

# Analyzing the causes of falling from height accidents in construction projects with analytical hierarchy process (AHP)

Shahram Vosoughi<sup>1,\*</sup>, Mohammad Hossein Chalak<sup>2</sup>, Sajjad Rostamzadeh<sup>3</sup>, Manouchehr Jahanpanah<sup>4</sup>, Hossein Ebrahimi<sup>5</sup>

<sup>1</sup> Department of Occupational Health Engineering, Faculty of Health, Occupational Health Research Center, Iran University of Medical Sciences, Tehran, Iran

<sup>2</sup> Department of Occupational Health Engineering, Faculty of Health, Iran University of Medical Sciences, Tehran, Iran

<sup>3</sup> Occupational Health Research Center, Iran University of Medical Sciences, Tehran, Iran

<sup>4</sup> Department of Occupational Health Engineering, Safety Engineering, Tehran, Iran

<sup>5</sup> Department of Occupational Health Engineering, Faculty of Health, Iran University of Medical Sciences, Tehran, Iran

## Abstract

**Introduction:** Fall from height is one of the main causes of death in the construction workers. Therefore, this study aimed to identify and prioritize the factors affecting falls from height accidents in construction industry.

**Material and method:** A descriptive-analytical study was conducted on five constructional projects in Pars Jonoobi industrial region, Iran. All of the reported events from 2011 to 2015 were investigated and 74 out of 377 occupational accidents were considered as falls from height accidents. The identified factors and sub-factors were divided into 3 main factors including individual, organizational and environmental factors and 14 sub-factors based on the experts' opinion. Then, AHP method was used to determine and prioritize of the factors and sub-factors.

**Results:** The results of hierarchical analysis of fall from height accidents causes showed that environmental, individual, and organizational factors with weights of 0.359, 0.351, and 0.290 were in the first, second, third priorities, respectively. Meanwhile, among all examined sub-factors, work platform elevation, mental/occupational stresses and safety culture had the highest priority.

**Conclusion:** Paying attention to the strategies that enhance the safety culture of employees and reduce their occupational stress levels in the workplace can be very effective in preventing of fall from height accidents.

**Keywords:** Construction Projects; Hierarchical Analysis; Fall from Height; Accident Management.

\*Corresponding Author: Shahram Vosoughi

Email Address: vosoughi.sh@iums.ac.ir

## 1. Introduction

Work-related accidents are the third cause of death in the world and the second in Iran after traffic accidents [1]. Construction workers are at higher risk of injuries than other industries due to the dynamic nature of construction activities as well as the instant changes in the working conditions [2]. Work-related injuries and mortalities resulting from the construction projects not only lead to the loss of human life and its quality but also delay the process of the project and impose financial losses on employers and workers. In the previous studies performed in construction sites, fall from height is introduced as the most important factor that attributed to death, followed by getting stuck, collision with objects, and cardiac attacks [3]. Most researchers have suggested that occupational injuries and accidents occur as a result of three main factors, namely unsafe acts, unsafe conditions and unpredictable causes. Therefore, the unsafe behavior of employees is one of the main and direct causes of occupational accidents [4], and more recent studies have contributed 76% of all accidents to the individual factors and 20% to both individual and environmental factors [5]. In addition, organizational factors have been recognized as an important indicator of safety in the industries, and hence investigating on this topic is vital to prevent future accidents [6,7].

The Analytic Hierarchy Process, normally called AHP, is a powerful yet simple method for making decisions. This method allows us to determine the weights and prioritization (significances) of hierarchically non-structured or particular hierarchical level criteria in respect of those belonging to a higher level. In the current research, while investigating and identifying the factors affecting fall from height accidents in the construction projects, identification and prioritization of factors affecting falls from height accidents carried out using Analytic Hierarchy Process (AHP) method.

## 2. Material and Methods

In this descriptive-analytical study, the surveyed

population was 4000 workers of five construction projects of a gas refinery in southern part of Iran. After collecting the research data, 74 fall from height accidents were selected based on the TMEPM accident analysis model. Also, in order to divide the accident causes, the method provided by Shiliang et al. was used. The TMEPM model classifies the factors influencing work-related accidents into five categories: tasks, equipment, work environment, personnel, and management [8].

Using the Integrated Management System (IMS) information, factors and sub-factors affecting the occurrence of falling from height accidents in the construction projects were determined. The causes of fall from the height were classified into 3 main factors including individual, organizational and environmental factors and 14 sub-factors based on the experts' opinion (N=10). The reliability of the experts' questionnaire, which was designed based on comparison of the couples, was approved according to the compatibility rate of the paired comparison. Then, using the AHP method and Expert Choice software version 11, the relative weight of the criteria was determined and the ranking of the factors and sub-factors was carried out based on the geometric mean and their normalized weight.

## 3. Results and Discussion

In the current study, the AHP method was used to prioritize factors influencing fall from height accidents. As, the geometric mean technique was used for final prioritization of the expert opinions. This is mainly because of the fact that geometric mean is the most appropriate mathematical method for combining ideas and retains the inverse property in the pairwise comparisons matrix.

**Determining the priority of the main criteria:** Considering that there were 3 main criteria in this study, 3 pairwise comparisons were made from perspective of experts group. Table 1 provides a pairwise comparisons matrix based on the results obtained from the consolidation of expert opinion.

**Table 1.** Pairwise comparison matrix of main criteria.

Criteria	Individual factors	Organizational factors	Environmental factors	Geometric mean	Normal weight value
Individual factors	1	0.904	1.305	1.057	0.351
Organizational factors	1.106	1	0.606	0.875	0.290
Environmental factors	0.766	1.650	1	1.081	0.359

Then, to determine the weight of the criteria, the geometric mean of each row was calculated as follows:

$$\pi_1 = \sqrt[3]{1 * 0.904 * 1.305} = 1.057$$

The geometric mean of the second and third rows was calculated 0.875 and 0.81, respectively. Then, sum of geometric mean was calculated for the all rows. By dividing the geometric mean of each row by the sum of the geometric mean of the rows, the normal weight value was obtained, which is also called the Eigen vector. The values of normal weight and geometric mean are given in Table 1. Based on the obtained Eigen vector, the criterion of environmental factors with normalized weight of 0.3595 is in the first priority,

the criterion of individual factors with normalized weight of 0.351 is in the second priority and the criterion of organizational factors with normalized weight of 0.290 is in the third priority. Also, the incompatibility rate of the performed comparisons was 0.081, indicating that the comparisons were carried out under high reliability since this value is less than 0.1. Therefore, the comparisons made have the necessary reliability.

Tables 2, 3, and 4 show pair-wise comparisons and prioritization of the individual, organizational, and environmental factors, respectively.

*Determining the prioritization of individual sub-factors:* Based on the obtained Eigen vector,

**Table 2.** Prioritization of sub-criteria of individual factors.

Sub-criteria	Training				Psychological/ Occupational stress	Geometric mean	Normalized weight value
	Education	hours	PPE	Age/ experience			
Education	1	1.173	0.613	1.157	0.504	0.906	0.177
Training hours	0.584	1	1.714	1.322	0.383	0.873	0.171
PPE	1.632	0.583	1	1.956	0.696	1.053	0.206
Age/experience	0.849	0.757	0.511	1	1.128	0.823	0.161
Psychological/ Occupational stress	1.196	2.609	1.437	0.886	1	1.459	0.265

**Table 3.** Prioritization of sub-criteria of organizational factors.

Sub-criteria	Management commitment	Safety culture	Mutual understanding	Monitoring /Inspection	Organization size / project size	Geometric mean	Normalized weight value
	Management commitment	1	0.969	1.816	1.081	0.491	0.986
Safety culture	1.032	1	0.924	2.041	1.239	1.193	0.237
Mutual understanding	0.551	1.082	1	0.491	1.520	0.850	0.169
Monitoring /Inspection	0.925	0.490	2.035	1	1.744	1.104	0.219
Organization size / project size	2.038	2.807	0.658	0.564	1	0.906	0.180

the psychological/occupational stress, personal protective equipment (PPE), and education sub-factors with normalized weight of 0.285, 0.206, and 0.177 were in the first, second, and third priorities. Then, the sub-criteria of training hours and age/experience were in the fourth and fifth priorities. Also, the incompatibility rate of the performed comparisons was 0.087, which is less than 0.1. Therefore, the comparisons had the necessary reliability.

*Determining the prioritization of organizational sub-factors:* Based on the calculated Eigen vector, the safety culture, monitoring/inspection, and management commitment sub-factors with normalized weights of 0.237, 0.219, and 0.196 were in the first, second, and third priorities. After that, the organization/project size and mutual understanding sub-factors were in the fourth and fifth priorities, respectively. The incompatibility rate of the performed comparisons was 0.096, which is less than 0.1. Therefore, the comparisons have the necessary reliability.

*Determining the prioritization of environmental sub-factors:* Based on the calculated Eigen vector, height of the work platform, interference, and thermal stress sub-factors with normalized weights of 0.298, 0.260, and 0.243 were in the first, second, and third priorities. Also, the incompatibility rate of the comparisons was 0.078, which is less than 0.1. Therefore, the comparisons had the necessary reliability.

Studies conducted on the causes of accidents occurring in various industries have shown that safety culture as an organizational sub-factors is one of the most effective factors in the occurrence

of accidents. Strictly speaking, a strong safety culture can play an important role in preventing workplace accidents and injuries associated with them. Obviously, the development of an appropriate safety culture leads to the correction of behavior and reduction of human errors and accidents. Occupational stressors, as one of the of individual sub-factors, have a significant role in the occurrence of unsafe actions by workers through decreasing concentration, creating distractions, memory disturbances, hesitation in doing things, lowering decision-making ability, etc. Considering the direct effects of stress on employee performance, identifying stressors related to each field of work and reducing or eliminating the adverse effects of these factors is one of the basic and important measures in increasing employee productivity, reducing unsafe actions, and ultimately preventing accidents in industries, especially in the construction industries. Finally, the height of work platform (as one of the environmental sub-factors) can affect the occurrence of falls from height accidents. In contrast to beliefs of many experts, most height-related work accidents happen at heights less than 9 meters.

#### 4. Conclusion

Based on the results of the present study, construction projects must always follow a codified strategy to reduce environment unstable situations. Also, a stress management program along with specialized training in the use of relevant safety principles and promotion of the safety culture can play an important role in reduce of the falling from height accidents in the construction industry and hence the management efficiency increases. Based on the results of the AHP technique, the

**Table 4.** Prioritization of sub-criteria of environmental factors.

Sub-criteria	Thermal		Smooth surface	Work platform heights	Geometric mean	Normalized weight value
	stress	Interference				
Thermal stress	1	1.023	1.261	0.716	0.980	0.243
Interference	0.978	1	2.192	0.564	1.049	0.260
Smooth surface	0.793	0.456	1	1.184	0.809	0.200
Work platform heights	1.397	1.774	0.845	1	1.203	0.298

organizational factors and their sub-factors have the most effect on the other sub-factors. While, in most of the construction projects in different parts of Iran, all of the health and safety systems are focused on training, controlling and supervising the employees that can take a lot of time from the health and safety specialists. Therefore, it seems necessary to pay attention to organizational factors and their dimensions in the construction industries in order to prevent falling from height accidents.

### 5. Acknowledgment

This study was approved by the research ethics committee of Iran University of Medical Sciences, Tehran, Iran. Authors would like to express special thanks to all the experts and subjects for giving up their time for this research.

### 6. References

- [1] Azami-Aghdash S, Sadeghi-Bazargani H, Shabaninejad H, Gorji A. Injury epidemiology in Iran: a systematic review. *J Inj Violence Res.* 2017;9(1):27.
- [2] Vosoughi S, Rostamzadeh S, Chalak MH, Farshad AA, Jahanpanah M. A Novel Approach Based on DEMATEL Method for Causal Modeling an Effective Factors in Falling from Height Accidents in Construction Projects. *Iran J Heal Saf Environ.* 2020;6(4):1355–65.
- [3] Hatipkarasulu Y. Project level analysis of special trade contractor fatalities using accident investigation reports. *J Safety Res.* 2010;41(5):451–7.
- [4] Jiang L, Tetrick LE. Mapping the nomological network of employee self-determined safety motivation: A preliminary measure in China. *Accid Anal Prev.* 2016;94:1–7.
- [5] Couto JP, Santos FJB, Rabbani ERK. How Time Constraints Affect Safety Conditions at Construction Sites: Analysis of the Perception of Portuguese Construction Participants. *Electron J Geotech Eng.* 2017;22(02):563–76.
- [6] Beltran SL, Vilela RA de G, De Almeida IM. Challenging the immediate causes: A work accident investigation in an oil refinery using organizational analysis. *Work.* 2018;59(4):617–36.
- [7] Vosoughi S, Chalak MH, Rostamzadeh S, Taheri F, Farshad AA, Motallebi Ghayen M. A cause and effect decision making model of factors influencing falling from height accidents in construction projects using Fuzzy-DEMATEL technique. *Iran Occup Heal.* 2019;16(2):65–74.
- [8] Shi S, Jiang M, Liu Y, Li R. Risk assessment on falling from height based on AHP-fuzzy. *Procedia Eng.* 2012;45:112–8.