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Mitigating Human Error in Oil and Gas Accidents Using TRACEr-OGI: A Middle Eastern Case Study

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Abstract

Persistent human error remains a significant contributor to Middle Eastern oil and gas accidents despite ongoing efforts to analyze and mitigate these risks. This study investigates the applicability of the Technique for Retrospective and Predictive Analysis of Cognitive Error (TRACEr-OGI) for analyzing human error in offshore/onshore drilling accidents. Data from 16 accidents between 2000 and 2014 were obtained from the IOGP safety zone and analyzed using TRACEr-OGI. A total of 1131 errors associated with the accidents were coded. The analysis revealed operator context (55.26%) as the most prevalent error source, followed by task errors (51.93%) within the context of incidence. It suggests a need for interventions targeting operator decision-making processes during drilling operations. Interestingly, both internal (33.66%) and external (33.17%) error modes were highly prevalent within the operator context. It indicates operators' susceptibility to errors arising from both internal cognitive factors and external influences on their decision-making. Additionally, the analysis identified personnel and management factors (23.41%) and Psychological Error Modes (PEM) (19.27%) as significant contributors to accidents. These findings suggest a multi-faceted approach is necessary to mitigate human error in Middle Eastern drilling operations. This study highlights the importance of considering operator cognitive factors and broader personnel and management practices that can influence psychological well-being. The oil and gas industry can significantly enhance safety in drilling operations across the Middle East by addressing these factors.

Keywords: Accident investigation, Cognitive error, Psychological error, Internal error, External error.

1 | Introduction

The oil and gas industry is essential for powering economies and meeting global energy demands, but it is also a hazardous industry with a significant risk of accidents that can cause harm to workers, the environment, and the industry's reputation [1].

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Therefore, it is vital to understand the causes and consequences of accidents in this sector to ensure workers' well-being and operations' sustainability. Safety in the oil and gas industry is paramount because accidents can result in fatalities and property damage [2]. The causes of oil and gas industry accidents are complex and can involve human, technological, and organizational factors [3].

Among the primary causal factors are human error, equipment failure, fire and explosion risks, falls, transportation incidents, natural disasters, and communication failures. Some of these causes are thoroughly examined to identify potential risk mitigation strategies [4] to mitigate these risks. Although the oil and gas industry is vital to the global economy, it is also dangerous, with a high risk of accidents that can cause fatalities, environmental damage, and economic losses. Human error is one of the significant contributors to accidents in the oil and gas sector [5]. Therefore, it is crucial to understand how human error manifests in drilling operations to develop effective safety interventions. To comprehensively understand human error in offshore/onshore drilling accidents in the Middle East, this study evaluates the applicability of the Technique for Retrospective and Predictive Analysis of Cognitive Error (TRACEr-OGI) framework [6], [7]. TRACEr-OGI is a comprehensive framework designed to categorize and analyze cognitive errors, providing valuable insights into the underlying causes of human error accidents. This study aims to identify the most prevalent types of human error, analyze the specific cognitive factors behind them, and evaluate how broader personnel and management practices influence these errors using a specific set of Middle Eastern drilling accident data.

1.1 | Accident Investigation and Analysis with TRACEr-OGI

The complexity of the socio-technical systems in this industry means that accidents may occur due to a variety of factors, such as human error, bad weather conditions, poor infrastructure, and technological failure[8], [9]. Understanding the root causes of accidents is essential for preventing future occurrences. The study employs the TRACEr-OGI framework to analyze human error in offshore/onshore drilling accidents in the Middle East. This framework provides a comprehensive approach to categorizing and analyzing cognitive errors, offering valuable insights into the human factors contributing to accidents [2]. Accident investigation intelligently covers everything from planning and allocating resources, collecting and examining information, and executing recommendations to assessing the impact of those recommendations [8]. On the other hand, accident analysis focuses on understanding what happened given available information and data [9]. The oil and gas industry has seen an increase in the complexity of socio-technical systems, leading to incidents and accidents that are beyond explanation. As such, novel approaches have been developed to account for these accidents and incidents. Finally, *Fig. 1* from the IOGP safety zone shows some of the causes of accidents in the oil and gas industry. In contrast, *Fig. 2* gives the trends of accidents that have occurred during operations in the industry worldwide for 30 years.

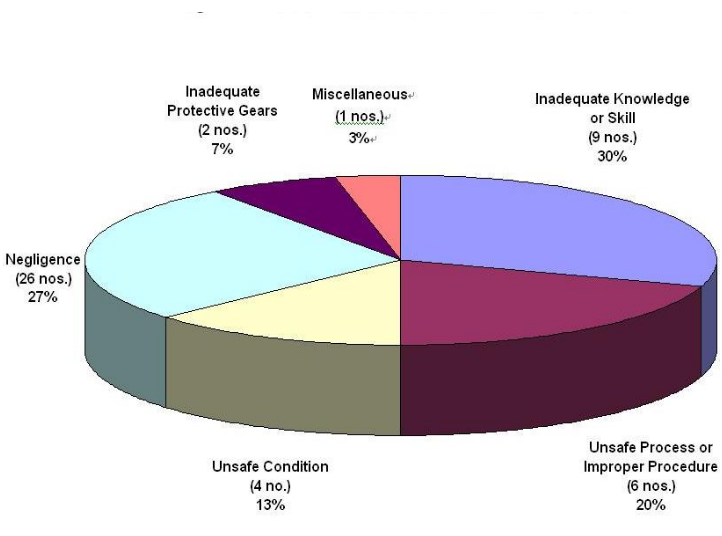

Fig. 1. Some common causes of accidents in drilling [12].

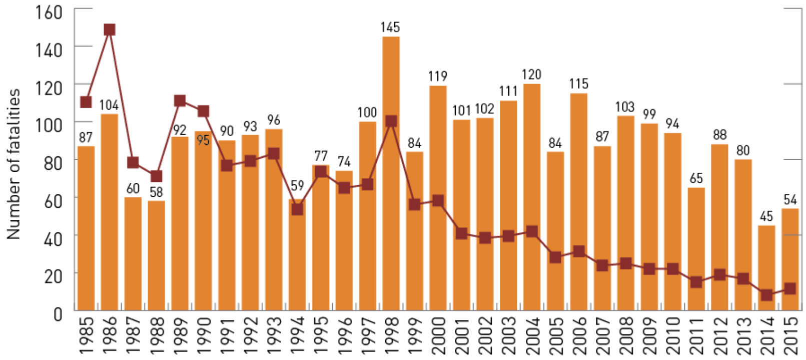

Fig. 2. Accident trends in the oil and gas industry [4].

1.2 | Tracer Adaptation and its Numerous Modifications

The TRACEr taxonomy offers a unique feature that allows for identifying and classifying human errors. This feature gives organizations valuable insights into the causes of errors in various systems and processes. Organizations can develop targeted training and prevention strategies to minimize the likelihood of future errors by pinpointing specific types of human errors. The flexibility of the TRACEr taxonomy makes it an adaptable tool tailored to meet the specific needs of different industries. Initially developed for air traffic control accident analysis, TRACEr has since been modified for use in the UK rail sector as TRACEr-Rail and further adjusted for the rail sector as TRACEr-RAV [10]. In addition, the taxonomy has been adopted by various industries, including Medicine and Marine, to improve health and safety standards [11]. The following is a summary of the different versions of TRACEr, highlighting the sectors where they have been utilized and the specific changes made.

Table. 1. TRACEr version, key modifications and sections applied

S/N	Title	Author (s)	Section	TRACEr Version	Modification
1	Development and application of a human error identification tool for air traffic control	[10]	Aviation	TRACEr- Aviation	8 taxonomies
2	Error classification for safety management: finding the right approach.	[12]	ATM	TRACEr-lite	8 taxonomies to 6 taxonomies
3	Development, use and usability of TRACEr-Rav: The technique for the retrospective analysis of cognitive errors-for rail, australian version.	[15]	Rail	TRACEr-Rail	Modified from 8 to 5 taxonomies
4	A reliability and usability study of TRACEr-RAV: The technique for the retrospective analysis of cognitive errors–for rail, australian version.	[8]	Rail australian version	TRACEr-RAV	Modified to 10 taxonomies
5	The classification and analysis of railway incident reports	[14]	Railway nottingham university version	Rail	Modified 6 taxonomies to 4 taxonomies
6	Classification of human errors in grounding and collision accidents using the TRACEr taxonomy.	[11]	SHIP	TRACEr-for SHIP	8 Taxonomies

1.3 | Proposed Modification

The TRACEr method is a proven technique for detecting human errors in various fields, including air traffic control and railway medicine. However, it has yet to be implemented in the oil and gas industry's drilling operations. The original TRACEr framework comprises eight taxonomies grouped into three categories: incident context, operator's context, and error recovery [10], [11]. Although primarily designed for rail-related incidents, the TRACEr framework can be customized to identify human errors in different sectors [15]. By utilizing the TRACEr framework in drilling operations, we can identify and mitigate potential human errors, improving safety and efficiency. This adaptation could lead to a more comprehensive analysis and prevention approach in an industry where human error can have severe consequences. The TRACEr framework's flexibility enhances safety precautions and procedures in drilling operations, reducing the risk of accidents and enhancing overall operational performance. A proposed conceptual framework is shown in *Fig. 3*.

Human error identification is a valuable technique that aids in predicting, describing, and detecting human mistakes or operator errors, thus allowing for their correction and recovery.

By understanding the typical errors that individuals make in various tasks, organizations can implement measures to prevent such errors from occurring in the future. This approach can lead to a significant improvement in safety, efficiency, and overall performance within the workplace. By studying human error identification, companies can proactively address potential issues before they escalate into more significant problems. *Fig. 4* illustrates the interconnection between classification systems, tasks, and the environment.

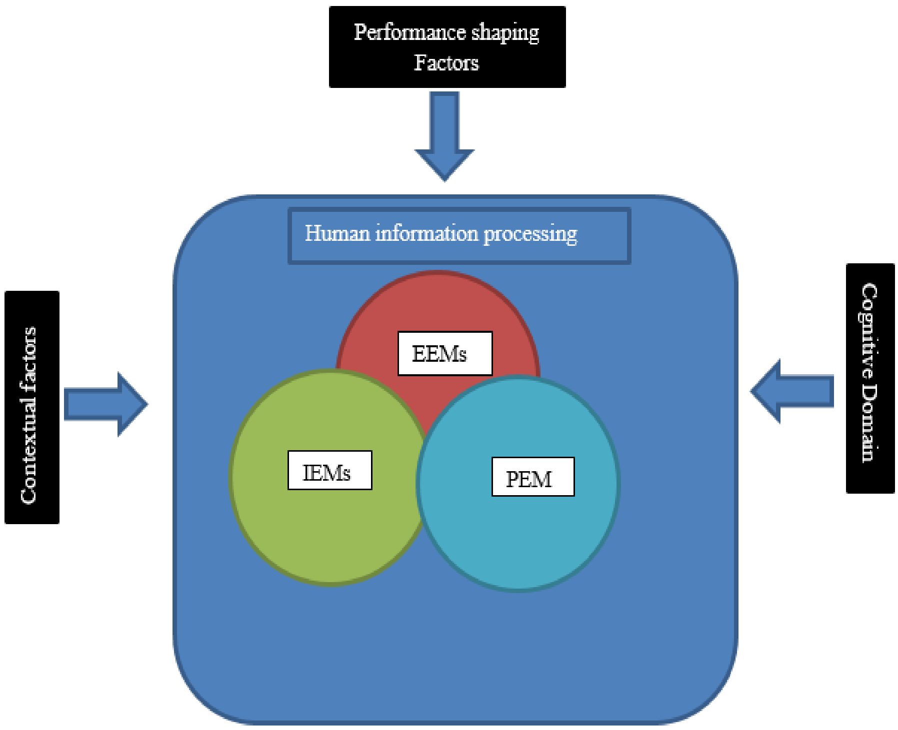

Fig. 3. A proposed conceptual framework of TRACEr-OGI.

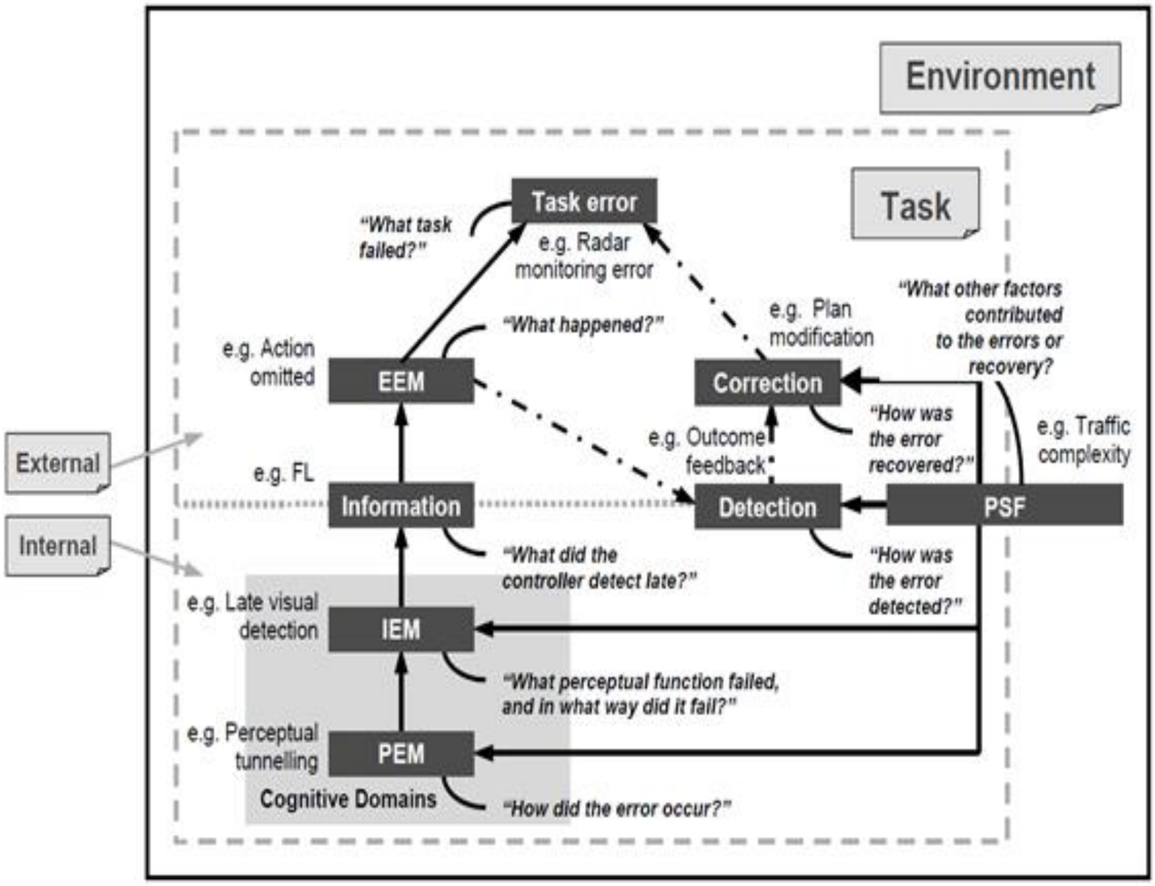

Fig. 4. The relationship between TRACEr classification systems [9].

The oil and gas industry has developed the TRACEr-OGI human error identification technique, which involves eight categories for error detection and correction: Task Error, Information Error, External Error Mode (EEM), Internal Error Mode (IEM), Performance Shaping Factor (PSF), Psychological Error Mechanism (PEM), and Error Recovery. By utilizing TRACEr-OGI, organizations can effectively categorize and address errors that may occur within their operations. This technique allows for a comprehensive analysis of human errors, helping to improve overall safety and efficiency in the oil and gas industry. By identifying and correcting errors systematically, companies can minimize the potential for accidents and disruptions in their operations.

1.4 | Proposed TRACEr-OGI Taxono

The TRACEr-OGI system is designed with a modular structure encompassing eight taxonomies. Each taxonomy is tailored to capture specific aspects of an individual's behaviour and personality, resulting in a comprehensive overview of their characteristics. This modularity allows for flexibility in tailoring assessments to various contexts and purposes, making it a versatile tool for a wide range of applications. Furthermore, using multiple taxonomies ensures a more nuanced and accurate representation of an individual's traits, leading to more insightful and actionable insights. The system's main taxonomies are divided into three major sections, providing a detailed analysis of an individual's actions in different scenarios. This division offers a holistic understanding of their decision-making process and problem-solving abilities. By incorporating multiple taxonomies, the assessment tool can provide a more comprehensive evaluation of an individual's performance, identifying strengths and areas for improvement with greater precision. Overall, this multi-dimensional approach enhances the effectiveness of the assessment process, making it a valuable tool for personal development, training, and organizational decision-making.

The system's first taxonomy evaluates errors that occur due to task, information error, and casualty level, while the second taxonomy focuses on assessing the individual's critical thinking skills, creativity, and ability to adapt to new situations. By combining these two taxonomies, the assessment tool provides a well-rounded view of an individual's capabilities and potential growth areas. This comprehensive approach benefits both individuals and organizations alike, enabling more informed decisions regarding talent development and resource allocation. Incorporating multiple taxonomies in the assessment process leads to more targeted and effective personal and professional growth strategies. The operators' context taxonomy addresses external, internal, and psychological errors, providing a focused understanding of the factors contributing to errors in an operational environment. Organizations can proactively manage risks by identifying potential risks and implementing mitigation strategies.

In contrast, the taxonomy for overcoming accident reoccurrence offers a structured approach to learning from past mistakes and implementing preventative measures. By integrating both taxonomies in the assessment process, organizations can develop a comprehensive personal and professional growth plan that considers individual capabilities and environmental factors. The proposed TRACEr-OGI is shown in *Table 2*.

Table 2. Modified Levels and Subdivision of TRACEr –OGI taxonomy [16], [17].

Major Divisions	Sub-Divisions	TRACEr-OGI
Context of the incident	Task error	Control room communication error Controller-operator Communication error Drilling mud control error (volume, viscosity, density etc.) Gauge/meter monitoring error (pressure and temperature monitor) Human-Machine interface error Well testing error Hand-over/take-over error Rig operation error Rig equipment error Unsafe task Equipment selection error Safe system of work (JSA) Training and supervision error Personal protective equipment error Other task error
	Information error	Controller material error Coordination activities error Time and location of activities System failure Regulations, laws and standards Permit to work Safety management system Risk assessment Safety data log
	Casualty level	Casual Contributory Compounding

Table 2. Continued.

Major Divisions	**Sub-Divisions**	**TRACEr-OGI**
Operators context	EEM	Timing and sequence Omission error Commission error Action too early Action too late Action too fast Action too slow Repeated action Mis-ordering Quality and Selection Action in the wrong direction A wrong action on an object Right action on wrong object Action too high Action too low Extraneous error Communication Error Unclear information transmitted Unclear information recorded Information not transmitted Information not recorded Incomplete information transmitted Incomplete information recorded Incorrect information recorded Incorrect information transmitted Rules contraventions Exceptional violation Routine violation General violation
	Cognitive Domain	
	IEM	Perception No detection (auditory) Late detection (auditory) No identification (visual) Mis-identification Misread Mishear Memory Forget to monitor drilling mud Forget former action Misrecall information Forget stored information Judgement/decision making Incorrect decision Mis projection Poor plan No decision Late decision Action execution Selection error Position error Timing error Incorrect information transmitted Unclear information transmitted Information not transmitted Information not recorded Unclear information recorded Incorrect information recorded

Table 2. Continued.

Major Divisions	Sub-Divisions	TRACEr-OGI
	Cognitive Domain	
Operators context	PEM	Expectation bias Association bias Spatial confusion Perceptual confusion fatigue Perceptual tunnelling Vigilance failure Monitoring failure Visual search failure
	PSFs	Driller controller communication Procedures Personal factors Environmental factor Organizational factors Workplace design Human-machine interface Social and team factors Training and experience Policies Emergency response plan Rig and equipment fault
Error recovery	Error recovery	Physical barrier symbolic barrier Functional barrier Incorporeal barrier

2 | Methodology

This research investigates human-caused drilling mishaps in the Middle East's onshore and offshore sites, utilizing a comprehensive theoretical and methodological approach to analyze qualitative and quantitative data. The goal is to understand the underlying reasons behind these incidents within the oil and gas industry. By examining the gathered data through a variety of concepts and methodologies, this study aims to extract significant insights into the root causes of drilling mishaps in the region.

2.1 | Data Collection

During drilling operations, this study used accident reports from the International Association of Oil and Gas Producers (IOGP Safety Zone) in the Middle East oil and gas industry. To ensure a comprehensive and accurate analysis, only accidents and incidents resulting in fatalities were considered for inclusion in the data collection. The analyzed data involved operations from onshore and offshore rigs in the Middle East region. A total of 16 fatal accidents between 2000 and 2014 were collected and coded for this study. As per [11], accidents can result from multiple task errors identified and reported in the IOGP report. These task errors were identified and coded separately using the modified TRACEr-OGI taxonomy. It resulted in a total of 1131 errors that were coded using the TRACEr-OGI taxonomy for this study. The study's methodology ensured that all the necessary data was collected and analyzed to comprehensively understand the factors contributing to fatal accidents in the Middle East oil and gas industry during drilling operations.

2.2 | Drilling Operation Accident Coding and Analysis

The data used in the analysis was obtained from the IOGP safety zone located in the Middle East. The study aimed to analyze 16 accidents by coding them using the TRACEr-OGI taxonomy, as detailed in *Table 2*. The coding process involved identifying the sequence of events and subdivisions associated with the TRACEr-OGI, which was crucial for the analysis.

3| Result and Discussion

The findings of this analysis are presented and discussed in this section.

3.1| Context of Incident

According to the IOGP safety zone site report of the Middle East, 16 accidents were recorded, and 1131 errors were made during drilling operations. The first major TRACEr-OGI taxonomy identified three types of errors, namely "task error" (51.93%), "information error" (41.20%), and "casualty level" (6.87%). Task errors were the most frequent type of error reported, indicating potential issues with the procedures or tasks undertaken during the drilling operations. Information errors were also prevalent, suggesting that communication or documentation may not have been adequate. Although less common, casualty-level errors emphasize the importance of ensuring proper safety measures to prevent injuries or fatalities during drilling activities. The percentage context of the incident is shown in *Fig. 5*.

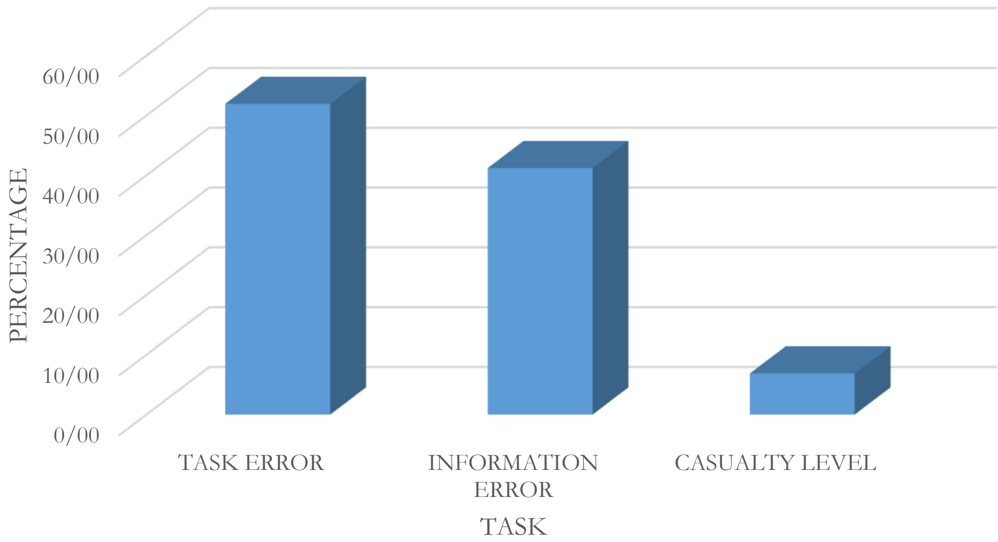

Fig. 5. Percentage context of incident

3.2| Task Error

According to *Fig. 5*, task errors contribute the most to drilling accidents, accounting for 51.93% of total errors. It aligns with previous research, highlighting human error as a major factor in oil and gas accidents [5]. *Fig. 6* provides a detailed breakdown of specific task error categories. The training and supervision errors (12.40%) category encompasses errors arising from inadequate training, unclear procedures, or insufficient supervision during drilling operations. It could include operators not being fully trained on the equipment or procedures involved in a drilling task, supervisors failing to monitor operations or communication gaps between supervisors and operators. The safety system of work errors Job Safety Analysis (JSA) (12.40%) category relates to errors resulting from improper implementation of JSA procedures. It could result from incomplete or inaccurate JSA procedures, failure to follow established JSA procedures during drilling operations, or a lack of understanding among personnel about the importance of JSA procedures. Unsafe task and rig operation errors (11.57% & 10.74%) encompass a broader range of unsafe actions or decisions made during drilling tasks. These could include operators taking shortcuts, failing to properly use or maintain drilling equipment, or inadequate planning or risk assessment before commencing operations. The high prevalence of task errors emphasizes the need for a multi-faceted approach to improving safety in drilling operations.

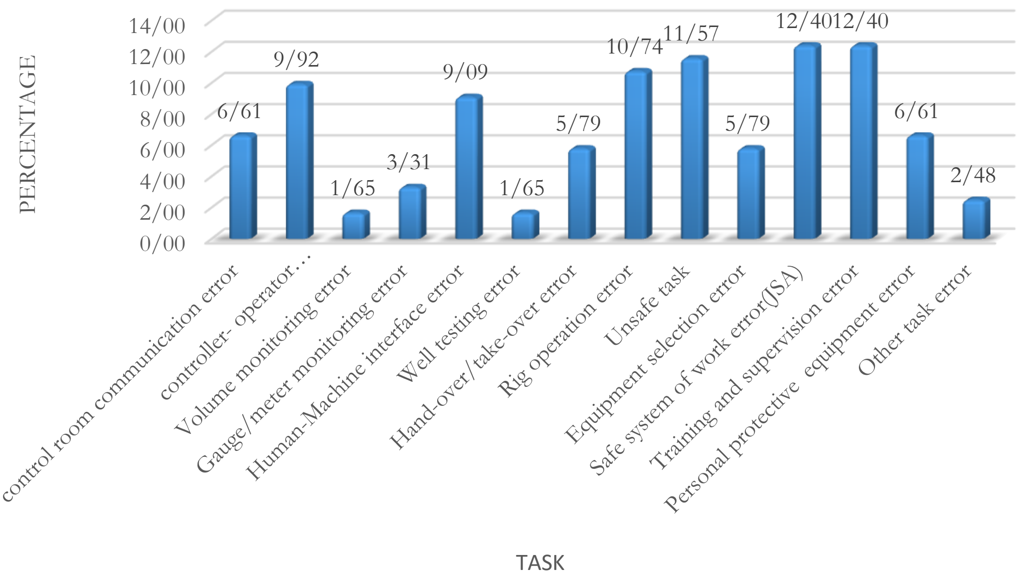

Fig. 6. Percentage of task error accident.

3.3| Information Error

Effective communication is said to be a success of any organization and industry. In the drilling operation, communication error categories have subdivisions of controller material error, system failure, coordination activities error, regulation, laws and standards, permits to work risk assessment and safety data log with error due to 'regulations, 'laws and standard', safety in system management, risk assessment, system failure and coordination activities error with 15.63%, 14.58%, 13.54% 12.5% and 12.5% respectively as shown in *Fig. 7*. They are said to have the highest percentage of 96 errors coded from the accidents. The data analysis indicates that information errors significantly contribute to drilling accidents. These errors accounted for 41.20% of the coded errors and included 466 incidents. They revealed critical communication breakdowns that can lead to severe consequences. Understanding the landscape of information errors can provide valuable insights into specific areas for improvement. The category of regulations, laws, and standards (15.63%) refers to errors that arise from a lack of awareness, misunderstanding, or misapplication of relevant regulations, laws, and industry standards. Such errors could involve operators or personnel unaware of or failing to follow established safety regulations or standard operating procedures. Misinterpreting the requirements of specific regulations or standards could lead to non-compliant practices.

Inconsistencies between internal company protocols and external regulations create confusion. System failure (12.50%) encompasses breakdowns in information systems, communication channels, or data management practices that hinder the flow of accurate and timely information. This could be due to technical failures in communication systems, such as radio malfunctions or software glitches. Inadequate data management procedures lead to incomplete or inaccurate information being shared, and poor design of information systems makes it difficult for personnel to access or understand critical data. The category of coordination activities error (12.50%) refers to errors arising from miscommunication or lack of coordination between different teams or personnel involved in drilling operations. Examples could include inadequate handover of information during shift changes, leading to incomplete knowledge about the ongoing operation. Failure to communicate critical updates or changes in plans to all relevant personnel and lack of collaboration between different departments or teams hinder effective information sharing.

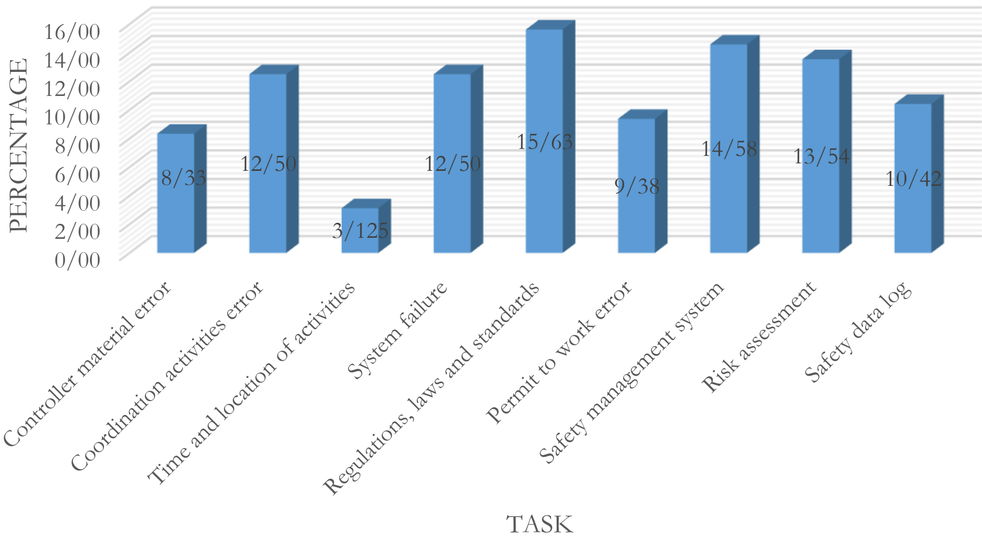

Fig. 7. Percentage information error.

3.4 | Casualty Level

According to the findings presented in *Fig. 8*, compounding errors play a significant role in the severity of drilling accidents within the reviewed data set. These errors, accounting for 56.25% of the total, are closely linked to incidents that result in the most significant losses, including fatalities and equipment or property damage. The study classified drilling accidents into three levels of casualty, each representing varying degrees of severity. Compounding errors, which make up the majority, result in the most severe consequences, including fatalities and extensive damage to equipment or property. It highlights the importance of identifying and mitigating human errors early in drilling. Compounding errors typically occur when initial mistakes go unnoticed or unreported, leading to subsequent errors that compound the situation and cause increasingly severe consequences. Therefore, it is critical to implement safeguards and rectify mistakes promptly to prevent a snowball effect of errors.

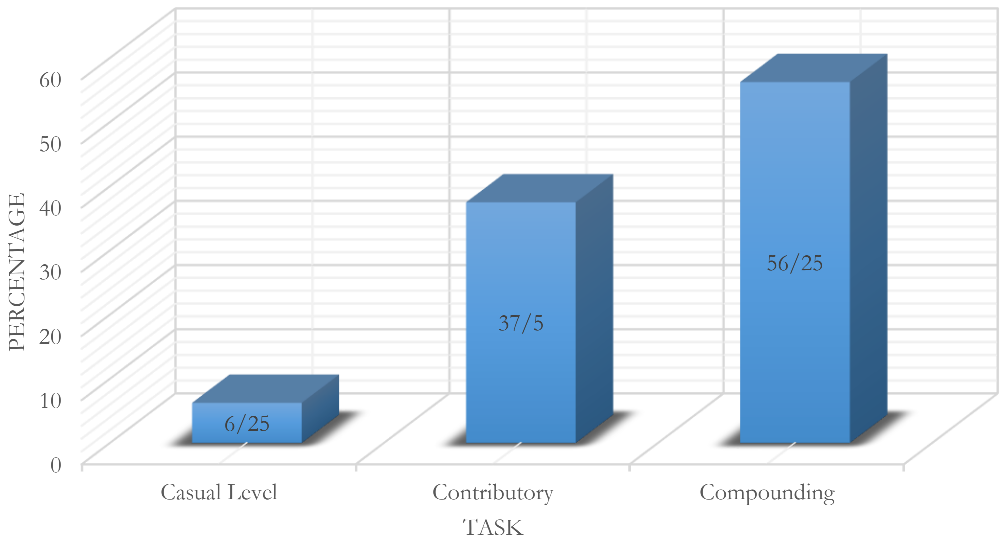

Fig. 8. Percentage of casualty level.

3.5 | Operators Context

The TRACEr-OGI framework explores the human factors contributing to drilling accidents by examining the operator's work environment. Specifically, it looks into four key categories that impact the operator's performance and decision-making. These categories are IEMs, EEMs, PEMs, and performance-shaping factors. IEM, accounting for 33.66% of drilling accidents, refer to cognitive limitations or mistakes made by the operators themselves. These errors can stem from physical and mental fatigue, which can reduce concentration, cloud judgment, and delay reaction time, making errors more likely. High-pressure environments can induce stress, leading to unclear judgment and hindering decision-making. Operators may become complacent with repetitive tasks or overconfident, overlooking potential risks or safety protocols.

Limited awareness of the drilling environment, ongoing tasks, or critical equipment readings can also contribute to errors. EEMs, contributing to 33.17% of drilling accidents, refer to external factors that affect the operator's decision-making and actions. These factors can include poor communication between team members, leading to misunderstandings and errors. Inadequate procedures, such as unclear, poorly designed, or outdated drilling procedures, can also increase the risk of errors. Equipment failures due to malfunctioning equipment or limitations of drilling technology can also create situations where errors are more likely to occur. Environmental factors like extreme weather conditions, noise, or limited visibility can also contribute to operator error. PEMs, accounting for 19.27% of drilling accidents, explore how an operator's psychological state influences the occurrence of errors. These mechanisms can include cognitive biases in decisions that skew how operators interpret information and make decisions, potentially leading to errors. A high mental workload can overwhelm operators, limiting their ability to process information effectively and increasing the risk of errors. Low motivation or job dissatisfaction can also lead to reduced focus and a higher error propensity. PSFs, contributing to 23.41% of drilling accidents, include organizational or environmental influences that impact operator performance. These factors can include inadequate training or a lack of experience that leaves operators unprepared to handle complex drilling situations. Weak safety cultures that do not prioritize safety procedures or risk management can increase the likelihood of errors. Limited staffing, time constraints, or inadequate resources can pressure operators, increasing the risk of errors. Ineffective fatigue management programs can also lead to tired operators making critical errors. The percentage operators' context is shown in *Fig. 9*. The almost equal distribution of errors between internal and external factors underscores the need for a holistic approach to improving drilling safety. Such an approach must consider the individual operator and the work environment, teamwork, and organizational practices that impact their decision-making and performance.

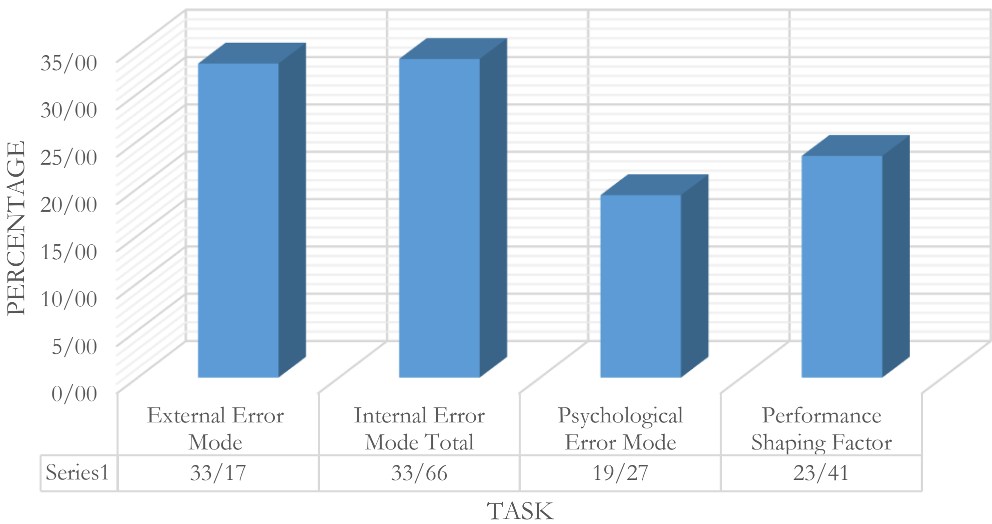

Fig. 9. Percentage operator's context.

3.6 | External Error Mode

The data analysis indicates that external factors significantly impact drilling accidents. Specifically, EEMs account for 33.17% of errors within the operator's context (*Fig. 10*). EEM includes three subcategories that affect drilling safety: timing and sequence (41.91%), quality and selection (33.09%), and rules and contraventions (25.00%). Mistakes in the order of drilling activities, miscommunication among team members, unsuitable materials or equipment, and violating established safety protocols are the primary causes of errors within each subcategory. Rushed procedures, time constraints, faulty equipment, inaccurate technical data, complacency, inadequate knowledge of safety regulations, and a weak safety culture within the organization can lead to these errors.

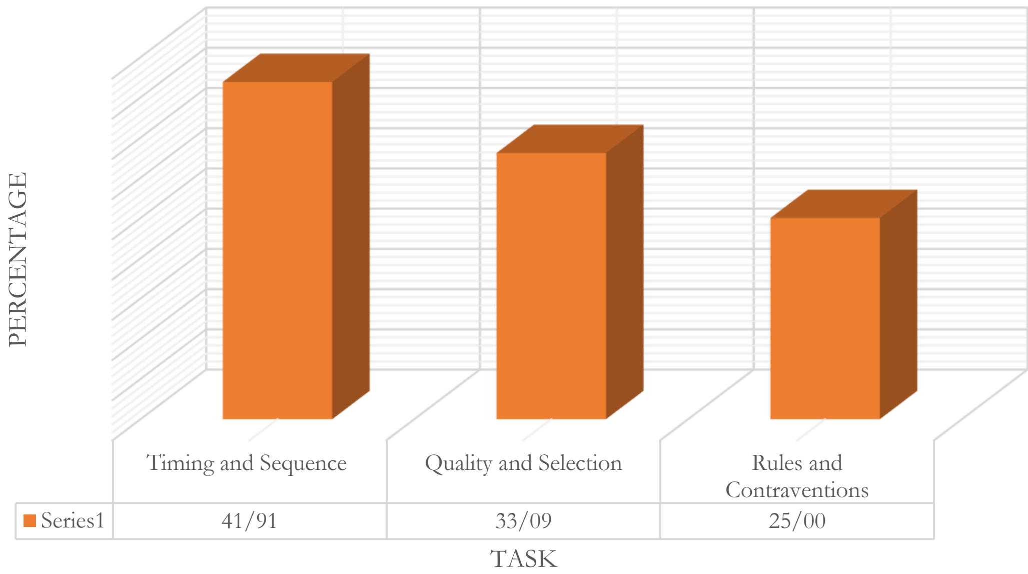

Fig. 10. External Error Mode.

The TRACEr-OGI framework thoroughly analyses task errors by classifying them according to specific behavioural factors. Within task errors, there are two main subdivisions: routine violations and general violations. These two subdivisions represent a substantial proportion of coded task errors. Routine violations (32.35%) refer to intentional deviations from established procedures, rules, or safety protocols frequently occurring during drilling operations. These violations can stem from factors such as complacency, time pressure, inadequate training, and a weak safety culture. Understanding these subdivisions can lead to significant improvements in drilling safety.

General violations, which account for 38.24% of all violations, relate to procedural deviations or unintentional mistakes made during drilling tasks. These can occur due to various factors, such as slips and lapses, lack of skills, fatigue, stress, and distractions. The percentage external error summary is shown in *Fig. 11*.

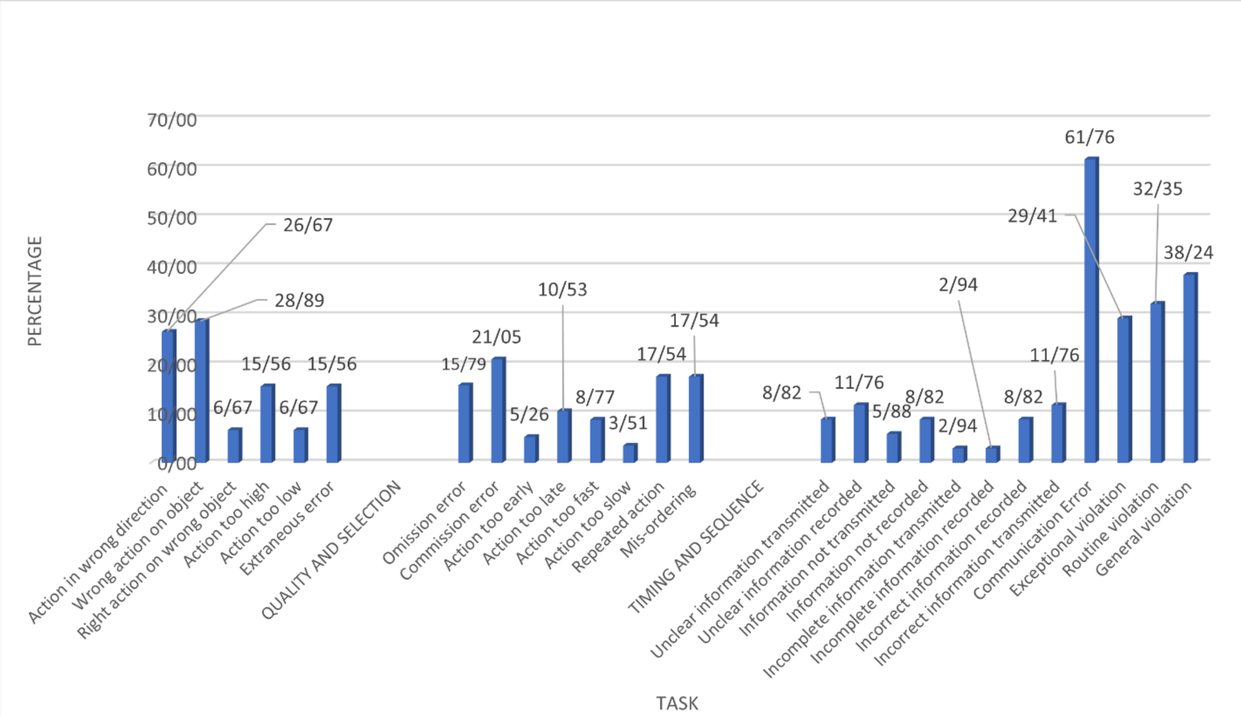

Fig. 11. Percentage external error summary.

3.7| Cognitive Domain

According to the TRACEr-OGI framework, errors that occur during drilling operations can be attributed to the cognitive domain, which encompasses mistakes made by the operator's mental processes (*Fig. 12*). Upon conducting research, it has been discovered that this domain is a significant contributor to 1131 analyzed errors, with 294 coded errors (26%) falling within this category. IEM make up the majority of these errors (63.59%), stemming from the operators' limitations or mistakes. Various internal factors, including perception errors, memory lapses, judgment/decision errors, and action/execution errors, can cause these errors. On the other hand, Psychological Error Modes (PEM) (36.41%) delve into the operator's psychological state and how it can affect error occurrence. Stress and workload, fatigue, complacency, and situational awareness can all contribute to these errors. The breakdown between IEM (63.59%) and PEM (36.41%) underscores the complex interplay between cognitive limitations and psychological factors in drilling accidents. Additionally, mental fatigue, stress, and complacency can exacerbate the effects of internal limitations, while cognitive biases can cloud judgment and lead to risky decisions.

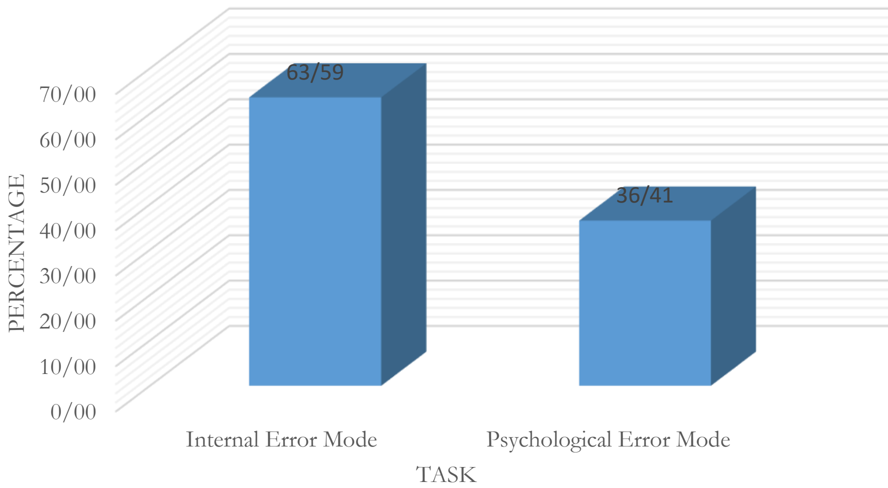

Fig. 12. Percentage cognitive domain.

3.7.1| Internal error mode

Within the TRACEr-OGI framework, IEM can occur during drilling operations. These items are classified as cognitive limitations or mistakes the operators make. IEMs account for 33.66% of errors in the operator's context. The high occurrence of judgment/decision errors and action/execution errors (both at 31.88%) suggests that cognitive biases and limitations can significantly impact operator performance (*Fig. 13*). Judgment/decision errors may include misinterpretation of data, incorrect procedures or rules, oversight of important factors before deciding, and fatigue from prolonged analysis periods. Action/Execution errors may include errors in manual skills, mistakes due to memory lapses or lack of skills, coordination issues causing missed steps, and difficulties recalling information. The rate of "forgetting stored information" (41.18%) highlights the critical role of memory in drilling operations. Due to stress, fatigue, and distractions, operators may forget important information or procedures. Additionally, the "lack of identification" (36.36%) may indicate difficulties in identifying potential dangers or equipment issues due to insufficient training or inattentiveness. The percentage internal error summary is illustrated in *Fig. 14*.

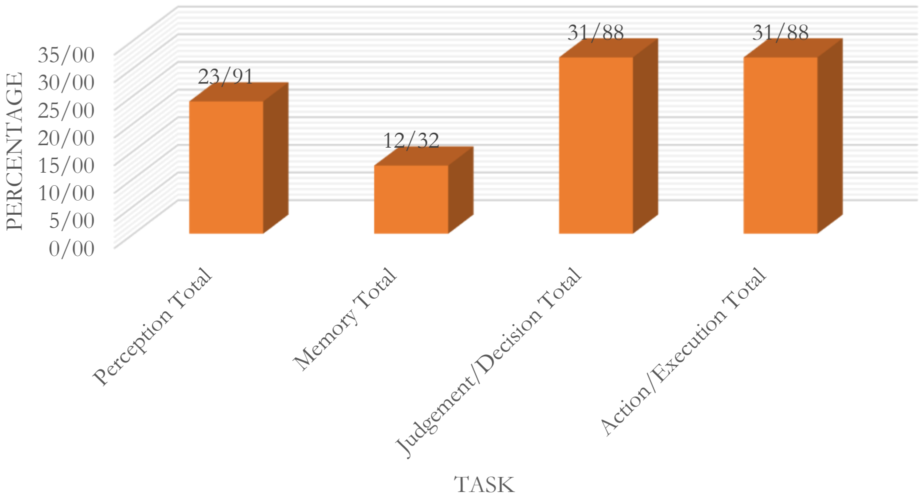

Fig. 13. Internal error Mode.

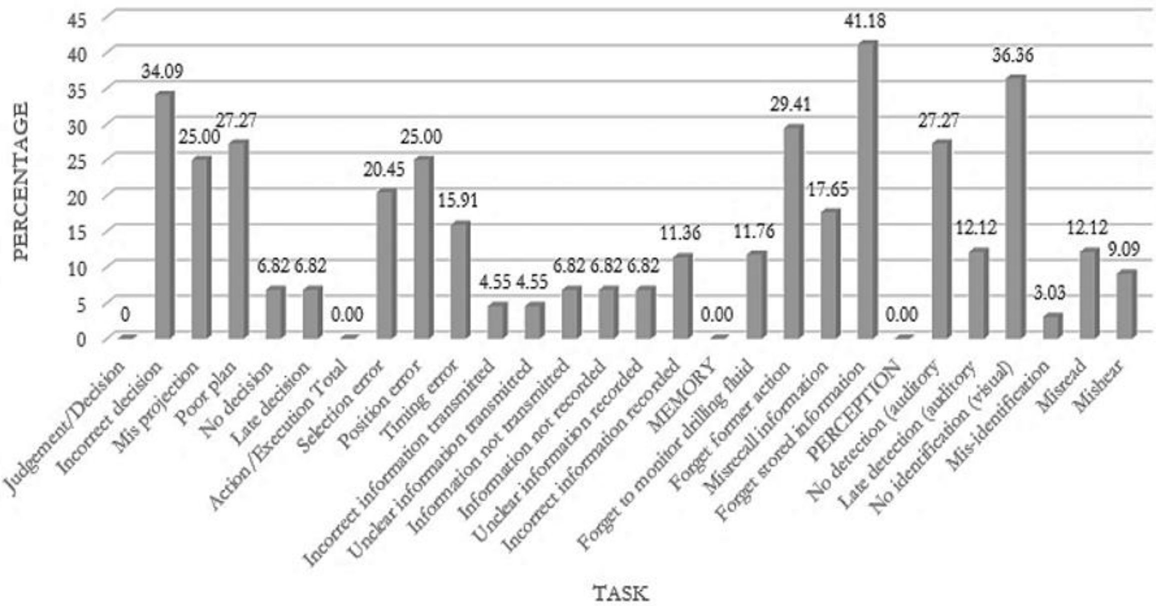

Fig. 14. Percentage internal error summary.

3.7.2 | Psychological error mode

The TRACEr-OGI framework utilizes PEM to understand how an operator's mental state can contribute to drilling accidents. PEM is identified as a significant factor within the cognitive domain, accounting for 36.41% of the coded errors in this category (*Fig. 15*). Vigilance failure (18.99%) and monitoring failure (18.99%) errors share a common theme: a breakdown in an operator's ability to maintain focus and detect critical information during drilling operations. Additionally, the Bias expectation (13.92%) subcategory highlights how cognitive biases can distort an operator's perception of a situation and lead to errors. Biases such as overconfidence, confirmation bias, or anchoring can cause operators to overestimate their abilities or the safety of a situation, disregard information that contradicts their expectations, and rely too heavily on initial impressions or anecdotal evidence. Spatial confusion and visual search failure (11.39% each) errors can arise from limitations in processing visual information or navigating the drilling environment. These errors are important to consider to prevent accidents and promote safety in the workplace.

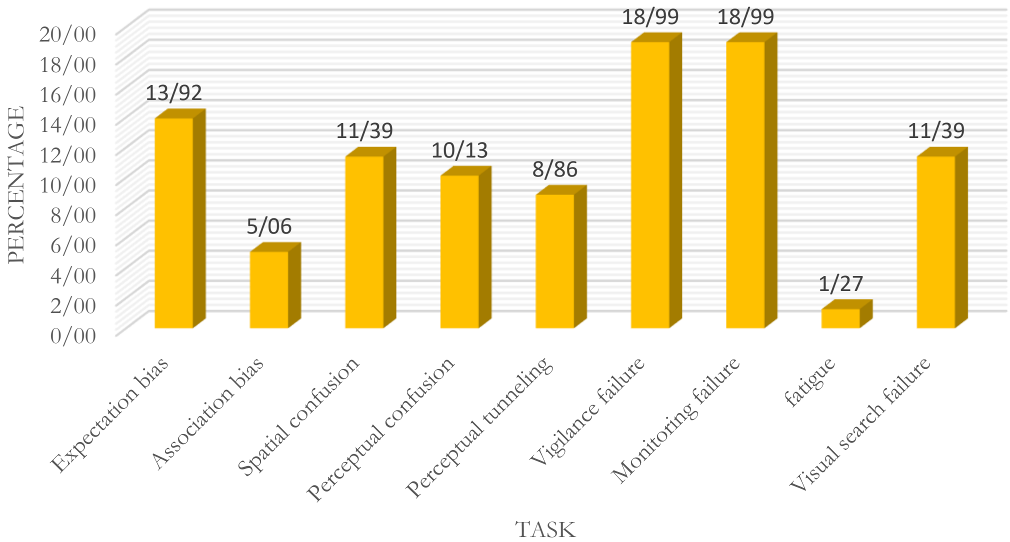

Fig. 15. Percentage of psychological error mode.

3.8 | Performance Shaping Factor

The TRACEr-OGI framework recognizes that external factors beyond an operator's control can significantly contribute to human error in drilling. These factors, known as PSFs, can create an environment that increases the likelihood of errors or hinders safe operations. It is revealed that PSF played a role in 96 errors (8.5%) of the total analyzed (*Fig. 16*). The interrelated factors of Policy, Organization, Training, & Experience (13.54% each) underscore the importance of a robust safety culture within drilling organizations. Deficiencies in any of these areas can create a breeding ground for errors, including policies, organizational structure, training, and experience. Factors such as procedures and controller communication (12.50% each) highlight the critical role of clear and standardized communication throughout drilling operations to minimize misunderstandings and errors.

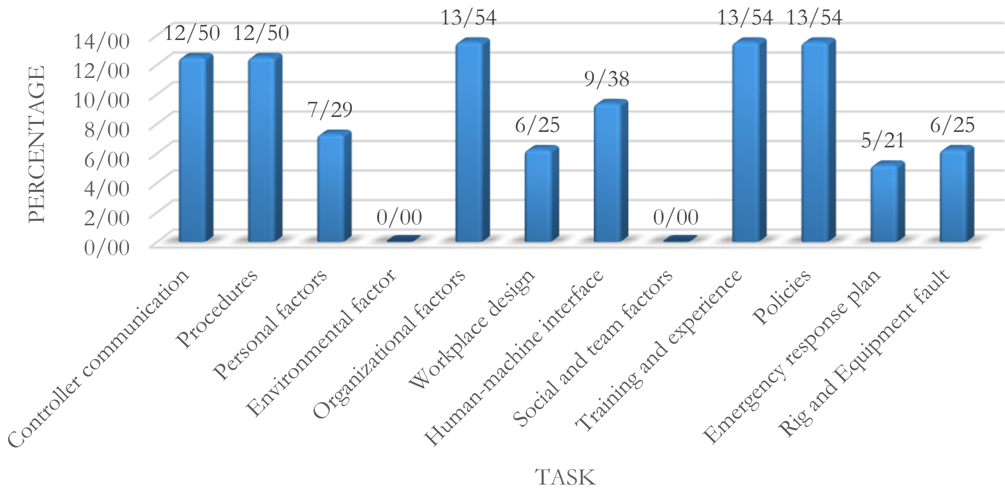

Fig. 16. Performance Shaping Factor (PFS).

3.9| Error Recovery

The TRACEr-OGI framework strongly emphasizes prioritizing error recovery to ensure safety during drilling management. The goal is to prevent accidents by implementing various methods and barriers. Analyzing 19 incidents, the framework has identified error recovery measures that have been instrumental in preventing accidents (*Fig. 17*). Physical barriers, such as safety equipment and design features, are initial measures to prevent accidents. These barriers include well-controlled equipment, machine safeguards, and safety interlocks. Symbolic barriers, which include procedures, signs, and non-physical measures that convey safety expectations and precautions, also serve as important preventative measures. These barriers include operating procedures, safety signage, and permit-to-work systems. Finally, functional barriers, which involve personnel's expertise, skills, and decision-making abilities in drilling operations, play a critical role in recognizing and responding to errors effectively. Examples include operator competency, situational awareness, and effective communication.

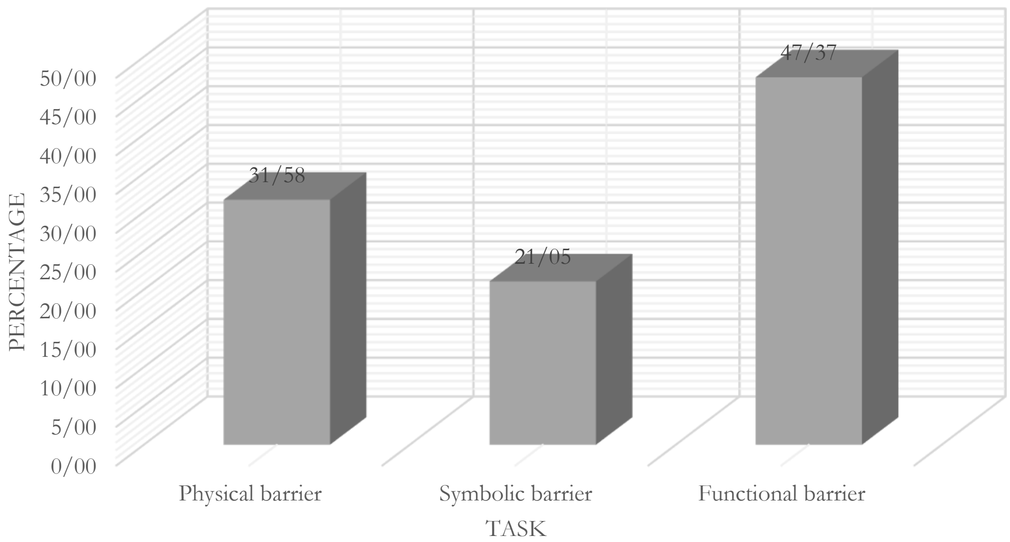

Fig. 17. Percentage error recovery.

4| Conclusion

This study investigated the applicability of the TRACEr-OGI, a method used to analyze human error in offshore and onshore drilling accidents in the Middle East. The analysis of 1131 errors coded from 16 accidents between 2000 and 2014 provided valuable insights, highlighting key patterns and trends in human errors during drilling operations. The findings highlight the environment in which operators work (55.26%) as the most prevalent source of errors, with task errors (51.93%) being the most frequent type within this environment. It suggests a need for interventions targeting operator decision-making processes during drilling operations. Interestingly, both internal types of errors (33.66%) and external types (33.17%) were prevalent within the operator context, indicating operators' susceptibility to errors arising from cognitive limitations and external influences.

Furthermore, the analysis identified personnel and management factors (23.41%) and psychological factors contributing to errors (19.27%) as significant contributors to accidents. These findings emphasize the need for a comprehensive approach involving multiple strategies to reduce human error in Middle Eastern drilling operations. The study highlights the importance of considering not only the cognitive aspects of operators but also broader personnel and management practices that can impact psychological well-being. It has provided information to guid safety professionals in the oil and gas industries. The oil and gas industry can significantly improve safety measures in drilling operations across the Middle East by addressing these factors.

Author Contribution

The authors' contributions are: "The Conceptualization, Amani David Haruna. and Y.Y; Methodology, Amani David Haruna. and Adinife Patrick Azodo; Software, Amani David Haruna; Validation, Okwuchi Smith Onyekwere, Amani David Haruna. and Adinife Patrick Azodo; formal analysis, Okwuchi Smith Onyekwere, Amani David Haruna; Investigation, Amani David Haruna; resources, Okwuchi Smith Onyekwere, Amani David Haruna. and Adinife Patrick Azodo; data maintenance, Amani David Haruna; writing-creating the initial design, Amani David Haruna; writing-reviewing and editing, Adinife Patrick Azodo. And Okwuchi Smith Onyekwere; visualization, Amani David Haruna; monitoring Amani David Haruna; project management, Amani David Haruna; funding procurement, Okwuchi Smith Onyekwere, Amani David Haruna. and Adinife Patrick Azodo. All authors have read and agreed to the published version of the manuscript. All Authors have made a significant contribution to the work reported.

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Data Availability

Some data were obtained from literature, which has been included in the references. No special permission was required to obtain and use the data.

Conflicts of Interest

The authors declare no conflict of interest. No Funders, other than the authors, played a role in the study's design, in the collection, analysis, or interpretation of the data, in the writing of the manuscript, or in the decision to publish the results.

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