Archives of Occupational Health | Volume 6 | Issue 3 | July 2022 | 1309-15.

Case Study

Analysis of Factors Affecting Safety Outcomes in Construction Projects: A Field Study in One of the Large Construction Projects in Iran

Samira Ghiyasi [1], Milad Koushki Rad [2], Ahmad Soltanzadeh [3*], Mona Ghafourian [4], Hadi Najafiyan [5]

[1] Department of Environmental Engineering, Engineering Faculty, Central Tehran Branch, Islamic Azad University, Tehran, Iran• [2] Department of Health, Safety, Environment (HSE), Engineering Faculty, Central Tehran Branch, Islamic Azad University, Tehran, Iran• [3] Department of Occupational Health & Safety Engineering, Faculty of Health, Qom University of Medical Sciences, Qom, Iran• [4] Department of Occupational Health Engineering, Shahr-e-Rey Health and Medical Network, Tehran University of Medical Sciences, Tehran, Iran• [5] Department of Industrial Management, Management Faculty. Arak Branch, Islamic Azad University, Arak. Iran• *Corresponding author: Ahmad Soltanzadeh, Email: soltanzadeh.ahmad@gmail.com

ABSTRACT

Background: In addition to detrimental effects on economy and people, safety consequences could negatively affect the efficiency and productivity of construction projects. This study aims to analyze the factors affecting safety consequences in construction projects. **Method:** This was a descriptive-analytical and cross-sectional study conducted in 2020 in a large construction project (a sewage treatment plant) in Tehran. The 250 people working in this construction project participated in this study. Data for this study were collected based on a safety parameter assessment checklist. Independent variables in this study were age and work experience, education, daily working hours, harmful physical and ergonomic factors, and unsafe practices. Analytical variables included Accident Frequency Rate (AFR) and Safe-T score. A multiple linear regression model and SPSS version 22.0 were used for data analysis. **Results:** Age and working experience of the participants were 35.8± 9.8 and 3.4± 1.7, respectively, and nearly half of them had high school diploma (47.6%). AFR for two consecutive years of 2019 and 2020, were 5.16 and 4.43 accidents, respectively. Safe-T-Score was calculated as – 0.011. The results of regression analysis revealed a significant relation ($p<0.05$) between Safe-T-score and working experience, daily working hours, unsafe practices, noise and thermal stress exposure, carrying and moving loads, and safety risk factors variables. **Conclusion:** Results of this study indicated that although safety performance at the studied construction site was relatively favorable, several variables had an impact on the safety consequences of the project. Hence, the safety consequences of construction projects might benefit from the results of this study.

Keywords: Construction Industry; Safety; accident; Iran

Introduction

Construction projects have a crucial role in the economic development of countries. Neglecting safety has unfavorable consequences which could endanger the organization's existence and have catastrophic results. In the past two decades, more than 26,000 construction workers in the United States have died in their workplaces. This equates the death of five active construction project workers on each working day. Despite the fact that precautions have been

Citation: Ghiyasi S, Koushki Rad M, Soltanzadeh A, Ghafourian M, Najafiyan H. **Analysis of Factors Affecting Safety Outcomes in Construction Projects: A Field Study in One of the Large Construction Projects in Iran.** Archives of Occupational Health. 2022; 6(3): 1309-15.
Article History: Received: 8 March 2022; Revised: 03 June 2022; Accepted: 26 July 2022

[DOI: 10.18502/aoh.v6i3.10706]

offered for construction projects since 30 years ago, the roles and responsibilities associated with various departments for safety have either not been implemented or are ineffectively applied. [1-3]

Construction project workers are involved in a variety of activities with different risks. Construction workers are both directly and indirectly at risk of a variety of accidents. Supervisors and project managers are also at risk of construction-related activities [4, 5]. According to some findings, people's awareness of safety issues and ability to handle risky situations should serve as the foundation for safety responsibility at construction sites [6].

The International Labor Organization estimates that 360 million occupational accidents occur each year, and about 2,300,000 deaths occur as a result of these accidents. More than 4% of the countries' gross national products is consumed by the compensation for these accidents. According to the statistics of Iran's construction engineering organization, more than 47% of occupational accidents involve construction employees. These statistics and figures demonstrate the high frequency of construction site injuries brought on by disregard for safety precautions. Occupational accidents and the consequent injuries (death, disability, etc.) impose a significant financial burden on employers, employees, and society, and could also cause pain and suffering to the worker's life at work, home, and in society [7]. Other consequences for construction projects might result from these accidents [8].

According to the findings of a some researches analyzing the variables affecting safety performance in construction projects, managers and supervisors who communicate with workers have the greatest impact on safety. Another significant finding is that everyone involved in a construction project contributes to the safety system, and is ultimately accountable for its effectiveness [9, 10].

Therefore, without considering safety, it is impossible to prevent all accidents and work-related injuries due to sustainable development and productivity growth. Hence, assessing and analyzing the safety situation and its consequences is one of the activities that could lead to a reduction in the frequency of accidents and injuries. In other words, this result could only be achieved in settings where the workforce experiences the least amount of physical discomfort at work. With this in mind, this study was designed and conducted with the aim of analyzing the safety outcomes of large construction projects in Iran.

Method

This was a descriptive-analytical and cross-sectional study conducted in 2020 in one of the large construction projects in Iran. The study population included the employees of a construction project in Tehran. Everyone was allowed to participate in this study. Sampling was done using a simple random method. Therefore, all individuals who volunteered to participate in the study were included. The exclusion criteria included individuals who refused to participate in the study for any reason. In addition, those whose data were not fully included in the study were also excluded. This construction site was one of the largest industrial projects involving construction of a sewage treatment plant in Tehran. It involved 532 employees, contractors, and supervisors.

The sample size was estimated using the Cochran formula, which is one of the most commonly used methods for calculating sample size. The expected sample size of was 224. Considering the possibility of 10% of participants dropping out, researchers included 250 workers in the study.

Data collection tool and method

Since this study was conducted in 2020, its data refer to two years earlier, 2018 and 2019. To assess the factors affecting safety outcomes, a researcher-made checklist was used to collect data.

The data for this study included personal and demographic, occupational and organizational

[DOI: 10.18502/aoh.v6i3.10706]

variables, safety risk factors, and safety outcomes. These variables include age, job experience, education, daily, weekly, and monthly working hours, type of activity, organizational attitude and organizational climate, history of accidents, quasi-accidents and unsafe practices, exposure to excessive amounts of harmful physical factors (including sound, vibration, thermal stress, and UV radiation) and ergonomics (improper posture, repetitive movements and carrying and moving loads), safety risk factors (including working at height, heavy construction activity, welding and cutting, exposure to electricity, unsuitable housekeeping of the workplace, outdoor work, uneven surfaces, and inadequate usage of appropriate personal protection equipment), and safety outcomes (including Accident Frequency Rate (AFR) and Safe-T-Score). It is noteworthy that physical and ergonomic risk factors have been assessed in compliance with the acceptable exposure limit (TLV) of the ACGIH organization and the occupational exposure limits of Iran [11].

According to Occupational Safety and Health Administration (OSHA), accident frequency rate indicates the number of accidents that result in lost working hours during a specified number of working hours within a certain time period [12].

Safe-T-Score is a dimensionless index and a statistical index of T-student. This formula yields an integer with an algebraic sign. If this algebraic sign is positive, it suggests that the organization's performance has worsened; if it is negative, it suggests that the organization's safety performance has improved compared to the past (Equation 1) [12].

$$Safe - T - score = \frac{AFR_{ny} - AFR_{ly}}{\sqrt{\frac{AFR_{ny}}{\frac{W_n}{200000}}}}$$

Data analysis

Data analysis for this study was done using SPSS statistical software version 22.0. Factors affecting Safe-T-Score were modeled in this study using the multiple linear regression model.

Results

The mean and standard deviation of age and job experience were 53.8± 9.8 and 3.4± 1.7 years, respectively. Nearly half of the participants had a high school diploma (47.6%). The lowest frequency was related to people with a bachelor's degree or higher (5.2%). In two educational groups, high school diploma and associate degree, the frequency of the studied subjects was 26.4% and 20.8%, respectively. For the individuals studied in this construction project, the mean and standard deviation of working hours per day, week, and month were, respectively, 8.24±0.95, 55.63±8.16, and 197±24.12 hours (Table 1).

Exposure to physical factors -noise, vibration, thermal stress, and UV radiation- was hazardous for 23.2%, 10.0%, 26.4%, and 26.4% of the workers respectively. According to the results of the evaluation of harmful ergonomic factors, including improper posture, repetitive movements, and carrying and moving loads, this study revealed that 44.8%, 23.2%, and 7.2% of the participants had, respectively, poor posture, repetitive movements, and non-ergonomic carrying and moving of loads in this project (Table 2).

Findings related to safety risk factors in the studied environment showed that most the exposures were related to working in open space and uneven surfaces (59.2%), improper housekeeping (57.6%), and heavy construction activity (51.2%). In addition, welding and cutting, exposure to electricity and not using proper personal protection equipment was related to the lowest exposure to safety risk factors (9.6%, 14.0%, and 14.4%, respectively) (Figure 1).

The accident rates in this project in 2018 and 2019 were 5.6% and 4.8%. These findings revealed that the number of accidents has decreased during these two years. The frequency of this event in

[DOI: 10.18502/aoh.v6i3.10706]

2018 and 2019 was 16.8% and 18.8%, respectively, according to the analysis of the results of the near-misses recorded in two consecutive years. These results demonstrated that there was a rise in near-misses in this construction project. The frequency of unsafe practices discovered throughout these two years was equal (51.2%). The results of the AFR and Safe-T-Score in two consecutive years, 2018 and 2019, were 5.16 and 4.43 accidents, respectively. The Safe-T-Score was calculated as –0.011 (Table 3).

The results of regression modeling of the effective factors regarding the Safe-T-Score showed that the variables of work experience, daily working hours, unsafe practices, exposure to harmful physical factors (noise and thermal stress), and ergonomics (carrying and moving loads) and various types of safety risk factors had a significant relation with Safe-T-Score ($p<0.05$). The highest and lowest correlations in this modeling were evaluated for unsafe practices (impact ration= 4.4) and carrying and moving loads (impact factor= 1.44) (Table 4).

Table 1. The Results of Demographic and Occupational Characteristics of the Participants (n=250)

Variable		Mean/Frequency	SD/%
Age (year)		35.8	9.8
Job experience (year)		3.4	1.7
Education	Under high school diploma	119	47.6
	High school diploma	66	26.4
	Associate degree	52	20.8
	Bachelor's degree/higher	13	5.2
Work hours	Per day	8.24	0.95
	Per week	55.63	8.16
	Per month	197.12	24.12

Table 2. Evaluation of Findings Regarding Exposure to Physical and Ergonomic Harmful Agents (n=250)

Variable		Frequency	%
Physical harmful agents	Noise	58	23.2
	Vibration	25	10.0
	Heat stress	66	26.4
	UV	66	26.4
Ergonomic harmful agents	Awkward posture	112	44.8
	Repetitive motions	58	23.2
	Material handling	18	7.2

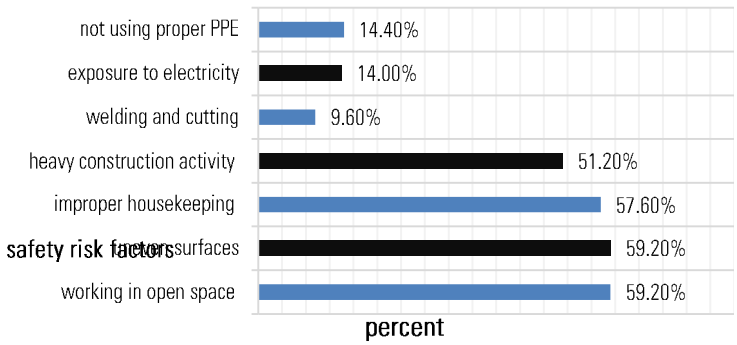

Figure 1. Findings Related to Exposure to Safety Risk Factors (n=250)

[DOI: 10.18502/aoh.v6i3.10706]

Table 3. Findings of Incident Records and Safety Outcomes

Variable	2018		2019	
	Frequency	%	Frequency	%
Accident	14	5.6	12	4.8
Near-miss	42	16.8	47	18.8
Unsafe acts	128	51.2	128	51.2
AFR	5.16		4.43	
Safe-T-Score	- 0.011			

Table 4. Modeling the Results Regarding Safe-T-Score for the Construction Project

Independent variable	Regression coefficient	Standard error	Lower CI	Upper CI	p-value
Job experience	1.92	0.07	1.7828	2.0572	0.010
Working hours per day	1.74	0.23	1.2892	2.1908	0.007
Unsafe acts	4.4	1.45	1.558	7.242	0.003
Noise	1.92	0.22	1.4888	2.3512	0.003
Heat stress	2.18	0.38	1.4352	2.9248	0.024
Material handling	1.44	0.06	1.3224	1.5576	0.040
Safety risk factors	3.12	1.02	1.1208	5.1192	0.018

Discussion

The results of this study indicated that safety performance is poor on construction sites and projects. According to some studies, the safety of construction projects is not as strong as it is in other industrial fields, and a variety of events, from minor accidents to fatal ones, occur in this sector [4, 5, 13]. In the field of construction safety, numerous studies have been conducted, each of which examined a few risk factors [1, 5, 14, 15]. A comprehensive approach to modeling safety consequences in the form of safety indicators in construction projects could aid the development of safety strategies to prevent accidents and mitigate their damage.

Furthermore, the results suggested that there could be a variety of safety failures in construction projects. Numerous studies have revealed that a significant number of fatalities and accidents are related to construction projects [1, 5, 11]. All team members on construction projects are directly exposed to safety risks and a variety of harmful factors, including physical and ergonomic hazards. In addition to endangering workers in many ways, these risks have an effect on the project's costs, schedule, and quality [14, 16]. According to the results of this study, authors can also add high-risk environmental circumstances, including noise, vibration, dust, and direct exposure to environmental thermal stress, to the list of factors that put these projects at high risk [17, 18]. Moreover, the results of this study indicated that the prevailing claim that, "the construction sector is one of the most dangerous sectors in the industry", has been validated despite the fact that the safety results in this large construction project were estimated to be below normal and usual limits. This is evidenced by the occurrence and prevalence of various types of events throughout the study [5, 9].

Numerous studies have highlighted the multiple causation theory in terms of the frequency of accidents, different types of injuries, and the outcomes that jeopardize worker safety, especially in the construction industry [4, 5, 9]. The results of the study, presented in the form of a regression analysis model for the Safe-T-Score in construction projects, showed that a number of risk factors, including personal and work-related variables such as work experience [10, 15] and time of accident [5, 15], exposure to physical and ergonomic risk factors [19]. Different types of risks are known to be significant risk factors for the frequency of safety consequences in construction projects [5, 10], safety factors as well as environmental conditions in these projects, and variables such as improper housekeeping, the presence of defective equipment, and unsafe activities [9, 20]. There is a significant relationship between these risk factors and safety indicators. These findings are consistent with those of other studies [9, 10, 14]. The environment of construction projects is a "world of potential accidents and disasters" which can lead to an accident or catastrophic emergency if even the slightest force or unintended change is applied [21].

The results of the regression modeling of the variables related to the safety outcomes in this large construction project revealed that the role of workers in the frequency of accidents in these projects was very prominent. This is due to the frequency of unsafe

[DOI: 10.18502/aoh.v6i3.10706]

practices. In addition, a number of risk factors, including personal variables, environmental conditions, safety training, as well as the results and functions of hazard identification and risk assessment, could affect unsafe practices in these projects. The frequency and severity of these risks could change as a result of each risk factor [22]. In a study, Mohammadfam et al. noticed that the severity of occupational accidents has a substantial correlation with safety training factors and safety risk management and assessment parameters. Inadequate and ineffective training could result in carelessness, unsafe behaviors, and various types of human error, which could affect the frequency of accidents and their consequences on construction projects [10]. Likewise, several studies have demonstrated that educational interventions could enhance risk perception and hazard identification [23]. Consequently, focusing on safety training and improving training indicators will increase risk perception and identification in these projects, improve safety and lessen the frequency of accidents and injuries. The following could help to reduce accidents and their consequences in these projects: Regular and systematic activities in the field of identifying safety risks in construction projects (using a safety checklist), carrying out a safety risk assessment before the start of the project ,developing extensive and practical guidelines for recording and reporting unsafe conditions and anomalies, and using them in after-work meetings, observing workplace housekeeping in high-risk environments of construction projects, along with monitoring the quantity and quality of protection equipment (PPE) and its proper use.

Conclusion

Various personal and occupational variables, exposure to physical and ergonomic risk factors, and other conditions that are more unusual in construction environments than in production contexts affect the risk of various safety outcomes such as the Safe-T-Score. Accordingly, the results of the regression modeling indicated that the variables of work experience, daily working hours, unsafe practices, exposure to harmful physical factors (including noise and thermal stress), exposure to harmful ergonomic factors, (including carrying and moving loads), as well as various safety risk factors had a significant correlation with Safe-T-Score ($p<0.05$). The conclusion drawn from the overall results of this study is that, despite the unstable conditions present in construction projects, it is still possible to directly and indirectly influence the frequency of all types of traumatic occupational incidents by promoting and improving safety-related parameters.

Conflict of interest

All authors declared no conflict of interest.

Acknowledgement

This study is derived from a master's thesis regarding Health, Safety and Environment Management (HSE) at Islamic Azad University, Central Tehran University (code: 10129053249241213991656555).

Authors Contribution

Conceptual design: Ahmad Soltanzadeh; Samira Ghiyasi

Data gathering: Milad Koushki Rad

Data analysis and modelling: Ahmad Soltanzadeh; Mona Ghafourian

Manuscript preparation: Ahmad Soltanzadeh; Hadi Najafiyan; Samira Ghiyasi

Reference

1. Passmore D, Chae C, Borkovskaya V, Baker R, Yim J-H, editors. Severity of US construction worker injuries, 2015-2017. E3S Web of Conferences; 2019: EDP Sciences.
2. Ghorbani A, Soltanzadeh A. An Investigation of the Attitudes of Health & Safety Personnel toward Safety in Construction Projects. Archives of Occupational Health. 2019;3(1):291-8.
3. Motamedzadeh M, Mahdinia M, Darvishi E, Shahidi R, karimi A. Investigating the Effect of Insomnia Severity on the Employees'

[DOI: 10.18502/aoh.v6i3.10706]

Work Ability in Construction Projects. Archives of Occupational Health. 2020;4(3):594-9.
4. 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. 2017;15(7):959-65.
5. Soltanzadeh A, Heidari H, Mahdinia M, Mohammadi H, Mohammadbeigi A, Mohammadfam I. Path analysis of occupational injuries based on the structural equation modeling approach: a retrospective study in the construction industry. Iran occupational health. 2019;16(3):47-57.
6. Grill M, Nielsen K, Grytnes R, Pousette A, Törner M. The leadership practices of construction site managers and their influence on occupational safety: an observational study of transformational and passive/avoidant leadership. Construction management and economics. 2019;37(5):278-93.
7. Esmaeili A, Rezaeian M, Sheikh Fathollahi M, Mobini M. The Frequency of occupational accidents in Rafsanjan city in 2008-2012. Health and Development Journal. 2015;4(3):200-8.
8. Alizadeh Savareh B, Mahdinia M, Ghiyasi S, Rahimi J, Soltanzadeh A. Accident Modeling in Small-Scale Construction Projects Based on Artificial Neural Networks. Journal of Human Environment and Health Promotion. 2019;5(3):121-6.
9. Soltanzadeh A, Mohammadfam I, Moghimbeigi A, Akbarzadeh M, Ghiasvand R. Key factors contributing to accident severity rate in construction industry in Iran: a regression modelling approach. Arhiv za higijenu rada i toksikologiju. 2016;67(1):47-53.
10. Mohammadfam I, Soltanzadeh A, Moghimbeigi A, Akbarzadeh M. Confirmatory factor analysis of occupational injuries: presenting an analytical tool. Trauma monthly. 2017;22(2).
11. Smith CJ, Perfetti TA. Improving the ACGIH threshold limit value (TLV) process. Toxicology Research and Application. 2018;2:2397847318801758.
12. Laal F, Pouyakian M, Madvari RF, Khoshakhlagh AH, Halvani GH. Investigating the impact of establishing integrated management systems on accidents and safety performance indices: A case study. Safety and health at work. 2019;10(1): 54-60.
13. Darvishi E, Moradi A. Assessment of Workers' Exposure to Cement Dust, in Concrete Batching Unit of a Dam Project before and after Control Measures. Health and Development Journal. 2014;2(4).
14. Pereira E, Taghaddos H, Hermann R, Han S, Abourizk S, editors. A Conceptual Accident Causation Model Based On The Incident Root Causes. 5th International/11th Construction Specialty Conference; 2015.
15. 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. 2016;5(3).
16. Dadfarma V, soltanzadeh a, Ghiyasi S. Analysis of Occupational Accidents: A Data Mining Study. Archives of Occupational Health. 2021;5(3):1051-8.
17. Pinto A, Nunes IL, Ribeiro RA. Occupational risk assessment in construction industry–Overview and reflection. Safety science. 2011;49(5):616-24.
18. Mohammadi H, Heidari H, Arsang Jang S, Ghafourian M, Soltanzadeh A. Relationship between Reactive and proactive Safety Indices: A Case Study in the Chemical Industries. Archives of Occupational Health. 2020;4(4):842-8.
19. Mirmohammadi ST, Gholizadeh Abbasabad A, Mousavinasab SN, Hosseininejad SE, Alizadeh H. Ergonomic Evaluation of the Manual Material Handling Tasks in the Food Industries of Malard County Using the 3D. Health and Development Journal. 2019;8(2):175-86.
20. Soltanzadeh A, Heidari H, Mohammadi H, Mohammadbeigi A, Sarsangi V, Darakhshan Jazari M. Comprehensive causal analysis of occupational accidents' severity in the chemical industries; A field study based on feature selection and multiple linear regression techniques. Journal of Health and safety at Work. 2019;9(4):298-310.
21. Zhang F, Fleyeh H, Wang X, Lu M. Construction site accident analysis using text mining and natural language processing techniques. Automation in Construction. 2019;99:238-48.
22. Zhang J, Zhang W, Xu P, Chen N. Applicability of accident analysis methods to Chinese construction accidents. Journal of safety research. 2019;68:187-96.
23. Perlman A, Sacks R, Barak R. Hazard recognition and risk perception in construction. Safety science. 2014;64:22-31.

[DOI: 10.18502/aoh.v6i3.10706]