Modeling Causal Factors of Occupational Accidents in Chemical Industries: A 10-Year Field Study in Iran

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ABSTRACT: *Analyzing and modeling causal factors of occupational accidents play an important role in planning prevention programs. The study aimed to explore the causal factors of occupational accidents in chemical industries in Iran. The reports of 1322 accidents from 2007 to 2016 were gathered from 22 chemical industries. First, the Accident Frequency Rate (AFR) was calculated and all the effective factors were reviewed and labeled as "dependent" and "independent" factors. Second, feature selection was conducted to find the important causal factors. Then, multiple linear regression analysis was employed to model the most frequent causal factors in accident occurrence. The average accident frequency rate (AFR) was 87.75±74.82. A total of 30 independent casual factors were identified to be eligible for further analysis. Results of multiple linear regression analysis showed that 21 out of 30 important casual factors had the most important role in occupational accidents which are categorized into personal factors, organizational factors, HSE training, risk management, unsafe acts, and conditions as well as the type of accident occurrence. This study revealed that any preventive program should consider the importance of each casual factor in occurring occupational accidents. The higher level of importance needs the higher level of attention.*

KEYWORDS: *Chemical Industry; Occupational Accident Modeling; Accident Frequency Rate (AFR); Causal Factor; Feature Selection; Multiple Linear Regression.*

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INTRODUCTION

Because of working with a high inventory of chemicals, high process pressure, high temperature, a high flow of fluids, the toxicity of hazardous chemicals, the complexity of the process, and so forth, chemical processing industries are always facing catastrophic disasters [1-3]. The occurrence of catastrophic accidents such as Bhopal and others had proven this. The most detrimental accidents in these industries are fire, explosion, and chemical toxic dispersion [4]. According to the statistics reported by MARSH, industrial accidents in hydrocarbon process industries led to $ 36 billion from 1974 to 2014 [5].

The high frequency of occupational accidents also remains a great challenge in these industries. To prevent detrimental outcomes, accident prevention should be considered by providing better safety and health management systems. Once an accident happened, lessons learned from it can also be regarded as the elimination of causes of such accidents. Hence, identifying the causal factors associated with occupational accidents is the essential step to develop an accident prevention program. Therefore, it is necessary for us to be aware of the factors which have great influences on the accident occurrence [6, 7].

To do so, choosing valid and reliable tools or methodologies must be taken into account in the early developing stage of any plan. One of the popular tools for analyzing and modeling accidents is multiple linear regression analysis which can help decision-makers to identify the magnitude portion of each causal factor. To achieve better results, we need to employ supplementary methods to select the best input for data analysis. Several studies reported that bias in selecting the input data can lead to deviating all the acquired results. Hence, through a combination of multiple linear regression and feature selection tools, it can be expected to obtain a better estimation on the contributory level of each factor [8, 9]. *Tauseef et al.* indicated that past accident analysis in the chemical process industry through a comprehensive database can help prevent and mitigate occupational accidents [10, 11]. Also, Abdolhamidzadeh et al., showed that applying the domino effects methodology can better reveal accident-related factors in chemical industries [11, 12].

Chemical industries had a great influence on the economy of Iran, although occupational accidents always overwhelmed this target. The history of occupational accidents in these industries alerts the stakeholders to have vigorous preventive plans, although lessons learned from these accidents are mostly forgotten after a while. There are a few databases for occupational accidents in chemical industries in Iran; also, in most cases available data are very incomplete. In such a condition, a combination of analysis tools is required to make better accident analysis. Hence, the aim of the present study was to model causal factors of occupational accidents in chemical industries in Iran through combining multiple regression analysis with feature selection.

THEORETICAL SECTION

This survey was a descriptive-analytical and retrospective study that was designed and done with the aim of modeling causal factors of accident rate in chemical industries in Iran.

Studied Samples

The statistical sample size included all the occupational accidents which had happened during the last 10 years (2007-2016) in 22 selected chemical industries. The studied samples included disabling occupational accidents. During the initial survey, 1322 accidents were identified but only accidents in which all the considered factors and variables were reported or accidents in which the research team could collect data by doing the collecting steps remained in the study. For example, the accidents without the report form were excluded from the study. Finally, 1142 accidents were considered eligible for the study as final samples.

Data Collection

In this study, the main tool for data collection was the accident report form. Also, data collection was done by tools such as checklists, direct review of the history, and interview. It should be noted that the accident report forms were identical for these industries and were standardized by reference organizations.

It should be noted, information related to personal factors, Unsafe conditions and Unsafe acts factors, and type of accident were collected from accident report forms. HSE training and HSE risk management factors were collected from a direct review of the history and documents and records of HSE management system. Organizational factors were collected by interview. Additionally, accident frequency rate (AFR) was calculated from data related to organizational factors and type of accident.

Studied Factors

According to the algorithm and aims of this study, the studied causal factors included independent and dependent factors which were classified into 7 independent groups of factors based on the criteria such as studying different texts, past accident analysis, and logical relations between factors. these groups were: personal factors, organizational factors, Health, Safety, Environment (HSE) training, risk management, unsafe conditions, unsafe acts and the type of accident, and one group of dependent factors including Accident Frequency Rate (AFR).

In this study, *personal factors* included the mean age and work experience, marital status, and level of education.

The type of jobs and actions which caused the accident, pressure and time limitation for doing the job, shift work, type of employment of the injured persons, and the accident time were determined as the *organizational factors*.

The *HSE training factors* included parameters such as training at the time of recruitment, periodic training, and training after the accident occurrence, training in terms of familiarity and usage of Personal Protective Equipment (PPE), informing the workers regarding the environment and work discipline, and its role in reducing the accident rate (industrial housekeeping), quantity and duration of the provided safety training and content or quality of these training.

Factors related to *HSE risk management* were determined with items including hazard identification (HAZID), general risk assessment, special risk assessment of each process, accident investigation and analysis, safety audit, incident reporting systems (including unsafe conditions and acts), implementing engineering control measures, management activities like Tool Box Meeting (TBM) and using PPE.

Unsafe condition factors were introduced by improper and dangerous work methods, insufficient protection systems, and improper safety, structural defects, and problems in using the equipment and hand tools, working with electrical devices, plus chemical materials and compounds.

Unsafe acts factors included variables such as not using or improper use of PPE, lack of knowledge and awareness about the dangers of the workplace, horseplay, being in unsafe positions and conditions, working without license, and supervisor’s permission.

The type of accident includes chemical spillage, contact with objects or power circuits, accidents caused by carrying loads and materials and fires.

Accident frequency rate was analyzed as the dependent factor in this study. This index was calculated based on the formula presented by Occupational Safety and Health Administration (OSHA) [13]:

$$AFR = \frac{200000 \times \text{rrecordable accidents}}{\text{total hours worked}}$$

Data Analysis

Today’s world issues include many entries and one or some exits. Exact analysis of data in this condition needs a lot of time and effort and may cause problems like the “Curse of Dimensionality” [14]. Therefore, to overcome such issues, “feature selection” algorithms are used. Feature selection was done using IBM SPSS Modeler v14.2. Since the entries of this study included a wide range of different data such as a lot of quantitative and qualitative, continuous and discrete, ordinal and nominal data, Pearson χ^2 coefficient was used and the significance point for feature, the selection was considered as 0.95 [15].

Linear regression is a statistical technique for classifying the history according to the value of nominal entry data. Linear regression minimizes the difference between the real and predictable exited amounts by drawing a straight line according to the results. For modeling the causal factors on the studied accident frequency rate, multiple linear regression analysis was done using IBM SPSS v23.0 [16]. It must be noted that the statistical tests used in this study were two-way and the significance level was considered less than 0.05. In addition, for showing significance, P-value and regression coefficient (B) were used.

RESULTS AND DISCUSSION

Descriptive Results

The mean and standard deviation of AFR was 88.75±74.82. The descriptive findings of 41 independent causal factors are shown in Tables 1-4. The mean and standard deviation of age and work experience were 38.05±5.85 and 9.34±6.32 years, respectively. 50.1% of the study participants were married and the level of education of 32.1% was diploma. Also, 25.4% of the injured people were site man and time pressure and limitation were involved in 29.5% of the occupational accidents. In addition, 64.4% of the accidents were occurred between 15-23 pm (Table 1).

Table 1: personal and organizational factors (n=1142).

Studied factors		Frequency (%)
Personal factors		
Age(year)		38.05±5.85
Work experience (year)		9.34±6.32
Marital status	Single	571 (49.9%)
	Married	573 (50.1%)
Education	Diploma	367 (32.1%)
	Bachelor	685 (59.9%)
	Masters	92 (8.0%)
Organizational factors		
Job	Technician	815 (71.2%)
	Site man	291 (25.4%)
	Process engineer	38 (3.3%)
Employment status	Official	312 (27.3%)
	Contracting	832 (72.7%)
Time pressure and limitation		338 (29.5%)
Shift Work		683 (59.7%)
Time (hr)	One (07-15)	110 (9.6%)
	Two (15-23)	737 (64.4%)
	Three (23-07)	207 (18.1%)

Table 2: HSE training and risk management factors (n=1142).

Studied factors	Frequency (%)
Training factors	
Training at the time of employment	292 (25.6%)
Periodic training	464 (40.6%)
Training after accident	169 (14.6%)
PPE training	305 (26.7%)
industrial housekeeping training	182 (16.0%)
Training quantity	313 (27.4%)
Training quality	294 (25.7%)
Risk management factors	
HAZID	233 (20.5%)
Periodic Risk Assessment	536 (46.9%)
Special risk assessment	142 (12.4%)
Accidents analysis	204 (17.8%)
Safety survey	242 (21.2%)
Incident reporting system	160 (14.0%)
Engineering control measures	72 (6.3%)
Management control measures	235 (20.6%)
PPE	339 (29.7%)

The lowest and highest favorability of HSE training belonged to after accident training (14.8%) and periodic training (40.6%), respectively. The lowest and highest favorability of risk management factors was dedicated to engineering control measures (6.3%) and general risk assessment (46.9%), respectively (Table 2).

The highest and lowest portion of unsafe conditions belonged to chemical materials and compounds (42.5%) and defects in hand tools (9.3%). Being in unsafe positions (54.3%) and lack of knowledge and awareness about the potential dangers in the workplace (45.7%) had the highest portion of unsafe acts. The lowest portion of unsafe positions belonged to working without permission (22.1%) (Table 3).

The findings of the type of the chemical accidents showed that most accidents in these industries were because of chemical spillage (38.3%) and fire (32.4%) (Table 4).

Results of "Feature Selection"

The findings of measuring the amount and importance of causal factors on AFR in the studied chemical industries using Pearson χ^2 analysis is presented in Fig. 1. As shown, 30 factors out of seven studied groups were selected as the most important causal factors on AFR and were considered eligible for entering the modeling of effectiveness of these factors in accident frequency. It must be noted that the most important factors were level of education, shift work and time, periodic training and training after the accident, general risk assessment and accidents analysis, chemical materials and compounds, not using or inappropriate use of PPE and being in unsafe positions, chemical spillage, and fire with the importance rate of 1.0.

Results of "Multiple Linear Regression" modeling

The results of AFR modeling showed that 21 factors including age and level of education (personal), shift work, time and the type of employment (organizational), periodic and after accident training, PPE training, training content (HSE training), HAZID, periodic risk assessment,

Table 3: Unsafe condition and acts factors (n=1142).

Studied factor	Frequency (%)
Unsafe condition factors	
Improper and dangerous method	315 (27.6%)
Insufficient protection system	420 (36.8%)
Improper safety protection	293 (25.7%)
Structural and management defects	403 (35.3%)
Defect in hand tools	106 (9.3%)
Working with electric devices	233 (20.5%)
Chemical materials and compounds	485 (42.5%)
Unsafe acts factors	
Not using or improper using PPE	407 (35.6%)
Lack of knowledge	522 (45.7%)
Horseplay	364 (31.9%)
Being in dangerous positions	620 (54.3%)
Working without permission	252 (22.1%)

Table 4: Accident type factors (n=1142).

Accident type factors	Frequency (%)
Chemical spillage	437 (38.3%)
Contact with objects or power circuits	209 (18.3%)
Accidents caused by moving loads & materials	126 (11.0%)
Fire	370 (32.4%)

accidents investigation, engineering control measures and PPE (risk management), insufficient protection systems, improper safety protections, working with electrical devices and chemical compounds (unsafe condition), not using or inappropriate use of PPE, lack of knowledge about the hazards of the workplace, being in unsafe positions and working without permission (unsafe acts) and chemical spillage and fire (accident type) had a significant relation with AFR (P<0.005).

Generally, the regression equation is:

AFR= (-1.80 Age) + (-4.70 Education) + (2.54 Shift work) + (1.0 time-one) + (16.52 time-two) + (4.75 time-three) + (1.0 Official Employment) + (7.77 Contracting Employment) + (-29.91 Periodic Training) + (-14.42 Past-Accident Training) + (-15.53 PPE Training) + (-20.07 Training Content) + ((-27.04 HAZID) + (-17.34 Periodic Risk Assessment) + (-21.21 Accident Analysis) + (-16.77 Engineering Controls) + (-22.27 PPE) + (7.77 Insufficient Safety Systems) + (2.54 Defect in equipment) + (8.95 chemical compounds) + (14.64 Not using PPE) + (6.44 Lack of knowledge) + (11.33 being in dangerous situations) + (14.74 activity without permission) + (16.52 Spillage of chemicals) + (17.92 Fire)

It must be noted that the calculation of R^2 coefficient indicated that among the analyzed factors, organizational factors (R^2=0.879), unsafe conditions (R^2=0.829), and unsafe acts (R^2=0.805) had the highest correlation with the AFR (Table 5).

The regression results showed that implementing HAZID (hazard identification), using PPE (personal protective equipment), accident analysis, and content of provided training respectively were the most influential factors on accident frequency rate (with coefficient value (B)= -27.04, -22.27, -21.21, and -20.07).

Discussion

Chemical industries as the upstream production, are considered as the most sensitive part of the production. Dynamic of chemical processes and hazardous nature of materials and compounds with the role of management and human factors increase the risk of activities in these industries and make them prone to accidents [12, 17, 18].

The causal analysis in this study indicates this important and practical finding that accidents in chemical process industries follow the multifactor and systematic approach and their occurrence can be affected by defects in different structures and levels [10]. Moreover, because of the different functions of different factors, the role and portion of each causal factor are different. The results of using feature selection algorithm showed that the accident frequency in this industry as a complicated phenomenon and outcome could be affected by different factors with different percentages. Also, the regression analysis results confirmed this finding and revealed that the estimated and extracted factors in this algorithm had great importance in analyzing these accidents [19].

However, the mean age and work experience of the participants were less than 40 and 10 years, respectively. The regression findings indicated that it can be recognized as an important factor affecting the accident frequency rate. Accordingly, some studies revealed that personal factors are considered as one of the important reasons

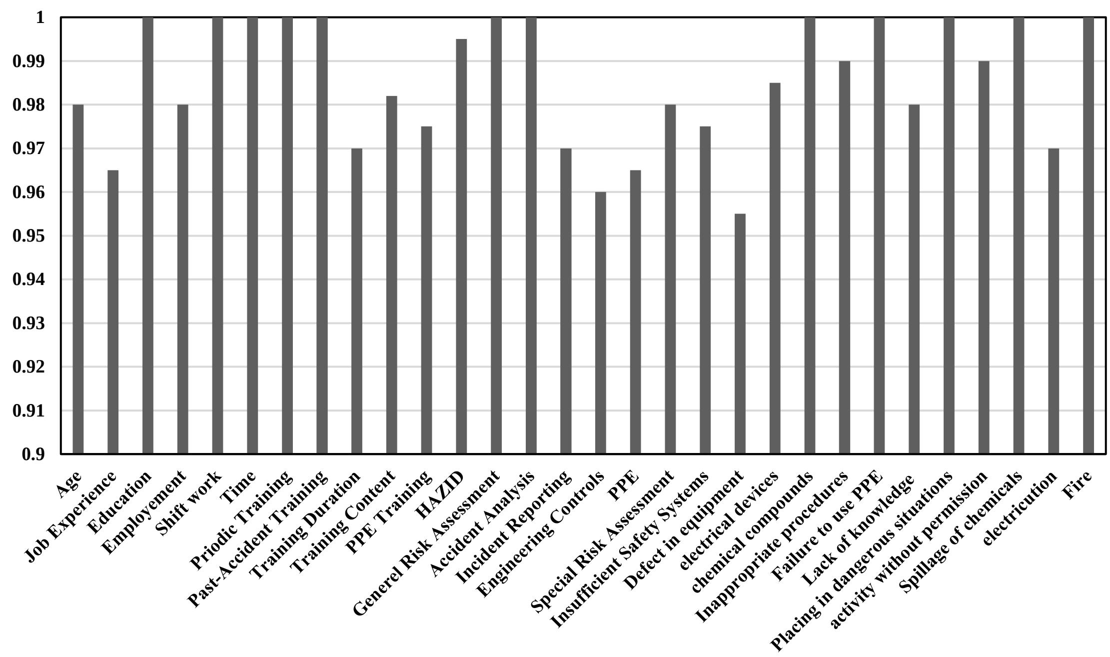

Fig. 1: The most important effective factors on the AFR.

in occupational accidents [20, 21]. Also, this study showed that the workers' mean age, work experience, and education were effective in the accidents. Results of some studies indicated that the accident rate had an inverse relationship with the victims' age [22]. Organizational factors and factors related to occupational environment and management structure are considered as basic factors in accident analysis and causes which can have different roles in the accident. These factors can cause different problems in implementing the work and its safe process, or under the effect of and interaction with other background factors indirectly influence occupational accidents [23].

Two-third of the occupational accidents occurred at time-two (15-23)., Our results revealed that this duration can be very important for the occurrence of occupational accidents. Therefore, the factor of *time* which was analyzed in this study with three-factors (time of accident, pressure and time limitation for activities as well as the shift work) must be considered as an undeniable reason for accidents especially in chemical industries, because it was proved that these factors could cause accidents and sometimes disastrous accidents [24].

The findings indicated that the favorability of training after the accident was very low (14.6%). The favorability of most of these factors was about a quarter (25.0%). The findings of models in this study showed that the favorability of training, factors had a significant relationship with the accidents rate. Different studies showed that insufficient and improper training could cause carelessness, dangerous behaviors, and different human errors and as a result cause an accident. Therefore, considering HSE training and improving training indexes improve the understanding and recognition of hazard sources, safety improvement and decrease of accidents [21].

The favorability of most risk management factors was less than 25%. Only the favorability of the periodic risk assessment and the use of PPE was higher than 25%. Furthermore, the results of regression modeling showed that these factors had the highest impact on the frequency of occupational accidents. Implementing risk management system in industries which are naturally threatened by different risks is very important and significantly reduces the accidents. According to the causal analysis findings, risk management factors including HAZID, periodic risk assessment, accident analysis, engineering controls, and PEE were identified as final factors in the frequency rate regression model. This indicated that in spite of the importance of these industries, the structure and processes of providing safety are weak and the function of the risk management system is not proper; therefore, an integrated

Table 5: AFR regression model results.

Remaining variables		B	SE	p-value†	$CI_{95\%}$	R^2
Age		-1.80	0.67	0.012	(-3.11)-(-0.48)	0.677
Education		-4.70	0.63	0.001	(-5.94)-(-3.46)	
Shift work		2.54	0.55	0.001	(1.46-3.61)	0.879
Time	One (07-15)	1.0				
	Two (15-23)	16.52	0.6	0.006	(15.34-17.62)	
	Three (23-07)	4.75	0.51	0.002	(3.75-5.75)	
Employment	Official	1.0				
	Contracting	7.77	0.76	0.001	(6.28-9.25)	
Periodic Training		-9.91	0.46	0.039	(-10.81)-(-9.0)	0.703
Past-Accident Training		-14.42	0.81	0.002	(-16.00)-(-12.83)	
PPE Training		-15.53	0.59	0.009	(-16.68)-(-14.37)	
Training Content		-20.07	0.57	0.001	(-21.18)-(-18.95)	
HAZID		-27.04	0.66	0.001	(-28.33)-(-25.74)	0.683
Periodic Risk Assessment		-17.34	0.55	0.002	(-18.41)-(-16.26)	
Accident Analysis		-21.21	0.74	0.005	(-22.66)-(-19.75)	
Engineering Controls		-16.77	0.63	0.009	(-18.0)-(-15.53)	
PPE		-22.27	0.69	0.001	(-23.62)-(-20.91)	
Insufficient Safety Systems		7.77	0.76	0.001	(6.28-9.25)	0.829
Defect in equipment		2.54	0.55	0.001	(1.46-3.61)	
chemical compounds		8.95	1.48	0.019	(6.04-11.85)	
Not using PPE		14.64	0.82	0.012	(13.03-16.24)	0.805
Lack of knowledge		6.44	1.78	0.032	(2.95-9.92)	
being in dangerous situations		11.33	0.67	0.001	(10.01-12.64)	
activity without permission		14.74	0.72	0.001	(13.32-16.15)	
Spillage of chemicals		16.52	0.6	0.006	(15.34-17.69)	0.790
Fire		17.92	0.7	0.011	(16.54-19.29)	

and practical structure for risk management in these industries is very important and essential [25-27].

Our findings regarding Unsafe conditions revealed that chemical materials and insufficient protection systems contributed to 42.5% and 36.8% of occupational accidents, respectively. In addition, regression results indicated that these two factors remain in the final model and are important as unsafe conditions for the occurrence of occupational accidents. Unsafe conditions are considered as an inseparable pillar of the integrated causes of chemical accidents. The findings revealed that factors such as insufficient safety systems, structural and management defects in using the equipment and chemical compounds significantly increased the chance of an accident. Unsafe acts have the highest portion in occupational accidents [8, 28].

Being in dangerous positions (54.3%) and lack of knowledge (45.7%), as unsafe acts, had the largest contribution in the studied accidents. Also, findings of regression modeling revealed that two factors of activity without permission and not using PPE remained in the final regression model, as unsafe acts affecting the frequency of occupational accidents. It has been reported in some studies that unsafe personal behaviors such as not using safety equipment and personal protection, being in unsafe positions, working without permission, and doing dangerous behavior, because of weak safety attitude, such as horseplay can cause different accidents influenced by other important factors like demographic and organizational factors and workplace conditions [29, 30].

Although in many studies the kind of outbreak of accidents is not considered as the cause of the accident, taking this factor into account can be a very important step in identifying possible accidents and then analyzing these types of accidents in the chemical industry. Results of this model showed that factors related to the type of accidents that caused accidents, such as chemical spillage and fire, had a direct, positive, and significant relationship with the frequency rate of accidents in chemical industries. Therefore, these are considered as important factors in occupational accidents in these industries and have an important role in identifying and analysis of factors and casual reasons for the outbreaks [10].

Finally, this study which was done in a large statistical sample size and on a significant number of accidents confirmed the multi-factor nature of accidents in chemical industries and indicated that the accidents in these industries were the result of the defects in the relation among humans, the environment, and work organization.

CONCLUSIONS

The results of this comprehensive study which was obtained using two different practical techniques scientifically approved the multi-reason and complicated nature of accidents in chemical industries and in this way promoted the understanding of this phenomenon. These causal factors showed that how different factors contributed and were involved in accidents occurring in the industry. Therefore, considering all the factors and classifying them can be very useful in the effectiveness of them on accidents in a comprehensive HSE program in these industries.

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REFERENCES

[1] Jiao W., Xiang S., Quantitative Safety and Health Assessment Based on Fuzzy Inference and AHP at Preliminary Design Stage, *Iranian Journal of Chemistry and Chemical Engineering (IJCCE)*, **35(4)**: 153-165 (2016).

[2] Cheraghi M., Bagherian-Sahlavani A., Mohammad Fam I., Toxic Chemical Release Hazard Distance Determination Using Chemical Exposure Index (CEI) in a Gas Refinery, *Iranian Journal of Chemistry and Chemical Engineering (IJCCE)*, **38(4)**: 273-291 (2018).

[3] Choobineh A., Soltanzadeh A., Tabatabaee H., Jahangiri M., Neghab M., Khavaji, S., Comparison of Shift Work-Related Health Problems in 12-Hour Shift Schedules of Petrochemical Industries, *Iran Occupational Health*, **7(4)**: 8-0 (2011).

[4] Jafari M.J., Nouraei M., Pouakian M., Torabi S.A., Rafiee Miandashti M., Mohammadi H.., Exploring Inherent Process Safety Indicators and Approaches for Their Estimation: A Systematic Review. *Journal of Loss Prevention in the Process Industries*, **52**: 66-80 (2018).

[5] MARSH, The 100 Largest Losses 1974-2013; Large Property Damage Losses in the Hydrocarbon Industry, 23rd ed. (2015).

[6] Jafari M.J., et al., Barriers to Adopting Inherently Safer Design Philosophy in Iran, *Process Safety Progress*, (2017).

[7] Soltanzadeh A., Mohammadfam I., Moghimbeygi A., Ghiasvand R., Exploring Causal Factors on the Severity Rate of Occupational Accidents in Construction Worksites. *International Journal of Civil Engineering*, **15(7)**: 959-965 (2017).

[8] Mohammadfam I., Soltanzadeh A., Moghimbeigi A., Akbarzadeh M., Confirmatory Factor Analysis of Occupational Injuries: Presenting an Analytical Tool, *Trauma Monthly*, **22(2)**: 1-9 (2017).

[9] Rathnayaka S., Khan F., Amyotte P., Accident Modeling Approach for Safety Assessment in an LNG Processing Facility, *Journal of Loss Prevention in the Process Industries*, **25(2)**: 414-423 (2012).

[10] Tauseef S., Abbasi T., Abbasi S.A., Development of a New Chemical Process-Industry Accident Database to Assist in Past Accident Analysis, *Journal of Loss Prevention in the Process Industries*, **24(4)**: 426-431 (2011).

[11] Abdolhamidzadeh B., Rashtchian D., Ashuri E., A New Methodology for Frequency Estimation of Second or Higher Level Domino Accidents in Chemical And Petrochemical Plants Using Monte Carlo Simulation, *Iranian Journal of Chemistry and Chemical Engineering (IJCCE)*, **28**(4): 21-28 (2009).

[12] Abdolhamidzadeh B., Abbasi T., Rashtchian D., Abbasi, S.A., A New Method for Assessing Domino Effect in Chemical Process Industry, *Journal Of Hazardous Materials*, **182**(1-3): 416-426 (2010).

[13] O.S.H.A., "Safety & Health Management System Etool", OSHA (2012)

[14] Hinrichs A., Novak E., Ullrich M., Woźniakowski H., The Curse of Dimensionality for Numerical Integration of Smooth Functions II, *Journal of Complexity*, **30(2)**: 117-143 (2014).

[15] Biesiada J., Duch W., "Feature Selection for High-Dimensional Data—A Pearson Redundancy Based Filter in Computer Recognition Systems", 2., Springer, 242-249 (2007).

[16] Seber G.A., Lee A.J., "Linear Regression Analysis", Vol. 329. John Wiley & Sons, Inc. (2012).

[17] Lees F., Lees' Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control, Butterworth-Heinemann (2012).

[18] Nassiri M., Kaykhaii M., Hashemi S.H., Sepahi M., Spectrophotometric Determination of Formaldehyde in Seawater Samples after In-situ Derivatization and Dispersive Liquid-Liquid Microextraction, *Iranian Journal of Chemistry and Chemical Engineering (IJCCE)*, **37(1)**:89-97 (2018).

[19] Mohammadfam I., Soltanzadeh A., Moghimbeigi A., Savareh B.A., Use of Artificial Neural Networks (Anns) for the Analysis and Modeling of Factors that Affect Occupational Injuries in Large Construction Industries, *Electronic physician*, **7(7)**: 1515 (2015).

[20] Mohammadfam I., Soltanzadeh A., Moghimbeigi A., Akbarzadeh M., Modeling of Individual and Organizational Factors Affecting Traumatic Occupational Injuries Based on the Structural Equation Modeling: A Case Study in Large Construction Industries, *Archives of Trauma Research*, **5(3)**: 1-7 (2016).

[21] Vinodkumar M., Bhasi M., Safety Climate Factors and Its Relationship with Accidents and Personal Attributes in the Chemical Industry, *Safety Science*, **47(5)**: 659-667 (2009).

[22] Horwitz I.B., McCall B.P., Disabling and Fatal Occupational Claim Rates, Risks, and Costs in the Oregon Construction Industry 1990–1997, *Journal of Occupational and Environmental Hygiene*, **1(10)**: 688-698 (2004).

[23] Nivolianitou Z., Konstandinidou M., Michalis C., Statistical Analysis of Major Accidents in Petrochemical Industry Notified to the Major Accident Reporting System (MARS), *Journal of Hazardous Materials*, **137(1)**: 1-7 (2006).

[24] Harrington J.M., Health Effects of Shift Work and Extended Hours of Work, *Occupational and Environmental Medicine*, **58(1)**: 68-72 (2001).

[25] Badri N., Nourai F., Rashtchian D., The Role of Quantitative Risk Assessment in Improving Hazardous Installations Siting: A Case Study, *Iranian Journal of Chemistry and Chemical Engineering (IJCCE)*, **30(4)**: 113-119 (2011).

[26] Soltanzadeh A., Mohammadfam I., Moghimbeigi A., Ghiasvand R., Key Factors Contributing to Accident Severity Rate in Construction Industry in Iran: A Regression Modelling Approach/Primjena Regresijskog Modela u Analizi Ključnih Čimbenika Koji Pridonose Težini Nesreća u Građevinskoj Industriji U Iranu, *Archives of Industrial Hygiene and Toxicology*, **67(1)**: 47-53 (2016).

[27] Mohammadfam I., Soltanzadeh A., Arsang-Jang S., Mohammadi H., Structural Equation Modeling Modeling (SEM) of Occupational Accidents Size Based on Risk Management Factors; A Field Study in Process Industries, *Health Scope*, **8**(1): 7 (2019).

[28] Reason J., *The Human Contribution: Unsafe Acts, Accidents and Heroic Recoveries*. CRC Press (2017).

[29] Darbra R., Palacios A., Casal J., Domino Effect in Chemical Accidents: Main Features and Accident Sequences, *Journal of Hazardous Materials*, **183(1-3)**: 565-573 (2010).

[30] Strauch B., "Investigating Human Error: Incidents, Accidents, and Complex Systems", CRC Press (2017).