Nafta-Gaz 2025, no. 2, pp. 133–139, DOI: 10.18668/NG.2025.02.06

Identification of external and internal factors influencing human error using HFACS-GI method in oil and gas industries

Identyfikacja czynników zewnętrznych i wewnętrznych w przemyśle naftowym i gazowym wpływających na błędy ludzkie przy użyciu metody HFACS-GI

Iraj Mohammadfam[1], Nazanin Pourfatah[2], Ghazaleh Monazami Tehrani[3], Meysam Hami[2], Seyedeh M. Yousefiani[4]

[1] *University of Rehabilitation Sciences and Social Welfare, Tehran, Iran*
[2] *Department of Health, Safety and Environment, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran*
[3] *Safety Promotion and Injury Prevention Research Center, Research Institute for Health Sciences and Environment, Shahid Beheshti University of Medical Sciences, Tehran, Iran*
[4] *National Iranian Gas Company, Tehran, Iran*

ABSTRACT: Identifying the patterns and root causes of errors is an important approach to understanding and improving safety management in industries. This study aims to investigate the external and internal factors influencing human errors using the Human Factor Analysis and Classification System-GI (HFACS-GI) method in the National Iranian Gas Company. The study was conducted using the HFACS-GI method, based on the HFACS framework, in the National Iranian Gas Company. In this study, all fatal accidents over an 8-year period were analyzed. To study external factors, three subgroups – governmental supervision, legal, and economic factors – were added to the main HFACS framework. For external factors, a questionnaire was prepared according to the opinion of the expert group (Cronbach's alpha of 0.981). Each questionnaire was completed by the HSE officers of the companies and gas refineries based on the documentation of related accidents and projects. In the final stage, the developed classification (HFACS-GI) was completed in 5 levels, and SPSS software was used to determine the frequency and percentage of subgroups for each of the 5 levels of this framework. The results of human error analysis based on HFACS-GI framework showed that among intra-organizational factors, 34.2% of causes were related to the unsafe acts, 26.3% to unsafe monitoring, 22.4% to the preconditions for unsafe acts, and 17.1% to organizational influences. The maximum and minimum external organizational factors influencing human error were related to governmental supervision (68.32%) and legal factors (14.6%), respectively. This study demonstrated that the HFACS-GI method can be used systematically to identify human errors and their occurrence according to external and internal organizational causes, thereby introducing effective and targeted safety interventions in the oil and gas industry.

Key words: human error, Human Factor Analysis and Classification System (HFACS), internal organizational factors, external organizational factors.

STRESZCZENIE: Identyfikacja wzorców i pierwotnych przyczyn błędów stanowi podstawę do skuteczniejszego zarządzania bezpieczeństwem w przemyśle. Niniejsze badanie ma na celu przeanalizowanie zewnętrznych i wewnętrznych czynników wpływających na błędy ludzkie przy użyciu systemu analizy i klasyfikacji wpływu czynnika ludzkiego na przyczyny wypadków (Human Factor Analysis and Classification System-GI, HFACS-GI) w państwowej spółce gazowej Iranu – National Iranian Gas Company. Badanie zostało przeprowadzone przy użyciu metody HFACS-GI, opartej na strukturze HFACS, w National Iranian Gas Company. W badaniu przeanalizowano wszystkie wypadki śmiertelne w okresie 8 lat. W celu zbadania czynników zewnętrznych do głównych ram HFACS dodano trzy podgrupy – nadzór rządowy, czynniki prawne i ekonomiczne. Do oceny czynników zewnętrznych przygotowano kwestionariusz oparty na opinii grupy ekspertów (współczynnik alfa Cronbacha na poziomie 0,981). Każdy kwestionariusz został wypełniony przez specjalistów ds. BHP w spółkach i rafineriach gazowych w oparciu o dokumentację powiązanych wypadków i projektów. W końcowym etapie opracowano klasyfikację (HFACS-GI) na 5 poziomach oraz użyto oprogramowania SPSS do określenia częstotliwości i procentu podgrup dla każdego z 5 poziomów tej klasyfikacji. Wyniki analizy błędów ludzkich w oparciu o ramy HFACS-GI wykazały, że wśród czynników wewnątrzorganizacyjnych 34,2% przyczyn było związanych z niebezpiecznymi działaniami, 26,3% z monitorowaniem niebezpiecznych działań, 22,4% z okolicznościami poprzedzającymi niebezpieczne działania, a 17,1% z wpływami organizacyjnymi. Spośród czynników zewnętrznych największy wpływ na błędy ludzkie miały czynniki związane z nadzorem rządowym (68,32%), a najmniejszy – czynniki prawne (14,6%). Badanie wykazało, że metoda HFACS-GI może być systematycznie wykorzystywana do

Corresponding author: G.M. Tehrani, e-mail: *ghazaleh.monazami@sbmu.ac.ir*

Article contributed to the Editor: 02.07.2024. Approved for publication: 31.12.2024.

identyfikacji błędów ludzkich i ich występowania w kontekście przyczyn wewnątrzorganizacyjnych i zewnętrznych, co umożliwia wprowadzenie skutecznych i ukierunkowanych działań poprawiających bezpieczeństwo w przemyśle naftowym i gazowym.

Słowa kluczowe: błąd ludzki, system analizy i klasyfikacji wpływu czynnika ludzkiego (HFACS), wewnętrzne czynniki organizacyjne, zewnętrzne czynniki organizacyjne.

Introduction

The human factor plays the most critical role in the occurrence of accidents, with 60 to 90 percent of industrial accidents attributed to human errors (Jensen, 2019). In the oil and gas industry, most human errors arise from deficiencies in the design of equipment, management systems, or work processes. Therefore, identifying the conditions that lead to errors and addressing them through appropriate interventions can reduce the likelihood of human error (Azhdari et al., 2017). However, it is important to note that no single factor can be solely considered as the primary cause of human error and its consequences. Instead, human error results from a combination of various factors such as ethical, individual, managerial and organizational factors, task complexity, environmental conditions, equipment design, training methods, monitoring, and the presence or absence of work instructions (Feyer et al., 1997). Some studies have shown that, in addition to intra-organizational factors, external factors such as government regulations and policies, performance of governors and legislators, economic and societal issues can affect the safety and health in an organization, and in some cases lead to unsafe conditions and acts and eventually can cause human errors (Shirali et al., 2013; Omole and Walker, 2015). Given a wide range of elements contributing to human errors, including organizational, environmental, and external, conducting a root cause analysis of human errors seems to be necessary to prevent accidents (Reinach and Viale, 2006; Wiegmann and Shappell, 2017).

One of the most recognized methods for analyzing human error risk factors is the Human Factor Analysis and Classification System (HFACS) technique, which is renowned for its ability to classify potential failures (Zheng et al., 2024). The HFACS method is highly flexible and capable of investigating the causal effects of accidents and human errors. Moreover, this method increases the probability of successful intervention strategies (Chauvin et al., 2013; Soltanzadeh et al., 2016). Dekker emphasized that HFACS serves as a powerful tool for analyzing human factors in accidents (Fam et al., 2008; Chan and Li, 2023). This method has been widely applied to investigate and analyze accidents across various domains, including military operations, marine and terrestrial transportation, mining, petrochemical industries, and error detection in clinical trials, to enhance system safety (Chauvin et al., 2013; Gong and Fan, 2016). Its hierarchical structure categorizes causal factors into four levels: unsafe acts, unsafe preconditions, unsafe supervision, and organizational influences, encompassing 19 specific classes of errors and potential defects (Shappell and Wiegmann, 2001). Zhan et al. showed the utility of the HFACS-RAs framework for railway accidents is a convenient analysis tool for incidents and accidents with different complexities (Zhan et al., 2017). In addition, Madigan et al. further demonstrated the utility of HFACS in the railway industry by successfully applying it to provide a retrospective analysis of minor incident investigations in the railway industry (Madigan et al., 2016). Theophilus et al. proposed the HFACS-OGI framework and applied it in the oil and gas industry (Theophilus et al., 2017). Studies have also shown that the HFACS framework is capable of identifying human error causes beyond the organizational level (Rasmussen, 1982; Azadeh et al., 2013; Mohammadfam et al., 2022). Its flexibility allows this method to be applied for investigating external organizational factors alongside internal factors.

Incident research in the petrochemical industries has revealed that 20% of all accidents are due to human factors (Behari, 2019; Gholamizadeh et al., 2023). Consequently, this study aims to identify the external and internal factors influencing human errors in the National Iranian Gas Company using the HFACS-GI method.

Method

The present study was conducted using the HFACS-GI method, which is based on the HFACS framework (Theophilus et al., 2017). All fatal accidents in the National Iranian Gas Company over an 8-year period were analyzed. The initial assessment of incidents features and HFACS data was performed using the frequency of accidents. Subsequently, actual errors and potential defects were classified into four levels according to the hierarchical structure of this method. First, the data were collected and recorded using a specifically designed worksheet. The HFACS levels include: unsafe acts directly contributing to accidents, categorized into subgroups of skill-based errors, decision-making errors, cognitive errors, routine infractions, and exceptional infractions; preconditions for unsafe acts such as psychological and physical factors influencing first-level errors, categorized into subgroups of undesirable mental state, undesirable

physiological state, physical constraints, mismanagement of human resources, individual preparedness, physical and technological environments; unsafe monitoring categorized into subgroups of inadequate monitoring, inappropriate planning of operations, failure to correct known problems, and regulatory infractions; organizational impacts covering organizational culture, organizational processes, and resource management (Ghasemi et al., 2017). Then, considering the versatility of this method, which makes it applicable across various industries and activities, as well as its adaptability based on the conditions in which it is used, including air traffic and military operations (Reinach and Viale, 2006), necessary modifications were made, while retaining the core structure, for the purpose of evaluating the external factors (level 5 of the HFACS) at the National Iranian Gas Company. The questionnaire on external factors affecting the occurrence of errors was evaluated based on opinions of an expert group in three sectors: government supervision, legal factors, and the impact of customers or consumers, along with their subdivisions. A 20-question questionnaire was developed, including 6 questions on government monitoring structures, seven on rules and regulations, and seven on the impact of customers/consumers (7 questions) structures. The questionnaire was designed by a group of experts using a Likert scale. The content validity index was 0.76, and the Cronbach's alpha for this questionnaire was 0.981 (Tavakol and Dennick, 2011). Each questionnaire was completed based on documentation of accidents and related projects by the HSE officers of the companies and gas refineries at the accident sites. In the final stage, the new classification (HFACS-GI) was completed in 5 levels (Table 1). The initial assessment of incident features and HFACS data was performed using accident frequency. SPSS software was employed to calculate the frequency and percentage of subgroups for each level of the HFACS framework.

Results

In this study, based on the HFACS-GI framework, 228 human errors were identified at the level of internal factors. The initial results, based on the number of errors, revealed that the unsafe acts of the operator unsafe acts (first level) accounted for 78 errors (34.2%), representing the highest contributor to accidents resulting in fatalities. These errors were present in 87.2% of the accidents. Unsafe monitoring and supervision

Tabe 1. The HFACS-GI framework
Tabela 1. Struktura HFACS-GI

Error level	Error cause		Error cause ID
Unsafe act	Errors [AE000]	Skill-based error	AE100
		Decision-making error	AE200
		Cognitive error	AE300
	Infractions [AV000]	Routine infractions	AV100
		Exceptional infractions	AV200
Precondition for unsafe act	Environmental factor [PE000]	Physical environment	PE100
		Technological environment	PE200
	Operator conditions [PC000]	Undesirable mental state	PC100
		Undesirable physical state	PC200
	Individual factors [PP000]	Mismanagement of human sources	PC300
		Individual preparedness	PP100
Unsafe monitoring	Inadequate monitoring		PP200
	Inappropriate planning of operations		SI000
	Failure to correct the problem		SP000
	Regulatory infractions		SF000
Organizational impacts	Resource management		SV000
	Organizational culture		OR000
	Organizational process		OC000
External factors	Government supervision		OP000
	Economic factors		EG000
	Legal factors		EC000

(third level) followed with 60 errors (26.3%), while preconditions for unsafe acts (second level) accounted for 51 errors (22.4%). Organizational impacts (fourth level) contributed to 39 errors (17.1%). These findings highlight the distribution of human error causes among the intra-organizational factors.

As shown in Table 2, the most frequent unsafe acts at the first level were skill-based errors, followed by decision-making errors, infractions, and cognitive errors. At the second level, individual factors and environmental factors, such as the technological environment, were the most common preconditions

Table 2. Frequency percentage of errors and their causes related to internal factors at each level

Tabela 2. Procentowy wskaźnik występowania błędów i ich przyczyn związanych z czynnikami wewnętrznymi dla każdego poziomu

Error level		Frequency [%]	Error cause	Frequency [%]
First level	Unsafe acts	34.2	Skill-based error	32.1
Second level	Pre-conditions for unsafe acts	22.4	Individual preparedness	25.5
Third level	Unsafe monitoring	26.3	Inappropriate planning of operations	40.0
Fourth level	Organizational impacts	17.1	Resource management	38.5

Table 3. Frequency and percentage of subgroups of causes of fatal accidents based on the 5 levels of the HFACS framework

Tabela 3. Częstotliwość i odsetek podgrup przyczyn wypadków śmiertelnych w oparciu o 5 poziomów ram HFACS

HFACS-GI sub-groups	Frequency	Percentage
Intra-organizational factors		
First level		
Skill-based error	25	61.0
Decision-making error	17	41.5
Cognitive error	9	22.0
Routine infractions	17	41.5
Exceptional infractions	10	24.4
Second level		
Physical environment	2	4.9
Technological environment	13	31.7
undesirable physical status	3	7.3
undesirable mental status	6	14.6
Mental/physical limitations	4	9.8
Management of human resources	10	24.4
Individual preparedness	13	31.7
Third level		
Inadequate monitoring	20	48.8
Inappropriate planning of operations	24	58.5
Failure to correct the problem	5	12.2
Regulatory infractions	11	26.8
Fourth level		
Resource management	20	48.8
Organizational culture	4	9.8
Organizational process	15	36.6
Extra-organizational factors		
Fifth level		
Government supervision	28	68.3
Legal factors	6	14.6
Economic factors	18	43.9

for accidents. At the third level, inappropriate planning of operations had the highest frequency, followed by inadequate monitoring and supervision, and regulatory infractions from the unsafe monitoring group. At the fourth level, resource management was identified as the most significant contributor within the organizational impacts subgroup, followed by organizational processes.

The frequency and percentage of subgroups of causes of fatal accidents based on the 5 levels of the HFACS framework are shown in Table 3. At the level of external factors influencing the occurrence of unsafe situations and errors within the organization, government supervision was identified as the most significant contributor to fatal accidents in the gas industry, with a frequency of 21 (68.3%). This was followed by economic factors, with a frequency of 14 (43.9%) and legal factors, with a frequency of 8 (14.6%). These findings underscore the substantial role of external factors in creating the unsafe situations and the occurrence of errors within the organization.

Discussion

At the first level, the most common unsafe acts, also known as active errors, are skill-based errors. Following these are decision-making errors, infractions, and cognitive errors, respectively, as the most frequent categories in the HFACS-GI framework. In the second level, the most commonly identified preconditions for accidents are individual factors and environmental factors, such as the technological environment. At the third level, in the unsafe monitoring and supervision group, the subgroup of inappropriate planning of operations, ranks highest, followed by inadequate monitoring and regulatory infractions. At the fourth level, resource management emerges as the most significant contributor, comprising a substantial proportion of potential defects within the organizational impacts group. Organizational processes follow as the second-ranked subgroup at this level.

The most frequently observed errors at the first level were skill-based errors (61%), which are also mentioned in similar studies (Baysari et al., 2009; Chan and Li, 2023). These errors in the gas industry are often due to a lack of procedural principles, deficiencies in the implementation of guidelines, and the adoption of inappropriate methods to facilitate work without knowing the dangerous consequences of these events. At the second level, individual preparedness (31.7%) and mismanagement of resources (24.4%) were the most impactful subgroups. These issues frequently stem from inadequate training and communication as well as poor coordination among staff. In case of the subgroup of individual factors, Azadeh et al. (2007) identified inappropriate organization in planning and management processes as a critical factor in preconditions for unsafe acts, which often lead to accidents. Mohammadfam et al. (2021) emphasized that employee failures in the performance of duties assigned to them are due to their lack of understanding about why they should observe the principles and regulations and how to carry their tasks properly. Therefore, proper employee training can reduce errors at this level (Mohammadfam et al., 2021). At the third level, inappropriate planning of operations (85.5%) and inadequate monitoring (48.8%) were the most significant subgroups contributing to errors. Common issues included a lack of risk management, failure to identify and evaluate hazards, unsafe working conditions, and poor monitoring of procedures for issuing work permits and practices of individuals. Lenné et al. (2012) also found that inappropriate planning (33%) is the most influential factor in unsafe monitoring and supervision group when it comes to the occurrence of errors leading to accidents, followed by other deficiencies such as poor communication between supervisors, management and staff, lack of employee-supervisor interaction, and excessive supervisor workload. The high percentage of unsafe monitoring factors in the results of the present study suggests the need for a greater focus and a more accurate assessment of the classification of supervision. The efficiency and effectiveness of organizational oversight are key factors in ensuring system safety and performance. Permanent and direct oversight by supervisors on enforcement activities plays a crucial role in meeting safety requirements and ensuring full compliance with the guidelines and procedures. Resource management was found to be the most effective factor in the organizational impacts group, accounting to 48.8% at the fourth level (organizational impacts). Similarly, the results of Li and Harris's study on 523 accidents in the Chinese Air Force using the HFACS framework showed that resource management, at 35%, was the most common type of error at level four (Li and Harris, 2006). The results of the fifth level survey (external factors influencing unsafe acts and unsafe conditions) showed the involvement of government supervision in 68.3%, economic aspects in 43.9%, and legal factors in 16.6% of accidents resulting in fatalities due to human error. These findings point to a lack of effective government audits of the organization's practices concerning contractor safety and performance, the lack of strict regulations regarding obtaining contractor safety certifications, economic instability caused by reduced production and demand, and international sanctions. Consequently, these factors contribute to reduced educational and retraining programs, disproportionate workloads and salaries, and low employee motivation. The study by Omole and Walker, using the developed HFACS-HE framework for offshore transportation accidents in Nigeria and the United Kingdom, also highlighted that external factors such

as government influence, laws and regulations, political and social impacts significantly contribute to the creation of unsafe conditions and consequent errors within organizations (Omole and Walker, 2015).

Overall, the findings of this study, utilizing the developed HFACS-GI framework at the National Iranian Gas Company, demonstrate that errors, infractions, and inadequate supervision at the level of intra-organizational factors, along with inadequate government supervision at the level of external factors, are the primary causes of accidents resulting from human error. Therefore, the participation of competent authorities and organizations in investigating accidents and providing appropriate solutions, providing training, organizing national and international conferences, forming a safe industry committee to institutionalize safety in industries, and identifying injury patterns in critical industries in terms of their severity and the frequency, and effective planning of prevention strategies and permanent monitoring of programs by competent authorities, the identification of specific educational strategies to raise the level of awareness of managers in organizations, seems necessary.

Conclusions

The results of this study showed that most human errors were caused by a combination of various factors, such as inadequate monitoring, incomplete implementation of instructions, and inappropriate planning of operations. Therefore, to prevent the recurrence of the identified errors and mitigate their consequences, improvements in employee training programs, permanent governmental monitoring of contractors and organizations performance, direct oversight of supervisors over executive activities and adherence to safety requirements, as well full compliance with guidelines are essential. These measures will play an important role in reducing incidents resulting from the human error in the company. Additionally, the developed HFACS-GI method can be systematically applied to identify human errors and their causes, enabling the implementation of effective and targeted safety interventions based on the identified weaknesses in the oil and gas industry.

References

Azadeh A., Fam I.M., Garakani M.M., 2007. Total ergonomic design approach to enhance the productivity in a complicated control system. *Information Technology Journal*, 6(7): 1036–1042. DOI: 10.3923/itj.2007.1036.1042.

Azadeh A., Rouhollah F., Davoudpour F., Mohammadfam I., 2013. Fuzzy modelling and simulation of an emergency department for improvement of nursing schedules with noisy and uncertain inputs. *International Journal of Services and Operations Management*, 15(1): 58–77. DOI: 10.1504/IJSOM.2013.053255.

Azhdari M., Tehrani M.G., Alibabaei A., 2017. Investigating the causes of human error-induced incidents in the maintenance operations of petrochemical industry by using HFACS. *Journal of Occupational Hygiene Engineering*, 3(4): 22–30. DOI: 10.21859/johe-03043.

Baysari M.T., Caponecchia C., McIntosh A.S., Wilson J.R., 2009. Classification of errors contributing to rail incidents and accidents: A comparison of two human error identification techniques. *Safety Science*, 47(7): 948–957. DOI: 10.1016/j.ssci.2008.09.012.

Behari N., 2019. Assessing process safety culture maturity for specialty gas operations: A case study. *Process Safety and Environmental Protection*, 123: 1–10. DOI: 10.1016/j.psep.2018.12.012.

Chan W.T.-K., Li W.-C., 2023. Development of effective human factors interventions for aviation safety management. *Frontiers in Public Healt*h, 11: 1144921. DOI: 10.3389/fpubh.2023.1144921.

Chauvin C., Lardjane S., Morel G., Clostermann J.P., Langard B., 2013. Human and organisational factors in maritime accidents: Analysis of collisions at sea using the HFACS. *Accident Analysis & Prevention*, 59: 26–37. DOI: 10.1016/j.aap.2013.05.006.

Fam I.M., Azadeh A., Faridan M., Mahjub H., 2008. Safety behaviors assessment in process industry: a case study in gas refinery. *Journal of the Chinese Institute of Industrial Engineers*, 25(4): 298–305. DOI: 10.1080/10170660809509093.

Feyer A.M., Williamson A.M., Cairns D.R., 1997. The involvement of human behaviour in occupational accidents: Errors in context. *Safety Science*, 25(1–3): 55–65. DOI: /10.1016/S0925-7535 (97)00008-8.

Ghasemi F., Kalatpour O., Moghimbeigi A., Mohammadfam I., 2017. Selecting strategies to reduce high-risk unsafe work behaviors using the safety behavior sampling technique and Bayesian network analysis. *Journal of Research in Health Sciences*, 17(1): e00372.

Gholamizadeh K., Alauddin M., Aliabadi M.M., Soltanzade A., Mohammadfam I., 2023. Comprehensive failure analysis in Tehran refinery fire accident: Application of accimap methodology and quantitative domino effect analysis. *Fire Technology*, 59(2): 453–472. DOI: 10.1007/s10694-022-01348-6.

Gong Y., Fan Y., 2016. Applying HFACS approach to accident analysis in petro-chemical industry in China: Case study of explosion at Bi-benzene Plant in Jilin. Advances in Safety Management and Human Factors. *Proceedings of the AHFE 2016 International Conference on Safety Management and Human Factors, July 27–31, 2016, Walt Disney World®, Florida, USA*.

Jensen R.C., 2019. Risk-reduction methods for occupational safety and health. *John Wiley & Sons, 1–496.*

Lenné M.G., Salmon P.M., Liu C.C., Trotter M., 2012. A systems approach to accident causation in mining: An application of the HFACS method. *Accident Analysis & Prevention*, 48: 111–117. DOI: 10.1016/j.aap.2011.05.026.

Li W.C., Harris D., 2006. Pilot error and its relationship with higher organizational levels: HFACS analysis of 523 accidents. *Aviation, Space, and Environmental Medicine*, 77(10): 1056–1061.

Madigan R., Golightly D., Madders R., 2016. Application of Human Factors Analysis and Classification System (HFACS) to UK rail safety of the line incidents. *Accident Analysis & Prevention*, 97: 122–131. DOI: 10.1016/j.aap.2016.08.023.

Mohammadfam I., Mahdinia M., Soltanzadeh A., Aliabadi M.M., Soltanian A.R., 2021. A path analysis model of individual variables predicting safety behavior and human error: The mediating effect of situation awareness. *International Journal of Industrial Ergonomics*, 84(3): 103144. DOI: 10.1016/j.ergon.2021.103144.

Mohammadfam I., Khajevandi A.A., Dehghani H., Babamiri M., Farhadian M., 2022. Analysis of factors affecting human reliability in the mining process design using Fuzzy Delphi and DEMATEL methods. *Sustainability*, 14(13): 8168. DOI: 10.3390/su14138168.

Omole H., Walker G., 2015. Offshore transport accident analysis using HFACS. *Procedia Manufacturing*, 3: 1264–1272. DOI: 10.1016/j.promfg.2015.07.270.

Rasmussen J., 1982. Human errors. A taxonomy for describing human malfunction in industrial installations. *Journal of Occupational Accidents*, 4(2–4): 311–333. DOI: 10.1016/0376-6349(82)90041-4.

Reinach S., Viale A., 2006. Application of a human error framework to conduct train accident/incident investigations. *Accident Analysis & Prevention*, 38(2): 396–406. DOI: 10.1016/j.aap.2005.10.013.

Shappell S.A., Wiegmann D.A., 2001. The human factors analysis and classification system (HFACS). DOT/FAA/AM-00/7 Office of Aviation Medicine Washington, DC 20591.

Shirali G., Karami E., Goodarzi Z., 2013. Human errors identification using the human factors analysis and classification system technique (HFACS). *Journal of Health and Safety at Work*, 3(3): 45–54.

Soltanzadeh A., Mohammadfam I., Moghimbeigi A., Akbarzadeh M., Ghiasvand, R., 2016. Key factors contributing to accident severity rate in construction industry in Iran: a regression modelling approach. *Arhiv za Higijenu Rada i Toksikologiju*, 67(1): 47–53. DOI: 10.1515/aiht-2016-67-2687.

Tavakol M., Dennick R., 2011. Making sense of Cronbach's alpha. *International Journal of Medical Education*, 2: 53–55. DOI: 10.5116/ijme.4dfb.8dfd.

Theophilus S.C., Esenowo V.N., Arewa A.O., Ifelebuegu A.O., Nnadi E.O., Mbanaso F.U., 2017. Human factors analysis and classification system for the oil and gas industry (HFACS-OGI). *Reliability Engineering & System Safety*, 167: 168–176. DOI: 10.1016/j.ress.2017.05.036.

Wiegmann D.A., Shappell S.A., 2017. A human error approach to aviation accident analysis: The human factors analysis and classification system. *Routledge*. DOI: 10.4324/9781315263878.

Zhan Q., Zheng W., Zhao B., 2017. A hybrid human and organizational analysis method for railway accidents based on HFACS-Railway Accidents (HFACS-RAs). *Safety Science*, 91: 232–250. DOI: 10.1016/j.ssci.2016.08.017.

Zheng Q., Liu X., Wang W., Han S., 2024. A hybrid HFACS model using DEMATEL-ORESTE method with linguistic Z-number for risk analysis of human error factors in the healthcare system. *Expert Systems with Applications*, 235: 121237. DOI: 10.1016/j.eswa.2023.121237.

Prof. Iraj MOHAMMADFAM, Ph.D.
Professor at the Department of Ergonomics, Health Research Center in Accidents and Disasters
University of Social Welfare and Rehabilitation Sciences, Tehran, Iran
E-mail: *ir.mohammadfam@uswr.ac.ir*

Nazanin POURFATAH
M.Sc. student at the Department of Health, Safety and Environment, Safety Promotion and Injury Prevention Research Center
Shahid Beheshti University of Medical Sciences, Tehran, Iran
E-mail: *npourfatah@gmail.com*

Ghazaleh Monazami TEHRANI, Ph.D.
Associate Professor at the Department of Health, Safety and Environment Safety Promotion and Injury Prevention Research Center; School of Public Health and Safety
Shahid Beheshti University of Medical Sciences, Tehran, Iran
E-mail: *ghazaleh.monazami@sbmu.ac.ir*

Meysam HAMI
M.Sc. student at the Department of Health, Safety and Environment, Safety Promotion and Injury Prevention Research Center
Shahid Beheshti University of Medical Sciences, Tehran, Iran
E-mail: *Meysam.hami.mh@gmail.com*

Seyedeh Masoumeh YOUSEFIANI, M.Sc.
Research expert at the National Iranian Gas Company
Tehran, Iran
E-mail: *yousefiani1386@gmail.com*