. Results

Findings related to the number of hazards in each section, as determined by the checklist, are presented in Table 5. Most of identified hazards are in section 2, which focuses on facility-related hazards. Following that, the section addressing external and environmental hazards ranked second.

The summary of the results is presented in Table 6. Finally, Table 7 displays all results related to the number of hazards and risks identified by the study nodes, both before and after accounting for the protection layers. The hazards identified through HAZID have the potential to cause 52 accidents and result in 189 risks affecting vulnerable elements such as people, the environment, assets, and company reputation. To prevent incidents and reduce their severity, a total of 190 protection layers were recommended. In the initial risk assessment, 35 risks were categorized as low risk, 88 as medium risk, and 66 as high risk. Their respective frequencies are 18% for low risk, 47% for medium risk, and 35% for high risk. The majority of identified risks fall within the medium risk range. High risks are most prevalent in node numbers 2 and 6, respectively. After implementing protection layers in the secondary risk assessment, the number of low-risk incidents increased to 108, medium risk incidents decreased to 79, and high-risk incidents reduced to 2.

Additionally, Figure 2 is provided to better illustrate the situation of the identified risks. the x-axis represents the severity of the event consequences on a scale from 1 to 5, while the y-axis denotes the likelihood of the event occurring, categorized from A to E. The z-axis displays the number of event consequences. This arrangement collectively aids in examining the potential outcomes for each risk area based on specific severity and probability levels.

Table 4. HAZID risk matrix

Severity	Ranking	Consequence Description				Possibility				
		People	Environment	Asset	Reputation	A	B	C	D	E
0	0	No Injury	No effect	No Damage	No Impact	0A	0B	0C	0D	0E
1	1	Slight Injury	Slight Effect	Slight Damage	Slight Impact	1A	1B	1C	1D	1E
2	2	Minor Injury	Minor Effect	Minor Damage	Limited Impact	2A	2B	2C	2D	2E
3	3	Major Injury	Localized Effect	Localized Damage	Considerable Impact	3A	3B	3C	3D	3E
4	4	Single Fatality	Major Effect	Major Damage	National Impact	4A	4B	4C	4D	4E
5	5	Multiple Fatalities	Massive Effect	Extensive Damage	International Impact	5A	5B	5C	5D	5E
Possibility Description						Very Low: Not expected to occur during facility life	Low: Could occur once during facility life	Medium: Has Occurred in industry	High: incident has occurred in Company	Very High: happens several times per year
Possibility						A	B	C	D	E

Table 5. The number of hazards in each section

	Section 1	Section 2	Section 3	Section 4
Node.1	0	0	0	1
Node.2	4	3	0	1
Node.3	1	1	0	0
Node.4	0	5	0	0
Node.5	1	1	0	0
Node.6	4	3	0	0

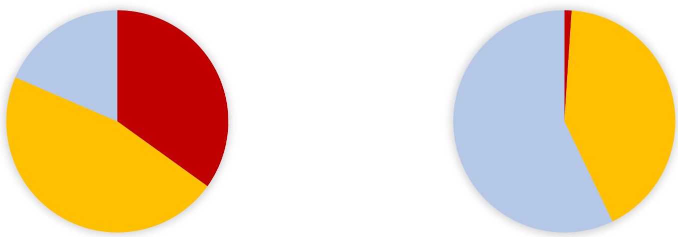
Table 6. Summary table of all study findings

		Number of Study Items				
Code	Description	Event	Causes	Consequences	Safeguards	Recommendations
N1-1	Design and Calculation	2	6	6	8	5
N2-1	Planning / Request	1	1	2	1	1
N2-2	Well Test Equipment Lifting Operation by onshore Crane	8	14	24	23	4
N2-3	Sea Fastening Operation	1	2	6	6	1
N2-4	Sailing	2	3	7	4	1
N2-5	Well Test Equipment Lifting Operation by rig crane	7	14	24	25	9
N3-1	Well Test Equipment Lifting Operation -Rig up operation	3	6	13	13	0
N3-2	Alignment and Make-up of the well test equipment	3	4	7	10	4
N4-1	Pressure Test	2	4	6	5	1
N4-2	Burner Test	1	1	1	2	1
N4-3	Open the well and Flow through separators and burner booms	1	4	16	21	3
N4-4	Sampling (To achieve BSandW)	1	3	6	5	1
N4-5	Emergency Maintenance during operation	1	3	6	5	0
N5-1	Well Test Equipment Lifting Operation - Rig Down	2	3	6	6	0
N6-1	Well Test Equipment Lifting Operation- Back Load	7	13	22	21	0
N6-2	Sea Fastening Operation	1	2	6	6	0
N6-3	Sailing	2	3	7	4	0
N6-4	Well Test Equipment Lifting Operation	7	14	24	25	0

Table 7. Primary and secondary identified risks

Nodes	Primary Risk Assessment			Secondary Risk Assessment			Total
	Low (L)	Medium (M)	High (H)	Low (L)	Medium (M)	High (H)	
1	6	0	0	6	0	0	6
2	9	32	22	34	27	1	63
3	2	7	11	13	7	0	20
4	11	15	9	23	12	0	35
5	1	3	2	2	4	0	6
6	6	31	22	30	28	1	59
Total	35	88	66	108	79	2	189

Percentage



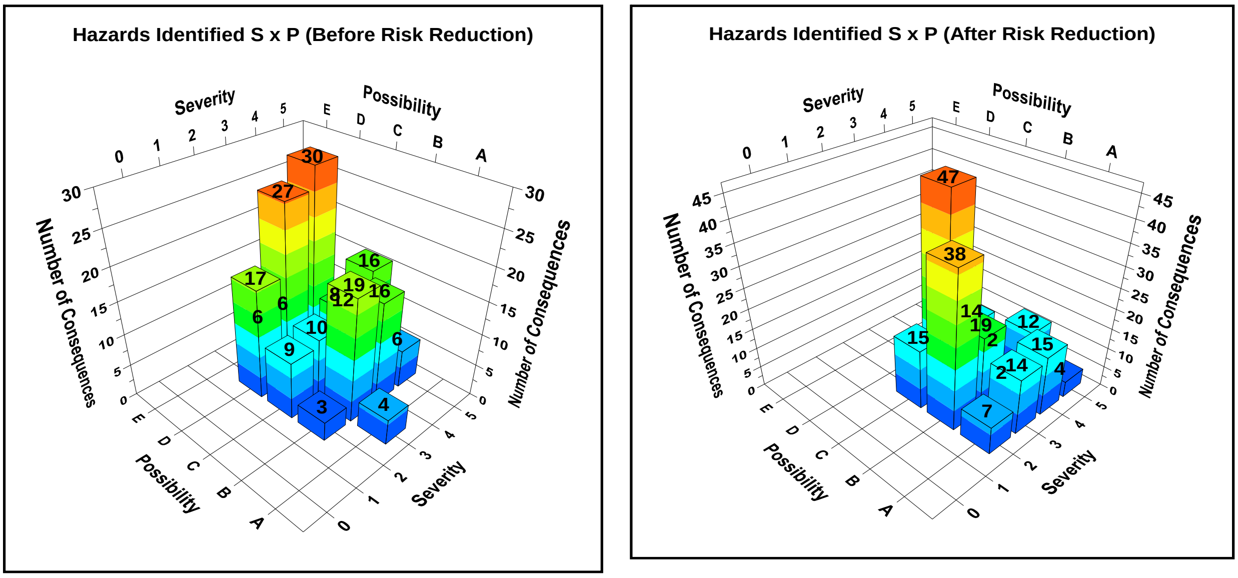


Figure 2. Before and after risk reduction graphics.

4. Discussion

Since there are few studies in the field of offshore operations and HAZID, some additional similar research is mentioned in this part. Rouzhan et al. (2020) in their article highlight that on offshore platforms, one of the primary reasons for hydrocarbon releases is the combination of process upsets and human errors. The results of our study indicate that more than 10% of the causes of high risks are attributed to human errors. Zhong et al. (2020) highlighted in their article on the risk assessment of gas well testing in the South China Sea that the process is highly challenging, costly, and risky. They identified 42 potential risk factors and used fault tree analysis to effectively mitigate these risks. These risk factors are consistent with the causes identified in our research result.

Aliev (2019) explored various hazards linked to offshore drilling, including chemical, physical, biological, ergonomic, and psychosocial risks, all of which may be influenced by the nature of the work or its offshore location. The study recommends a noise control subsystem that can significantly reduce the connection between accidents and factors such as the driller's health, fatigue, and qualifications. An analysis of the risks identified by HAZID reveals that human errors play a significant role in causing accidents. Implementing well-planned systems to improve employee health can be instrumental in reducing accident rates.

In other hazard identification for qualitative risk assessment on a hybrid gasoline-hydrogen fueling station, Nakayama et al (2016) find 314 accident scenarios by using HAZID. Kim et al. (2015) as a consequence of HAZID and post-HAZID processing, a total of 80 hazards (or hazardous scenarios) were identified, of which 31 hazards (approximately 39%) were deemed significant enough to warrant further consideration. The results of these studies are in line with our findings.

Deling Wang et al. (2023) combines historical accident cases from offshore platforms, analyzes them, and summarizes the risk factors impacting safety management by employing risk matrix analysis. They outlined the safety management measures that can be implemented for the associated risks in the operational process, based on the evaluated results of the risk factors, from four perspectives: environment, equipment, personnel, and management. In the HAZID method, the general classification of risks consists of four categories that align with the identified factors influencing accident occurrences in this study. In fact, this issue demonstrates that the study results align with the framework of the HAZID method, indicating that the HAZID method is a suitable approach for identifying offshore hazards to enhance safety management.

Brandsæter (2002) in his paper discusses the application and utilization of risk assessment in the offshore industry concerning safety aspects. The primary focus of this study is on quantitative risk assessments (QRA). It is noted that the consequence assessment in an offshore QRA typically addresses the following types of accidents: process accidents, riser and pipeline incidents, blowouts, dropped objects, ship collisions, and extreme weather events and earthquakes. In our HAZID study, weather conditions have been recognized as a significant factor contributing to the increased rate of accidents and according to the results, weather conditions and equipment transfer operations are high-risk activities, with the highest number of identified risks in the region related to transfers that can be significantly impacted by weather conditions.

Gunter et al. (2013) found that from 2003 to 2010, offshore transportation incidents were the main cause of worker fatalities in offshore oil and gas operations in the United States. Our results clearly indicate that the majority of high risks are associated with loading operations.

Abdussamie et al. (2018) analyzed the system of a submersible barge using the HAZID technique to determine the worst-case scenarios. They split the submersible barge into eight nodes, which are anticipated to be evaluated during the load-out and launching phases. Same as our study, review of nodes focused on the significance of potential hazards/failure modes in each operation. The hazards identified are quite similar to those identified in the loading operations in this study. Additionally, they note that the risks become tolerable once all reasonably practicable measures have been taken to mitigate them. After identifying the risks, expert opinions were consulted to define practical recommendations and establish necessary preventive layers in this study.

The results of this study can be utilized to conduct broader risk assessments using methods such as HAZOP, FTA, ETA, BOWTIE and so on. One of the most significant and widely used applications of HAZID results is in the Bowtie method. In this technique, the outcomes of the HAZID study are employed to prepare the major accident hazard identification.

Risks identified by the HAZID method in the red range, which have very high financial and life-threating consequences, are classified as major accident hazards. By identifying the threats, events, and protective layers revealed by the HAZID technique, a Bowtie diagram can be developed. Subsequently, critical activities and critical equipment are identified, and a performance standard is established for each.

5. Conclusion

Consequently, HAZID studies are crucial as they serve as the foundational basis for hazard identification and risk assessment in offshore industries. It is important that the risks arising from the routine operation of an offshore facility should be properly identified and managed through a standard formal safety assessment (Shouman et al.2021). Among the 189 identified risks, the majority are associated with nodes 2 and 6, which pertain to loading operations and sea transportation from the port to the drilling rig. Loading and unloading operations are among the most critical and frequently repeated activities in well testing operations. The analysis of past incidents under similar conditions reveals that incidents related to loading and the falling of suspended loads, which occur with high frequency and intensity, are the most common. In contrast, the incidence rate of toxic and flammable gas leaks is significantly lower compared to the rate of accidents caused by loading operations. The absence of limitations and the potential for defining effective protective layers for controlling toxic and flammable gas leaks contribute to the reduction of incidents in this area. In contrast, the number of protective and preventive layers for cargo operations is limited, leading to a higher rate of failure in these layers. Although the severity of consequences from loading operations is generally less than that from explosions and fires, the high frequency of these operations and the increased probability of incidents result in a higher number of accidents and a greater risk level for loading operations compared to other activities.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	N.F.	M.E. Ö
C	80	20
D	60	40
S	40	60
DCP	100	0
DAI	70	30
L	90	10
W	70	30
CR	40	60
SR	70	30
PM	60	40
FA	100	0

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. The experimental procedures were approved by the Non-Interventional Research Ethics Committee of Uskudar University, (approval date: 29 July, 2024, protocol code: 61351342/020-243).

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