ORIGINAL RESEARCH ARTICLE

Exploring the Root Causes of Accidents in a Gas Company: A Qualitative Content Analysis Approach

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Abstract

Background Multiple factors contribute to the occurrence of workplace accidents; however, these factors may differ based on the specific characteristics of operational processes and the workforce employed across various workplaces. Furthermore, a superficial investigation of accident causes often fails to identify the underlying factors that lead to their occurrence accurately. Therefore, this study was undertaken to systematically examine the factors contributing to accidents within a gas company.

Methods The necessary data were collected using the analysis of existing accident documentation, direct observation, and semi-structured individual interviews. Content analysis was employed to analyze the data.

Results Twelve key factors, including competence and qualifications, lack of safety resources, communication, risk perception, psychological factors, safety culture, supervision and safety management, responsibility, safety organization, training, management commitment, and work pressure, were consistently identified across all three data collection methods. These factors were subsequently classified into three categories: individual, occupational, and organizational factors.

Conclusion The findings emphasize the importance of implementing organizational, occupational, and individual measures to reduce accident risks within the gas industry. Prioritizing managerial safety commitment, enhancing communication, providing structured training, implementing effective planning/supervision, allocating resources, and establishing clear safety roles can strengthen the safety culture and minimize accidents.

Keywords Accidents, Content analysis, Gas industry, Safety commitment, Safety culture

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1 Introduction

Employees face numerous safety hazards in their workplaces, which can lead to accidents that result in significant human and financial losses for society. The oil and gas industry has historically reported higher rates of workplace injuries than other sectors. This is mainly due to hazards such as flammable gases, high-pressure systems, and heavy machinery.[1] The rapid growth of the oil and gas industry worldwide has contributed to an increase in accidents in recent decades. For example, 1,580 natural gas-related accidents, resulting in 146 fatalities, occurred in Italy between 2007 and 2016.[2] Analyzing accident data can help prevent catastrophic events that threaten workers, the environment, and public health. Therefore, greater attention to safety and identifying the factors contributing to workplace accidents in this industry is essential.

Workplace accidents are traditionally attributed to two main causes: unsafe acts (deviations from safe procedures) and unsafe conditions (hazardous environments).[3,4] In the context of hazardous environments, such as those involved in natural gas refining and distribution, unsafe acts can increase the likelihood of catastrophic events, including fires, explosions, and toxic exposures. Approximately 80% of workplace accidents are caused by unsafe behavior of workers.[5,6] The U.S. Occupational Safety and Health Administration (OSHA) highlights that nearly 80% of workplace accidents are preventable and can be attributed to unsafe behaviors or procedural violations. Research has shown that unsafe conditions often interact with unsafe acts to exacerbate risks, leading to incidents ranging from minor injuries to catastrophic events.[7] Recognizing how unsafe acts and conditions contribute to accidents is essential for developing effective safety strategies.

Potential factors that may influence the occurrence of accidents include aspects related to the individual circumstances, task/job, and organizational conditions.[8] Personal factors, such as cognitive abilities, risk perception, and behavioral tendencies, significantly influence workplace accidents. Fatigue, stress, and lack of situational awareness often lead to human error, increasing accident risks.[9] Overconfidence, complacency, and inadequate training further exacerbate unsafe behaviors, especially in high-risk industries.[10] Younger and less experienced workers are more prone to accidents.[11] Poorly designed jobs and excessive workloads increase injury risks by causing fatigue, stress, and errors.[12] Physically demanding tasks, extended work hours, and hazardous conditions all increase the risk of accidents in the oil and gas sector.[13,14] Inadequate training and unclear instructions further endanger workers.[15-17] Role ambiguity and insufficient resources also predict accidents.[18,19] Organizational factors significantly influence workplace accidents by shaping safety culture and operational practices. Deficiencies such as poor communication, inadequate training, a weak safety culture, and a lack of management commitment contribute to workplace incidents.[17,20] Understanding the association between organizational/job/individual factors and workplace accidents is crucial for developing strategies that mitigate risks and enhance safety performance.

Natural gas is vital to Iran's economy, fueling domestic energy needs and exports. With the world's second-largest reserves, it accounts for over 70% of Iran's energy consumption, ensuring energy security and economic stability. The natural gas required for consumption in Iran is transported through pipelines that cover a vast geographical area across the country, thereby increasing the potential for accidents. Iran's natural gas infrastructure is vulnerable to leaks, explosions, and fires, which can cause serious harm. These risks demand stringent safety measures. Additionally, due to the physical and chemical properties of natural gas, the complexities of transmission pipelines, and the resulting domino effects of accidents, the nature of accidents in the gas industry differs from other industries. Therefore, considering the importance of natural gas in Iran's economy and the risks associated with gas transmission operations, unsafe acts and conditions can significantly contribute to work-related accidents. Given the potential for catastrophic accidents, safety must be treated as a critical priority in this sector. Reducing unsafe acts and enhancing human performance are essential, especially in oil and gas workplaces. By identifying and examining the factors that contribute to unsafe acts and conditions during task execution, and by determining the most effective methods to enhance individual and group performance, accidents can be prevented. Therefore, this study was conducted to investigate contributing factors in the occurrence of workplace accidents in a natural gas company.

2 Methods

Study design

This study was conducted at a gas company located in West Azerbaijan Province. The development projects aimed at increasing the number of household gas connections are of great importance in West Azerbaijan Province, given the region's cold winter climate. However, the mountainous nature of the region, the challenging routes for gas pipelines, increased operational costs, and the slow and difficult process of gas supply to many affiliated villages highlight the complexities of these projects. At the same time, the associated risks also rise significantly. Before initiating the study, the necessary permissions were obtained from the gas company. A comprehensive

list of all active gas projects at various stages of implementation across West Azerbaijan Province was acquired from the Provincial Gas Company. Given the similarity of these projects, a purposive sampling approach was used to select representative sites from the northern, southern, and central regions of the province, ensuring both geographical and operational diversity. This approach enhances the transferability of the findings to similar industrial contexts. Several steel and polyethylene projects were then randomly selected, taking into account variations in weather conditions and contracting companies. Various tasks performed by workers were observed, and high-risk activities, including welding, jackhammer operation, and excavator driving, were studied to identify unsafe acts and conditions, as well as contributing factors.

The preliminary investigation at the gas company revealed that only occupational accidents with severe consequences were recorded and analyzed. Further examination revealed that the accident causal analysis was superficial, and the underlying factors contributing to the accident were not thoroughly investigated. Individual, occupational, and organizational factors influencing occupational accidents were not adequately identified. Therefore, the research team decided to study the factors affecting the occurrence of accidents in the company using a qualitative approach.

Data collection

Three methods, including analysis of existing accident documentation, observation, and semi-structured individual interviews, were employed to collect data. Sufficient time was allocated for continuous presence at the worksite to observe operations. After familiarizing with the work environment, work conditions, types of activities, interpersonal relationships, and other relevant aspects, high-risk activities in the projects were observed. The complete work cycle of the identified high-risk activities was observed at least five times by the second author during a two-month period of presence at the gas company. An observation guide, consisting of four sections (observation of tools and equipment used, workers' actions and behaviors, work methods, and work conditions), was developed through a review of relevant scientific literature. The guide includes 12 main questions regarding the suitability of tools and equipment for the task, defective tools, the presence of safety guards, unsafe acts, including errors and violations, safety behaviors, use of personal protective equipment, safe work methods, work speed, rushing in work, work supervision, and regional conditions. All aspects and details relevant to the study objectives were meticulously documented according to a predefined plan, and notes were written during the observations.

Documentation related to accidents was requested and collected from the company. Reports of accidents resulting in fatalities or severe injuries were provided to the researchers. The researchers carefully reviewed all accident reports and, if necessary, consulted with knowledgeable individuals in this field.

Interviews were conducted with 16 experts, including two contractors for execution and maintenance projects, two safety and execution consultants and supervisors, two safety and technical inspectors, two occupational health and safety specialists, two project managers, two operation and maintenance managers, and four workers employed in various project sections. Ten participants were from the main gas company, and six were from affiliated contractor companies. Participants were purposively selected during the observation period. The inclusion criteria for participants were willingness to participate in the study, a minimum of 5 years of work experience, and sufficient knowledge and experience regarding individual, occupational, and organizational factors that influence unsafe acts and conditions.

To conduct the interviews, an interview guide was developed based on the observation results, research objectives, and a review of scientific literature. The guide included demographic information about the participants and open-ended questions (individual's job and responsibilities, unsafe acts or conditions they have performed or observed, the most common unsafe acts and conditions in the company, causes of unsafe acts and conditions including individual, occupational, and organizational factors, existing control or preventive measures for unsafe acts and conditions, and suggested control measures). With the interview guide in hand, appointments were scheduled with the participants, and semi-structured interviews were conducted at their workplaces. The interviews were audio-recorded and later transcribed. The duration of the interviews ranged from 20 to 45 minutes.

Data analysis

The analysis of observation data was conducted after the initial observation. Each observation report was reviewed multiple times to gain a comprehensive understanding of the content. Sentences that addressed the questions posed during the observation were identified as sub-themes, and then the main concepts were determined. This process was repeated for all observations to complete the coding through continuous review. It is worth noting that the coding process and the extracted codes were reviewed by all other authors, and necessary revisions were made. Accident reports were also read line by line, and sub-themes and main themes were identified. We examined documentation related to seven major incidents, which included five fatalities and two cases of permanent

disability (amputation). The summarized themes were compared and described collectively.

The interview transcripts were reviewed multiple times by the researchers to familiarize themselves with the generated text. Various paragraphs were prepared for analysis through color coding and marginal annotations. For the analysis of data in this study, both detailed and holistic content analysis approaches were used. Data analysis was conducted concurrently with the first interview and continued alongside data collection (simultaneous analysis). Each transcribed interview was read multiple times to gain an overall understanding of the text. If one or several sentences/phrases conveyed a specific meaning, that section was selected as the analytical unit. Subsequently, the underlying meaning of the text was extracted. In this way, sub-themes were identified and then semantically categorized into main themes.

Trustworthiness

The researchers carefully selected projects, maintained continuous presence and long-term engagement, interacted sufficiently with participants, and allocated adequate time and attention to data collection to ensure the credibility of the data. Projects were observed through prolonged and consistent presence at the worksite, and discussions were held with workers during the observations. With the necessary permissions, all stages of activities and jobs were recorded on video. The videos were reviewed multiple times, and the entire content of the recordings and conversations was transcribed. To enhance the credibility of the results, the researchers repeatedly reviewed the interviews, and feedback from colleagues was regularly incorporated. The study participants validated the codes derived from the interviews. Additionally, to ensure dependability, a consistent method was used for data collection, including a standardized interview guide with approximately similar questions for all interviews. In this study, multiple techniques, including accident investigation, observation, and interviews, were employed to collect data, ensuring triangulation.

3 Results

The participants were all male, with a mean age of 43.2 years and an average work experience of 16.9 years. The analysis of the interviews identified 12 factors, including competence and qualifications, responsibility, lack of resources, communication, risk perception, psychological factors, safety culture, safety organization, supervision and safety management, training, management commitment, and work pressure. The results from observation revealed that nine factors, including competence and qualifications, resources, communication, risk perception, psychological factors, safety culture, supervision and safety management, training, and workload, influenced the occurrence of workplace accidents. The review of accident documentation also indicated that safety culture could significantly influence workplace accidents. Considering the overlap between the identified factors, it can be concluded that twelve factors, including competence and qualifications, lack of safety resources, communication, risk perception, psychological factors, safety culture, supervision and safety management, safety organization, responsibility, training, management commitment, and work pressure, were common across the three data collection methods. These factors were categorized into individual, occupational, and organizational factors. These factors are further described below in Figure 1.

Figure 1 Conceptual model of factors contributing to accident occurrence in the gas company

Individual Factors

Risk Perception: A review of accident documentation revealed that employees' understanding of occupational risks significantly influences their safety behavior. When employees are unaware of the hazards associated with a task and fail to take necessary precautions, it can be inferred that they lack a proper understanding of the risks involved. In experts' risk assessments, the focus is often on the consequences of accidents, such as injuries and financial losses. "*The common approach in the company is reactive to occupational accidents, where safety becomes a priority only after an incident occurs*" (Participant 15). However, individual risk perception depends on factors such as the predictability of the hazard, the degree of control individuals have over exposure and its consequences, and their familiarity with the potential outcomes of exposure.

Reporting unsafe acts and conditions can help identify

project risks. However, "*unsafe conditions are usually not reported, and when a problem arises, these conditions become more noticeable*" (Participant 14). Understanding risks is crucial for minimizing harm caused by occupational accidents and should be a priority. Yet, "*Unless pressure is applied to individuals and contractors, they are not willing to comply with safety measures! Therefore, before anything else, attention must be given to educating and raising awareness among individuals*" (Participant 1).

Psychological factors: Most safety experts and managers stated that preventing accidents is solely impossible through reducing unsafe conditions. Unsafe acts by individuals often lead to accidents; no one has found a reliable way to completely prevent such acts. There is no justification or explanation for why a person might act in unsafe ways. "*The overconfidence and pride in some individuals who are in charge of workers, who claim they know how to do everything, can create problems*" (Participant 5). A good psychological state among workers is essential for delivering quality and quantity in their work, as well as for preventing occupational accidents, since work-related stress can increase the likelihood of such incidents. Identifying psychological factors in the workplace is effective for improving the quality of life and preventing occupational accidents and mental health issues.

Occupational Factors

Work Pressure: According to the study participants, a reasonable amount of work pressure can prevent employee demotivation. When employees are under rational pressure, they are motivated to work harder and deliver their best occupational performance. However, "*Work pressure due to the premature opening of projects and other factors can reduce an individual's focus on performing tasks effectively*" (Participant 15). Work pressure creates a sense of urgency for employees to complete tasks more quickly. The reviewed accident documentation indicates that a reasonable level of pressure helps employees stay focused and creative in their job responsibilities. Still, excessive pressure beyond the normal level can also cause problems. Individuals who endure high levels of work-related stress may turn to alcohol or drug use, which can increase the likelihood of occupational accidents.

Competence and qualifications: Occupational competence can be synonymous with technical proficiency and possessing soft skills to perform assigned tasks. Competence refers to a set of abilities, skills, and even experiences that an individual must have to achieve the objectives of a job. The reviewed documents indicate that assigning employees to tasks outside their knowledge and expertise can lead to irreversible accidents. According to the interviewees' suggestions, "*Individuals with relevant qualifications should be selected for the respective job*" (Participant 12). In fact, "*Employees do not enter the workplace without obtaining the necessary certifications*" (Participant 13).

Organizational Factors

Lack of Safety Resources: Most interviewees expressed dissatisfaction with the economic challenges faced by the company and their impact on project safety in recent years. These issues have led to most tools and equipment being used by workers being defective, broken, or unsafe. Laziness and negligence among employees in repairing faulty tools, insufficient financial resources to repair or replace damaged equipment, acceptance of hard and unsafe work instead of replacing defective tools, and the willingness to take risks by working with faulty equipment were all observed as unsafe acts and conditions in the workplaces studied, which could lead to accidents. An interviewee stated, "*Due to the competitive nature of contracts, contractors bid very low prices, sometimes even below the contract value, to win tenders. As a result, after signing the contract, they are forced to cut further project costs, such as the budget needed for providing safe equipment or performing work activities safely*" (Participant 2). This increases safety risks in project execution. To enhance safety and prevent potential accidents "*workshops must be equipped with high-quality and safe tools and equipment*" (Participant 4). Interviewees also complained about the payments. Addressing these issues could improve safety levels by reducing unsafe acts in the workshops.

Responsibility: One of the most important ethical and personal traits is an employee's commitment to fulfilling assigned responsibilities. An interviewee emphasized that "*Everyone must be responsible for their own tasks and carry out their assigned duties properly to avoid hindering the company's goals in the workplace. Anyone who neglects their responsibilities must accept accountability and be answerable*" (Participant 10). Job responsibility refers to the set of duties an employee is expected to fulfill based on their position. It is worth noting that, in addition to defined responsibilities, supervisors may have additional expectations. Motivation can encourage individuals to perform their duties, and "*having a job and financial security*" (Participant 1) can foster a sense of responsibility and accountability in individuals.

Safety Supervision and Management

Implementing safety regulations is a highly effective measure for improving workplace safety. However, problems may arise during the execution of tasks without proper supervision. The primary goal of any workplace inspection is to identify hazards and determine and

implement appropriate control measures to prevent potential accidents. A review of accident documentation reveals negligence in project supervision, and sometimes contractors fail to adhere to contract principles and guidelines.

"*During operational activities, workers perform dangerous tasks using unsafe equipment, which increases the likelihood of accidents. Therefore, project supervisors/inspectors are present at the worksite to provide safety recommendations and warnings*" (Participant 10). "*Continuous monitoring and control can prevent potential unsafe acts in the implementation of guidelines*" (Participant 15). "*According to existing protocols, before starting work on a project, all tools and equipment must be inspected and approved*" (Participant 14). Additionally, "*There are daily, weekly, and monthly inspection programs for certain equipment, such as bulldozers and heavy machinery*" (Participant 1). In fact, safety inspections play a significant role in preventing occupational diseases and accidents.

Communication

Communication refers to a deliberate effort aimed at interaction, information exchange, sharing experiences, influencing others, and guiding individuals' thoughts and beliefs. Existing documentation indicates that workplace communication can occur for various reasons, such as making requests to superior managers, discussing work procedures, and more. Some interviewees emphasized that effective and appropriate workplace communication can enhance productivity. An interviewee stated, "*Communication in the workplace should be formal and follow proper protocols; otherwise, people won't take it seriously*" (Participant 12). However, some interviewees believe that "*A friendly environment can positively impact work performance*" (Participant 5). Therefore, a work environment should be created where everyone is encouraged to speak up and build relationships with other team members. When individuals feel comfortable discussing problems, emotions, and thoughts, and enjoy interacting with others, they will undoubtedly experience less stress.

Safety Culture

The reviewed accident documentation indicates that safety culture is a complex set of beliefs, knowledge, and behaviors that protect individuals against accidents, both in the workplace and in daily life. Most study participants emphasized that safety culture should be ingrained in individuals' minds before they enter industrial environments, to the extent that no one in society would willingly expose themselves to risks or unsafe conditions in their personal or professional lives. They should be able to predict potential accidents and respond appropriately to mitigate worsening situations during an incident. In fact, "*Cultivating a culture, not only in the workplace but also in society, can be highly beneficial*" (Participant 12). In the general culture of society, performing work unsafely or with high risk should never be considered normal. Only then can we hope for corrective actions to address unsafe practices; otherwise, changing unsafe behaviors will be extremely difficult. Participants also noted that education, as the first step toward changing behavior and fostering a culture in society and the workplace, is the most important and impactful aspect of safety activities.

Training

Study participants emphasized that providing safety training programs is an essential prerequisite, as these programs significantly reduce work-related accidents. In fact, "*all employees must receive training from a technical and vocational organization or a recognized institution approved by experts in this field and obtain a valid certificate before starting work*" (Participant 5). Training is a systematic effort aimed at aligning individuals' interests and future needs with the organization's goals and expectations. It is a process of systematically acquiring skills, rules, and attitudes that improve individuals' performance in the workplace. It is recommended that "*these training programs be conducted continuously and regularly within companies at specified intervals*" (Participant 6). A review of workplace accident records revealed that during these training sessions, workers become familiar with occupational hazards, safety regulations, and work standards, and "*awareness in the workplace increases*" (Participant 13).

Safety organization

Interviewees stated that fixing organizational problems depends on good organization and planning. They also mentioned that organizing is considered a process through which work is divided among employees and workgroups, and coordination is established among them to achieve goals. In fact, organizing involves determining the tasks that need to be performed, identifying who should perform them, grouping tasks effectively, and specifying who should report to or receive reports. However, they did not consider the current division of responsibilities to be appropriate. "*Safety representatives and officers should not have financial ties with contractors, as safety reports by the officers are often biased and tend to favor the contractors*" (Participant 15).

Management commitment

Most interviewees stated that the safety of a system cannot be achieved without the full and principled commitment of management, as well as mutual trust between the employer and the safety management team.

On the one hand, senior managers must be confident that knowledgeable and competent individuals are handling safety matters. On the other hand, a safety manager must also be assured of the employer's full support. Additionally, all personnel in the workplace, including workers and contractors, must be well-informed about the responsibilities of the safety team and the employer's support for this unit in carrying out their assigned duties. According to the study participants, for effective risk management, the organization's management must ensure that all employees and contracting organizations collaborate in the system's management program and "*adhere to existing guidelines*" (Participant 13). Furthermore, a review of accident documentation revealed that risk assessment should be mandated as part of every evaluation or review program and as a stage in all critical decision-making processes. Safety efforts will not be successful without these assurances as the minimum organizational management commitment.

4 Discussion

This study was conducted with the primary objective of identifying factors influencing workplace accidents in a natural gas company. The findings revealed that individual, occupational, and organizational factors are considered pivotal in influencing workplace accidents in the gas company.

While numerous studies have explored the role of individual and social factors in accident occurrence, organizational factors are increasingly recognized as key determinants of workplace safety. Organizational culture, safety policies, management commitment, and communication processes influence workers' perceptions and behaviors regarding safety, ultimately affecting accident occurrence. Additionally, deficiencies in organizational structures, including inadequate training, insufficient supervision, and weak enforcement of safety policies, have been linked to increased accident risks. Safety management plays a crucial role in mitigating workplace accidents by fostering a structured approach to risk identification, control, and prevention. A robust Safety Management System (SMS) is associated with reduced accident rates, as it provides workers with the necessary tools, training, and support to perform their tasks safely.[21,22] SMSs must align with organizational culture, as organizations with a positive safety culture show greater adherence to safety protocols and consequently experience fewer accidents.[23,24]

Moreover, effective planning and proper supervision are essential for achieving safety objectives and ensuring consistent safety management within an organization. Safety supervision plays a key role in accident prevention by ensuring that safety regulations and procedures are adhered to and by promptly addressing unsafe behaviors in the workplace. Research has shown that strong safety supervision is directly associated with lower accident rates, as it enhances workers' compliance with safety protocols and reinforces a culture of safety.[25,26] Effective safety planning, which involves proactive hazard identification, risk assessment, and the implementation of mitigation strategies, plays a vital role in accident prevention. Comprehensive safety planning, including clearly defined safety protocols, emergency procedures, and regular risk analysis, plays a vital role in accident prevention.[27,28] A robust safety culture is widely recognized as a critical factor in reducing workplace accidents, as it shapes the attitudes, perceptions, and behaviors of employees towards safety. Research has demonstrated that organizations with a positive safety culture, characterized by clear communication of safety priorities and shared values concerning risk management, tend to experience significantly lower accident rates.[29] Therefore, well-established SMSs help prevent accidents by fostering risk awareness, strong supervision, and proactive safety planning.

The results of this study indicated that the management's commitment to safety was a key factor in the occurrence of workplace accidents. Genuine management commitment to advancing safety practices is paramount, and this commitment must permeate the organization over time to prevent accidents effectively. Safety commitment, particularly when demonstrated by organizational leadership, is a critical determinant in reducing workplace accidents and fostering a proactive safety culture.[30,31] Research consistently shows that when management prioritizes safety, it creates an environment where employees are more likely to adhere to safety protocols and engage in risk mitigation behaviors.[32,33] These studies highlight the importance of robust safety commitment as a foundational factor in preventing workplace accidents.

Moreover, achieving an optimal level of safety is unattainable without adequate resources to perform routine safety tasks. Constraints in human and financial resources limit the availability of a sufficient workforce and impede the provision of essential tools, equipment, and facilities necessary for the development and enhancement of safety. Insufficient allocation of resources may contribute to higher accident rates in the workplace. Inadequate resources can lead to poor safety practices, insufficient training, and the use of unsafe equipment, all of which increase the risk of workplace injuries and fatalities.[34,35] Addressing these resource deficiencies through increased investment in safety infrastructure, regular equipment upgrades, and adequate staffing is essential for reducing accident rates and fostering a safer work environment.

Clearly defining responsibilities ensures that individuals understand their safety-related duties and strive to fulfill them. Additionally, it facilitates easier monitoring and supervision of tasks. Therefore, identifying this factor reinforces prior research findings and is crucial for preventing accidents. Responsibility—both at the individual and organizational levels—plays a critical role in accident prevention. Research indicates that when safety responsibilities are not clearly defined or communicated, it creates ambiguity in accountability, leading to lapses in safety practices and an increased risk of incidents.[36] Establishing clear responsibilities and accountability structures is essential for minimizing accident risks.

Based on the findings of the current study, the research showed that a lack of effective safety communication was an important factor in the occurrence of workplace accidents. Effective safety communication is a cornerstone of successful occupational safety programs, playing a critical role in mitigating accident risks by ensuring that essential safety information is conveyed clearly and promptly to all employees. Research has consistently demonstrated that robust safety communication contributes to the development of a positive safety climate, which is associated with reduced accident rates.[37] These findings highlight the importance of integrating comprehensive communication strategies into SMSs to facilitate better hazard recognition, promote proactive risk management, and ultimately prevent accidents.

Effective safety training is a fundamental aspect of accident prevention, as it enhances workers' awareness of potential hazards and equips them with the necessary skills and knowledge to mitigate risks. Research has consistently shown that well-structured safety training programs are directly related to a reduction in workplace accidents.[20,38-41] These studies demonstrate the critical importance of safety training as a key strategy for mitigating occupational hazards and preventing accidents.

Study participants identified work pressure as a key occupational factor affecting accident prevention. In several projects, limited resources and strict deadlines for early commissioning placed excessive physical and psychological strain on personnel, particularly contractors. This concern was strongly emphasized by participants during the interviews. Consequently, effective planning and reducing unnecessary workload pressures are critical to addressing this issue and mitigating the risk of accidents. Increased work pressure, including excessive workloads and tight deadlines, can lead to fatigue, stress, and reduced attention to safety protocols, which ultimately exacerbate accident risks.[42,43] Moreover, possessing the necessary qualifications and competence to carry out assigned safety tasks is essential for personnel. A lack of adequate knowledge, skills, and experience can prevent individuals from completing their safety-related duties within the designated timeframe. This misalignment can impose additional stress on the individual and may initiate a process that leads to accidents. These studies underscore how work pressure can compromise employees' ability to focus on safety, contributing to higher accident rates.

Competency, defined as the integration of knowledge, skills, and attitudes necessary for safe performance, plays a critical role in preventing workplace accidents. Research has shown that higher levels of safety competency are associated with a reduction in unsafe work practices and subsequent accident rates.[44] These studies underscore the essential role of competency development in reducing workplace accidents and enhancing overall occupational safety.

The findings of this study suggest that inappropriate risk perception is a significant factor contributing to accident occurrence. Enhancing individuals' knowledge and fostering a strong safety culture within an organization can influence attitudes toward risk perception. Moreover, the absence of essential safety equipment and facilities creates constraints that compel employees to tolerate higher levels of risk. Insufficient resource allocation for safety measures, exacerbated by the impact of economic sanctions in the country, has further compelled personnel to accept unreasonable risks. Additionally, deficiencies in contracting procedures for gas network development projects—such as selecting contractors primarily based on cost considerations—impede the establishment of necessary conditions for effective risk mitigation and safety improvement. Risk perception critically influences workers' safety behaviors, as their subjective assessments of hazard severity and likelihood shape their decisions to act safely or unsafely.[45,46] These studies emphasize that enhancing risk perception through targeted training and communication strategies is essential for improving safety outcomes and preventing accidents in the gas company.

Adverse economic conditions, including high inflation, low wages, and insufficient income to meet living expenses, have markedly increased individuals' focus on financial concerns as they struggle to manage household costs. Moreover, the inadequate allocation of resources for maintaining and improving safety measures has resulted in hazardous working conditions for personnel. This scenario imposes substantial stress on employees, thereby further compounding their challenges. Psychological conditions, including stress, anxiety, depression, and fatigue, have been shown to influence workplace accidents significantly.[47,48] Psychological distress can impair cognitive functions such as attention, memory, and decision-making, which are

critical for maintaining safety protocols and preventing risky behavior. These studies reinforce the notion that addressing psychological health in the workplace can play a crucial role in enhancing safety outcomes and reducing accident rates.

The factors identified in this study can inform the development of predictive models for accident risk in the gas industry. Future research could quantify these variables to build data-driven frameworks that identify high-risk conditions. The findings also offer practical guidance for improving SMSs, including contractor selection, training content, communication, and performance monitoring. By converting qualitative insights into measurable indicators, companies can develop SMSs that are both compliant and preventive, supporting more proactive accident prevention strategies.

While this qualitative study provides in-depth insights into the causes of accidents in a gas company, several limitations must be acknowledged. First, the findings are context-specific and derived from a small, non-representative sample, which limits their generalizability to broader populations. To address this, future studies could adopt mixed methods designs that combine qualitative depth with quantitative breadth, or use larger, more diverse samples across multiple sites. Second, the interpretive nature of qualitative research introduces potential subjectivity, as researcher bias during data collection (e.g., interview dynamics) or analysis (e.g., thematic coding) could influence results. Employing strategies such as independent coding by multiple researchers, the use of coding software, and external audits can help enhance objectivity and analytical rigor. Additionally, the absence of standardized protocols may hinder replicability, as the interactions between researchers and participants influence outcomes. Developing detailed documentation of interview guides, coding procedures, and decision-making processes can improve transparency and reproducibility. The reliance on self-reported data also raises concerns about social desirability bias or the Hawthorne effect, where participants modify their behavior due to being observed. Triangulating interview data with observational findings or organizational records, while ensuring anonymity and confidentiality, can help mitigate these risks. These limitations were addressed in the current study through methodological safeguards, including reflexivity, triangulation, and member checking, which enhance the trustworthiness of the findings. However, future longitudinal or multi-method studies could further validate and extend these results.

5 Conclusion

The primary objective of this study was to investigate the factors contributing to workplace accidents. By integrating findings from multiple data sources within the context of a gas company, the study provides a comprehensive understanding of the complex interplay among organizational, occupational, and individual factors that contribute to accident occurrence. The results highlight the importance of transitioning from isolated safety interventions to comprehensive, system-oriented approaches. To achieve this, managers in the gas industry should prioritize the development of a proactive safety culture by demonstrating visible and sustained commitment to safety, ensuring sufficient allocation of resources, and reinforcing accountability through clearly defined responsibilities and effective communication channels. This includes implementing stricter contractor prequalification procedures that assess not only technical capacity but also past safety performance and adherence to safety management systems. Efforts to improve safety culture should involve promoting leadership engagement at all organizational levels, encouraging near-miss reporting without fear of reprisal, and regularly evaluating the safety climate through employee feedback and safety audits. Additionally, training programs should be role-specific and go beyond basic compliance by enhancing workers' risk perception, situational awareness, and decision-making under pressure. These programs should be continuous and combine both classroom instruction and on-site, practical training.

Additionally, managers should address occupational stressors such as excessive workload, tight deadlines, and inadequate staffing, which compromise workers' ability to maintain safe behavior. Investing in psychological safety, adequate supervision, and practical workload planning will further reduce accident risk. Ultimately, the integration of these concrete, context-specific strategies can support the development of a more resilient, adaptive, and sustainable safety system tailored to the operational complexities of the gas industry.

Declarations

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Authors' Contributions
Abolfazl Ghahramani and Mohammad Hajaghazadeh designed the study. Zahra Samadi and Bahram Rahimi collected data. Abolfazl Ghahramani, Mohammad Hajaghazadeh, and Zahra Samadi analyzed the data. All the authors revised and approved the paper.

Availability of Data and Materials
The data supporting these findings are available from the corresponding author upon reasonable request.

Conflict of Interest
The authors declare that they have no conflict of interest.

Consent for Publication
All authors have read and approved the final manuscript and have provided their consent for publication.

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Ethical Considerations
This study was approved by the Ethics Committee of Urmia University of Medical Sciences, with the code IR.UMSU.REC.1397.261 in accordance with ethical principles.

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