Root Cause Analysis of Fatal Occupational Accidents in the South Pars Special Economic Energy Zone Using the Tripod-Beta Method (First Half of 2023)

MohammadSadegh Razmi
University of Science and Culture

Abstract

The aim of the present study was to identify the causes of occupational accidents among workers in the South Pars Special Economic Energy Zone during the first half of 2023. This was a descriptive-analytical study that employed the Tripod-Beta method to analyze fatal occupational accidents during this period. The study identified surface causes, preconditions, and latent causes, and developed incident trees for each case. The results of the analysis of fatal occupational accidents in the onshore construction phase of the gas refinery revealed six main risk factors contributing to these incidents: Responsibility/Organizational Influences (57.8%), Training (22.2%), Equipment, Machinery, and Tools (6.7%), Maintenance Management (6.7%), Operational Procedures (4.4%), and Error-Enhancing Conditions (2.2%).

It was found that by addressing the two main factors—responsibility/organizational structure and training—more than 80% of fatal occupational accidents could potentially be prevented. Therefore, implementing effective worker supervision systems, employing workers with adequate knowledge and skills, and improving training indicators can enhance risk awareness, improve safety, and reduce the occurrence of accidents.

***Keywords**: Accident, Industrial Accidents, Occupational Accidents, HSE, Tripod-Beta*

INTRODUCTION

With the onset of the Industrial Revolution and the expansion of mass production in factories, occupational health and safety became a fundamental concern in human resource management. In recent decades, with the emergence of the human relations school and the emphasis on the role of human capital in organizational productivity, attention to workplace safety has gained even more importance (Wang, 2017). Occupational accidents, which have always been an inseparable part of industrial activities (Mahmoudi-Haris et al., 2020), not only cause physical and psychological harm to employees but also lead to financial losses, decreased productivity, waste of human resources, and sometimes environmental damage (Quick, 2015; Mashroufeh et al., 2022).

Therefore, the prevention and analysis of the causes of workplace accidents—particularly in high-risk industries—has become both a managerial and human necessity. In recent years, Health, Safety, and Environment (HSE) management systems have been developed with the aim of reducing accidents and improving safety in workplaces (Van Vliet & Magrin, 2018). These systems, by utilizing analytical and modeling tools, enable the root cause identification of incidents and lay the groundwork for continuous improvement in safety processes (Poursoleiman et al., 2015). Numerous studies have shown that a significant portion of occupational accidents stem from unsafe behaviors and human errors, which themselves originate from psychological, organizational, and cultural factors (Shafiei et al., 2021; Bahreini et al., 2012).

The oil, gas, and petrochemical industries—being among the most complex and hazardous industrial sectors—are particularly exposed to occupational accidents due to the diversity of activities, equipment, human resources, and environmental conditions (Mahmoudi-Haris et al., 2020). The South Pars Special Economic Energy Zone, as the energy hub of Iran, is one of the country's most important industrial areas. Investigating occupational incidents in this zone can reveal risk patterns and the factors contributing to them (Shirmardi & Davazdah-Emami, 2019).

According to both national and international statistics, millions of occupational accidents occur worldwide each year, some of which lead to fatalities or permanent disabilities (Hämäläinen et al., 2017). In Iran as well, official statistics indicate the widespread and severe nature of such incidents, especially in energy-intensive industries (Hajimaghsoudi et al., 2021; Ghahramani et al., 2021). This underscores the necessity of conducting research with analytical and root-cause approaches to *identify both hidden and direct causes of accidents. To uncover root causes, one of the most essential and fundamental steps is collecting accurate data and using appropriate models that help reduce the likelihood of similar future accidents (Birhane et al., 2022). Among various models, the Tripod-Beta model is recognized as an effective method for systematic accident analysis due to its ease of implementation, graphical structure, and focus on identifying latent conditions (Akhavan et al., 2021).*

The present study was conducted with the aim of identifying and analyzing the causes of occupational accidents in the South Pars Special Economic Energy Zone during the first half of 2023, using the Tripod-Beta approach. The findings of this research can be used to improve management systems, promote safety culture, reduce accidents, and enhance organizational safety performance.

Materials and Methods

Study Design

This study adopts an applied research design, emphasizing the practical application of scientific knowledge to real-world problems. Applied research is typically aimed at addressing specific, tangible issues by drawing upon the insights and theories generated through basic (or fundamental) research. The primary objective is to produce outcomes that lead to the enhancement of behaviors, procedures, tools, products, and systems that are integral to the functioning and well-being of human communities, particularly in work-related contexts.

To achieve its objectives, the study employs a descriptive-analytical research approach. This methodological framework allows for a comprehensive understanding of the current situation through detailed observation and analysis. The research is retrospective in nature, involving the systematic review and interpretation of documented accident data. Specifically, it examines records of occupational accidents that occurred in the onshore sector of a gas refinery construction project during the first half of 2023. These records serve as the basis for identifying patterns, trends, and underlying causes associated with the incidents.

The key analytical tool used in this study is the Tripod-Beta methodology, a widely recognized framework for accident analysis and prevention. Tripod-Beta is designed to identify and categorize the root causes of accidents by examining the organizational, technical, and human factors that contribute to such events. Rather than focusing solely on the immediate or superficial causes, this method delves *deeper into latent conditions and systemic failures that create an environment where accidents become more likely. By applying this methodology, the study aims to provide a nuanced understanding of the factors leading to fatal accidents and to offer recommendations for improving safety performance and risk management practices within the construction and energy sectors.*

PARTICIPANT AND SAMPLING METHOD

The statistical population of this study encompasses all documented fatal work-related accidents that took place in the onshore section of one of the gas refineries operating within the South Pars Gas Complex during the first half of 2023. The South Pars Gas Complex is a major industrial hub in Iran's energy sector, spanning across the cities of Asaluyeh, Kangan, and Tombak. As the largest gas field development project in the world, the complex comprises 24 development phases and includes 14 active refineries, playing a critical role in the country's natural gas production and export infrastructure.

To ensure that the analysis is both focused and meaningful, the study employs a purposive sampling method. In this non-random sampling technique, only those cases were selected that met specific inclusion criteria: the fatal accidents must have been comprehensively documented and contain sufficient detail to allow for a thorough causal analysis. This targeted approach ensures that the selected sample provides the depth and richness of information necessary for the effective application of the Tripod-Beta methodology. By focusing on well-documented cases, the study is able to trace not only the immediate causes of each incident but also to uncover the latent conditions and underlying systemic failures that contributed to the occurrence of these fatal events.

Instruments and Data Collection Methods

The data for this study were gathered using a document-based data collection method. In the first phase, primary data related to fatal occupational accidents were extracted from official reports and documentation, including incident reports, witness statements, expert assessments from HSE (Health, Safety, and Environment) teams, medical reports from the site's health unit, as well as inspections and evaluations conducted by labor inspectors and judicial representatives. These sources provided comprehensive and reliable evidence regarding the nature and circumstances of each incident.

In the second phase, a detailed examination of supporting documents and technical records was conducted. This included reviewing event logs, maintenance records, and documentation related to the operational status of equipment, such as calibration certificates and safety approvals. Additionally, procedural documents, internal safety protocols, and technical evaluations of equipment functionality were analyzed to assess compliance and the presence (or absence) of preventive measures. This multi-layered documentation review ensured a thorough understanding of both the immediate conditions and the systemic factors contributing to each incident.

Statistical analyzes

In this study, data analysis was conducted using the Tripod-Beta method, a systematic approach designed to identify, map, and categorize the underlying causes of industrial accidents. Developed through a collaborative effort between Leiden University and the University of Manchester in the mid-1990s, Tripod-Beta is widely used in high-risk industries, particularly oil and gas. This method allows for a comprehensive investigation of incidents by emphasizing human error, latent organizational failures, and ineffective safety barriers. Its strength lies in visualizing the chain of events and the relationships between contributing factors through a tree-like diagram.
The first step in the Tripod-Beta analysis involves constructing an incident tree diagram for each case. This tree starts with the identification of three essential components:

- *the Agent of Change (the hazard or force that causes harm),*
- *the Object (the person or asset that is affected), and*
- *the Event (the actual harmful incident or consequence).*

These elements form the foundation of the analysis and establish the direct mechanism of the accident.

Following the initial mapping, the analysis proceeds to identify and categorize the barriers that were intended to prevent the accident but either failed or were absent. These barriers are classified into four types:

- *Failed Barriers: safety mechanisms that were in place but did not function as intended, allowing the Agent of Change to reach the Object.*

- *Missing Barriers: expected safety measures that were never implemented.*
- *Inadequate Barriers: barriers that were in place but were not sufficient in strength or effectiveness.*
- *Effective Barriers: those that successfully mitigated the consequences or prevented secondary damage, even if they did not stop the initial event.*

This categorization helps determine not only what went wrong, but also what worked and why.

In the final phase, the causal pathways leading to the event are traced in detail. Tripod-Beta emphasizes identifying three levels of causation:

1. *Immediate (or direct) causes,*
2. *Preconditions, and*
3. *Latent (or root) causes.*

Each causal path is explored to uncover system weaknesses or design flaws that may have contributed to the failure of safety mechanisms. The latent causes are particularly important, as they often stem from deeper issues in organizational processes, management, or culture.

These latent causes are grouped into standardized categories such as:

- *Design flaws (e.g., poor layout or equipment interface),*
- *Hardware/equipment failure,*
- *Maintenance mismanagement,*
- *Poor housekeeping,*
- *Inadequate procedures,*
- *Training deficiencies,*
- *Weak communication,*
- *Organizational structure issues,*
- *Incompatible operational goals (e.g., conflicting priorities between safety and production), and*
- *Failure in emergency defenses.*

Each root cause is documented and coded according to these categories, facilitating comparative analysis across cases.

The resulting data from all analyzed incidents are then compared to identify recurring patterns and system-wide weaknesses. This comparative evaluation helps prioritize areas for corrective action and preventive strategies. Though the Tripod-Beta method is qualitative in nature, it provides a structured and replicable framework that transforms complex accident data into actionable insights.

Research Findings and Results

To identify the root causes of fatal occupational accidents in the Pars Special Economic Energy Zone, three incidents occurring during the first half of 2023 were analyzed. These incidents included: a fall from height, a same-level fall while attempting to board a moving bus, and being struck by an object (a metal pipe). Detailed information about these accidents is provided in Table 4-1.

Table 1. Complete information on fatal occupational accidents that

Type of Incident	*Time of Occurrence*	*Job Experience*	*Education Level*	*Age (years)*	*Job Title*	*Number of Injured Persons (dead)*
Fall from height	*10:45*	*10 years 4.5 years 2 years*	*Middle school diploma (three individuals)*	*40 50 41*	*Assembler Welder Helper*	*3 persons*
Loss of balance and uneven surface fall	*12:05*	*7 years*	*Illiterate*	*39*	*Conduit Installer*	*1 person*
Object striking a person	*10:17*	*4 years*	*Middle school diploma*	*36*	*Grade 1 Driver*	*1 person*

Using the Tripod-Beta technique, an incident tree was constructed for each case, encompassing three levels of causal analysis: immediate causes, preconditions, and latent causes. The analysis revealed:

Fall from Height Incident

Surface Causes (10 items): *Including lack of proper personal protective equipment (PPE), use of overhead chain hoists against regulations, absence of regular equipment inspections, inadequate training on equipment usage, negligence in securing safety gear, misuse of tools, lack of active supervision* *on site, performing work at height without necessary safety measures, non-compliance with work-at-height guidelines, and malfunctioning warning systems.*

Preconditions (17 items): *Including lack of proper maintenance planning, insufficient funding for safety equipment, absence of reward and penalty systems, weak supervision of workers' performance, disregard for safety checklists, lack of clear operational procedures, ineffective personnel training, absence of continuous equipment monitoring, poor coordination among operational units, appointment of unqualified individuals to managerial roles, weak communication between HSE and operations, lack of training effectiveness evaluation programs, shortage of skilled personnel, poor resource management, failure to document maintenance records, mismatch between equipment and task type, and failure to employ competent personnel for equipment inspection.*

Latent Causes (24 items): *Including organizational structural weakness and lack of accountability, absence of a safety culture, lack of genuine managerial commitment to HSE, promotions without scientific or technical competency evaluations, low worker motivation, lack of standardized training, mismatch between job demands and workers' physical and mental capacity, imbalance between workload and time, low employee involvement in HSE programs, overemphasis on equipment over training, poor design of training programs, lack of two-way communication in training, unfamiliarity with the hazards of other equipment, absence of continuous assessment of trainees, lack of managerial support for training, insufficient time allocated to training, neglect of technical equipment documentation, use of equipment without manuals or guidance, outdated managerial knowledge, ignoring warning signs during design and execution, absence of continuous safety performance evaluation, resistance to safety changes, prioritization of productivity over safety, and weak feedback systems for incident reporting.*

Uneven Surface Fall Incident

Surface Causes (5 items): *Including slipping on wet or uneven surfaces, lack of safety footwear with appropriate grip, absence of hazard signage,* *working in high-temperature conditions without preventive measures, and ignoring weather conditions during operations.*

Preconditions (8 items): *Including poor planning for outdoor work, lack of climate condition forecasting, no fatigue management programs, insufficient communication regarding environmental conditions, neglect of workers' physical exhaustion signs, lack of on-site supervision, inadequate monitoring of environmental conditions, and absence of supportive workplace equipment.*

Latent Causes (11 items): *Including lack of management awareness of climate risks, disregard for seasonal incident data analysis, absence of adaptive policies for hot weather, neglecting heat effects on focus and reaction, ignoring work hour adjustments based on climate, poor training on safe work in hot weather, lack of cooling equipment or rest areas, prioritizing productivity over health, absence of fatigue monitoring, lack of procedures for recording early fatigue symptoms, and absence of a designated person for monitoring environmental conditions.*

Pipe Striking Worker Incident:

Surface Causes (11 items): *Including falling pipes during transport, improper pipe securing, use of unsuitable handling tools, failure to maintain a safe distance, absence of warning signs in loading zones, performing operations in confined spaces, disregarding load balance, poor coordination among workers, workers' unawareness of pipe movement paths, malfunctioning lifting equipment, and lack of proper load-handling training.*

Preconditions (14 items): *Including poor scheduling and route planning, undefined operational responsibilities, absence of standard load-handling procedures, weak supervision during transport, use of untrained personnel, lack of heavy object handling guidelines, absence of pre-operation equipment checks, use of worn or incompatible equipment, supervisors' unfamiliarity with handling procedures, high workload in short timeframes, poor use of feedback from past operations, lack of pre-operation briefings, absence of load-handling safety checklists, and failure to assess on-site hazards.*

Latent Causes (15 items): *Including lack of personnel competency evaluation policies, absence of continuous and updated training for load handling, unfamiliarity with load center of gravity, promotions based solely on seniority, lack of effectiveness assessments of previous operations, neglecting the role of safety supervisors, poor communication between logistics and operations, weak incident reporting culture, use of non-standard handling mechanisms, lack of a systems approach to handling processes, absence of risk prediction models, excessive workload on staff, disregard for workers' mental conditions, lack of documented similar incidents, and failure to conduct root cause analyses of past events.*

A key finding of this study was the identification of six Behavioral Risk Factors (BRFs) that significantly contributed to the occurrence of these accidents. Based on their frequency and impact, these risk factors were prioritized as follows:

۱. *Responsibility/Organizational Influences (57.8%): Including weak supervision, lack of proper delegation of responsibilities, and inefficient organizational structure.*

۲. *Deficiencies in Training (22.2%): Especially related to safety training and proper procedures for high-risk tasks.*

۳. *Poor Maintenance Management (6.7%): Particularly involving handling and lifting equipment such as chain hoists.*

۴. *Issues with Equipment, Machinery, and Tools (6.7%): Including outdated or inappropriate equipment for the task.*

۵. *Deficiencies in Operational Procedures (4.4%): Such as the absence of standard operating procedures or their improper implementation.*

۶. *Error-Inducing Conditions (2.2%): Such as rushing, time pressure, or worker fatigue.*

These results indicate that the majority of accident causes stemmed from organizational and behavioral factors rather than solely from individual or technical errors. Furthermore, non-compliance with safety requirements, *lack of practical training, and insufficient managerial oversight played key roles in shaping the preconditions and latent causes of these incidents.*

Discussion

The findings of this study indicate that the majority of fatal occupational accidents in the South Pars Special Economic Energy Zone are rooted in structural, managerial, educational, and human-psychological factors. The Tripod-Beta technique, with its ability to identify causes at three levels—immediate (active failures), preconditions, and latent factors—enabled a comprehensive mapping of the accident causation chain. Analysis revealed that six key Behavioral Risk Factors (BRFs) played the most significant role in these incidents. These align with prior research findings while also reflecting the specific characteristics of the national oil and gas industry.

1. Organizational Factors and Responsibility (57.8%): *This was identified as the most influential factor and is associated with inefficient organizational structure, lack of accountability, and weak oversight. The result aligns with the study by Shafiei et al. (2021), which identified "organizational system deficiencies" as the primary cause in approximately 20% of incidents. Similarly, Nematolahi et al. (2015) emphasized "inadequate supervision and ineffective oversight" as a root cause, supporting the findings of this study.*

2. Deficiencies in Training (22.2%): *Another major finding was the significant role of inadequate training, especially regarding safety and procedures in high-risk conditions. This aligns with Akhavan et al. (2021), who found that insufficient training and low employee awareness were the most influential factors in severe accidents. Biabani et al. (2021) also reported that over 30% of incidents resulted from a lack of safety training and safe work procedures. The importance of training was similarly highlighted in Mahmoudi-Harris's research, where it was identified as a leading latent cause of environmental accidents Mahmoudi-Harris (2020).*

3. Weaknesses in Maintenance Management (6.7%): *The results indicated that ineffective planning in equipment maintenance, including hoists and transport tools, posed significant risks. This aligns with Mahmoudi-Harris (2020), who identified maintenance management as the most recurrent latent* *factor. Shafiei et al. (2021) identified this factor as a root cause in 12% of incidents*

4. Equipment and Tool Issues (6.7%): *Mismatches between tools and tasks, equipment deterioration, and defects contributed to many incidents. This finding supports Biabani et al. (2021), who emphasized the substantial role of inappropriate equipment. Nikoomaram et al. (2022) also focused on environmental and technical factors as sources of human error in developing their model.*

5. Deficiencies in Operational Procedures (4.4%): *The absence of standardized procedures and poor execution of existing guidelines were identified as critical gaps in safety practices. This finding is consistent with Nematolahi et al. (2015) and Biabani et al. (2021), who emphasized that inadequate work procedures—particularly the lack of clear instructions—are significant contributors to severe incidents.*

Error-Enhancing Conditions (2.2%): *Although less frequently reported, these factors play a critical qualitative role in accelerating and intensifying human errors. Examples include high workload, time pressure, and extreme fatigue, all of which increase the likelihood of mistakes. This is consistent with Shafiei et al. (2021), who identified error-enhancing conditions as the second most common cause of incidents. Nematolahi et al. (2015) also highlighted haste and urgency as intermediate causes of accidents. Therefore, identifying, managing, and controlling such conditions is essential in accident prevention strategies.*

The findings are highly consistent with previous research in the field of root cause analysis of occupational incidents. For instance, Nikoomaram et al. (2022) emphasized expanding the Tripod-Beta model with a focus on human error, which contributed to a more accurate identification of risks and latent causes—an approach mirrored in this study through the multi-layered analysis (immediate, precondition, latent). Akhavan et al. (2021) also pointed to inadequate training and low safety awareness as key factors, supporting this study's second identified cause. Bordbar and Hosseini (2020) highlighted attitudinal, personal, and technical contributors, which *are traceable within the precondition and latent layers of this study—particularly in the absence of safety culture and weak responsibility.*

An analysis of the three accidents occurring in the South Pars region—fall from height, slip/trip, and pipe-strike—shows that despite superficial differences in incident type, their underlying structures share significant similarities. In all three cases, latent causes related to management structure, training deficiencies, and lack of oversight played a notable role. This demonstrates that merely addressing technical issues or replacing equipment will not effectively prevent incidents unless accompanied by improvements in deeper, systemic factors such as enhancing organizational safety culture and implementing continuous, practical training systems. These conclusions are consistent with the studies by Shirmardi and Davazdah-Emami (2019) on the organizational and environmental origins of human error, as well as with the findings of Mahmoudi-Harris et al. (2020) on maintenance and repair.

Implications for Practice and Policy

The analysis of fatal occupational accidents in the Pars Special Economic Energy Zone reveals critical insights for improving workplace safety practices and informing policy development. The findings highlight the predominance of organizational, educational, and systemic factors over isolated technical or individual failures, underscoring the need for a holistic approach to accident prevention. The following implications are proposed for both practice and policy:

Strengthening Organizational Accountability and Oversight: *Given that over half (57.8%) of the behavioral risk factors (BRFs) identified were related to weak organizational structure, insufficient supervision, and lack of clearly delegated responsibilities, it is imperative that companies within the zone implement robust oversight mechanisms. Policies should mandate the establishment of clear lines of accountability, regular safety audits, and the appointment of competent safety supervisors with authority and resources to act. Furthermore, organizational restructuring efforts should aim to reduce complexity and promote safety-driven decision-making.*

Mandating Comprehensive and Continuous Safety Training: *Deficiencies in training (22.2%) emerged as a major contributor to fatal incidents, particularly in high-risk operational contexts. In practice, this calls for the implementation of mandatory, hands-on safety training tailored to specific job roles and operational environments. Policy should require organizations to develop, document, and regularly update their training programs, ensuring they include modules on hazard recognition, use of personal protective equipment (PPE), and emergency response. A national or sector-wide certification system for safety training programs could help standardize content and quality.*

Improving Maintenance Planning and Resource Allocation: *Accidents involving lifting and handling equipment highlighted poor maintenance management as a recurring risk factor. Organizations should adopt preventive maintenance strategies that are supported by detailed documentation, regular inspections, and use of up-to-date equipment. At the policy level, guidelines should require companies to submit maintenance records for external review and to employ certified personnel for equipment inspections.*

Standardizing Equipment Use and Safety Protocols: *The analysis revealed several incidents linked to outdated, inappropriate, or malfunctioning tools and machinery. Policies must enforce the procurement and usage of equipment that meets approved safety standards. In practice, organizations should introduce routine compatibility assessments to ensure tools match task requirements, and create clear operational procedures for all machinery use, which should be included in worker training.*

Developing and Enforcing Operational Procedures: *The absence or improper implementation of standard operating procedures (SOPs) accounted for several surface and precondition causes. Organizations should be required to develop job-specific SOPs and ensure their consistent implementation through supervision and regular evaluation. Safety checklists, pre-task briefings, and real-time monitoring systems should become standard practice across all high-risk operations.*

Addressing Error-Inducing Conditions and Worker Well-being: *Though accounting for a smaller proportion (2.2%) of risk factors, error-enhancing conditions such as fatigue, time pressure, and extreme environmental exposure can significantly amplify the likelihood of accidents. Policies should promote the integration of fatigue risk management systems, climate-adaptive scheduling, and provisions for rest and hydration in hot environments. At the organizational level, early warning systems for physical or mental strain, especially in outdoor and high-temperature conditions, should be implemented.*

Cultivating a Safety Culture: *A recurring latent factor across all incidents was the absence of a proactive safety culture. Organizations must shift from reactive compliance to a culture of prevention, where safety is integrated into everyday operations. This involves promoting open communication, encouraging incident reporting without fear of reprisal, and engaging all levels of staff in safety planning. National and regional regulatory bodies should incentivize such cultural shifts through safety performance-based recognition programs.*

Policy Integration and Sector-Wide Learning: *The consistent patterns across all three incidents suggest the need for industry-wide learning systems. Regulators should establish a centralized accident reporting and analysis database that facilitates the dissemination of lessons learned. Furthermore, incident investigation standards should require multi-level causal analysis (e.g., Tripod-Beta or similar frameworks) to uncover root causes beyond surface-level observations.*

Limitations and Future Research

As with any empirical study, the present research faced several limitations that should be acknowledged. One of the most significant limitations was the prevailing cultural norm that perceives incident-related data in industrial settings as private and sensitive. This led to a general reluctance or resistance among individuals and organizations to share information, which in turn created obstacles in accessing accurate data, statistics, and incident details. To mitigate this challenge, all participants were assured of the *anonymity and confidentiality of the collected information, and necessary guidance was provided during the completion of the data collection forms.*

Another key limitation was the absence of a localized version of the Tripod-Beta model or similar incident analysis frameworks. This lack of contextual adaptation may have affected the applicability and effectiveness of the analysis, particularly in understanding the root causes of safety incidents within the cultural and operational framework of local industries.

These limitations open avenues for future research. It is recommended that future studies consider developing and validating a localized or culturally adapted version of the Tripod-Beta model to enhance the relevance and accuracy of incident investigations. Moreover, further research can explore strategies for improving organizational transparency and information-sharing practices in safety-critical environments. Longitudinal studies could also be conducted to examine the long-term impact of implementing structured safety management systems, including education, risk management, and permit-to-work systems, as proposed in this study. By addressing these limitations and extending the research in these directions, future work can contribute to the development of more robust, context-sensitive safety management practices in high-risk industries.

Conclusion

This study investigated the root causes of fatal occupational accidents in the Pars Special Economic Energy Zone during the first half of 2023, using the Tripod-Beta technique to conduct a multi-layered causal analysis. Despite the differing nature of the incidents—a fall from height, a slip on an uneven surface, and being struck by a metal pipe—the underlying causes shared significant structural similarities. These findings reinforce the notion that most workplace accidents are not the result of isolated technical failures or individual errors but rather stem from deeper organizational, behavioral, and systemic deficiencies.

The analysis identified six key Behavioral Risk Factors (BRFs), with organizational responsibility and structural inefficiencies accounting for the majority (57.8%) of the contributing causes. Deficiencies in safety training (22.2%) and poor maintenance management (6.7%) also played substantial

roles, followed by equipment-related issues, procedural gaps, and error-inducing conditions. These results highlight the urgent need for comprehensive improvements in organizational design, workforce education, maintenance practices, and safety culture.

Ultimately, the study underscores the importance of adopting proactive and preventive approaches to occupational safety. Rather than relying solely on compliance with technical standards, organizations must invest in continuous training, foster managerial accountability, and implement systemic reforms that prioritize worker well-being. The use of structured analytical models like Tripod-Beta provides a valuable tool for identifying and addressing the deeper, often overlooked causes of workplace incidents. By addressing these root issues, it is possible to create safer, more resilient work environments in high-risk industries such as oil and gas.

Acknowledgments

Resources

Akhavan A, salehi reyhani S H, Halvani G. Analysis of Fractures and Disability Defects Accidents in Lian Oil Company by Tripod Beta Technique. tkj 2021; 13 (2) :1-10.

Bahreini, Mohammad; Tayebi, Mohsen and Sharifipour, Ebrahim (2012). The relationship between organizational culture and HSE safety culture in Lorestan Province Electricity Distribution Company, Electricity Industry Automation Congress, Mashhad.

Birhane, G.E. Yang, L. Geng, J. & Zhu, J. (2022). Causes of construction injuries: a review. International Journal of Occupational Safety and Ergonomics; 28(1): 343-353.

BIABANI A, ZOKAIE M, FALAHATI M. Investigating the Relationship between the Prevalence of Occupational Accidents with Individual and Occupational Factors in the Workplace. Case Study: Industries of Qom Province. ohhp 2021; 5 (3) :208-223.

Bordbar, Gholamreza and Hosseini, Elahe (2020). An analysis of work-related accidents in the tile and ceramic industry of Yazd province, Quarterly Journal of Islamic Humanities Studies, Volume 2, No. 18, 11-1.

Ghahramani, A. Zavvar, H. & Hemmatjo, R. (2021). Modeling the Causes of Fuel Oil Tank Fire in an Industrial Plant Using Tripod Beta Method. Journal of Safety Promotion and Injury Prevention; 9(1):44-54.

Hämäläinen, P. Takala, J. & Kiat, T. (2017): Global estimates of occupational accidents and work-related illnesses 2017. Finland: Workplace Safety and Health Institute. 1-21.

Hajimaghsoudi, M. Dehghani, MH. & Sadooghian, M. (2021). Occupational accidents in Yazd University of Medical Sciences hospitals. Occupational Medicine Quarterly Journal; 13(2): 11-19.

Poursoleiman M S, Kazemi Moghadam V, Derakhshanjazari M. The effect of Health, Safety and Environment Management System (HSE-MS) on the improvement of safety performance indices in Urea and Ammonia Kermanshah Petrochemical Company. J Health Saf Work 2015; 5 (3) :75-84

Quick, J. (2015). Occupational health psychology. John Wiley & Sons, Inc.

Mahmoudi Herris S, Nikoomaram H, Ghaffari3 F, Miri Lavasani M. Identification and Assessment of the Effective Factors on the Occurrence of the Environmental Events Caused by the Construction and Operation of Gas and Steam Power Plants (Case Study: MAPNA Group(. johe 2020; 6 (4) :10-17.

Mashroofeh A, Bolboli M A, Pourbandori A, Shorofeh H, Karimi S. Analysis of root cause of the fatal occupational accidents in a gas refinery using the tripod-beta method. tkj 2022; 14 (1) :40-56

Nematolahi J, Nasrabadi M, Givehchi S. Analysis of accidents leading to amputations associated with operating with press machines, using Ishikawa and SCAT Combined method in a car manufacturing company. J Health Saf Work 2015; 5 (4) :23-36.

Nikoomaram, H., Modaresifar, H., KIANI, J., & Shanoofi, M. (2022). Enhancement of Tripod-Beta Model to Analyze Accidents based on Human Factors Engineering (Case Study: Esfahan', s Mobarakeh Steel Company).

Shafiei P, Jabbari M, Mirza Ebrahim Tehrani M. Investigation of Root Cause of Work-related Accidents in a Vehicle Manufacturing Company Using Tripod-Beta Method. J Health Saf Work 2021; 11 (2) :309-326.

Shirmardi, Ebrahim and Dazavdze Emami, Sina and Sultanzadeh, Ahmad and Velayatzadeh, Mohammad, 2019, Investigation of the causes of human error in process units; Case study: Phase-13 of South Pars.

VanVliet, G. & Magrin. G. (2018). The environmental challenges facing a Chinese oil company in Chad. 2e édition revue et corrigé.

Wang, Y. (2017). Study on the HSE Management at Construction Site of Oil and Gas Processing Area. Procedia Engineering; 45(1): 231-234.

Yap, J. Chua, C.Y. & Skitmore, M. (2021). Towards Sustainable Mobility with Transit-Oriented Development (TOD): Understanding Greater Kuala Lumpur. Planning Practice & Research; 36(3): 314-336.