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Full Length Research Paper

Analysis of occupational accidents induced human injuries: A case study in construction industries and sites

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There are many human injuries induced by occupational accidents in construction industries. Determination and analysis of construction accidents' contributing factors is a good way to accidents' prevention and reduction. Therefore, this study was done in view of identification and analyzing factors related to frequency and severity of construction accidents and injuries in the big construction industries. This analytical-cross sectional study was implemented on 500 occupational accidents during five years in the Iraninan big construction sites. Data gathering was done based on accident report form and information were related to all the reviewed construction accidents. Data analysis was carried out using statistical tests such as linear regression, independent sample T-test and One-way ANOVA, including statistical software of SPSS v22.0. The results revealed average values of accidents indices including accident frequency rate (AFR) and accident severity rate (AFR and ASR) respectively were 4.71 and 216.28. The findings showed that almost all factors including demographics, organization, accident type, work conditions and equipment, unsafe acts, unsafe conditions, nature of accidents, Health, safety and environment (HSE) training and control measures, and finally accident time and place were significantly related to the AFR and ASR ($p<0.05$). Conclusively, the results indicated that the frequency and severity of occupational accidents in construction industries were due to failures in combination of different contributing factors. Therefore, to promote HSE in the construction fields and reduce frequency and severity of the construction accidents, all these factors were considered.

Key words: Occupational accidents, human injury, construction industry, accident analysis, contributing factors.

INTRODUCTION

The construction industry is introduced as one of the main and important industries in any country. A large

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workforce have been employed in this industry, directly and indirectly. Health, safety and environment (HSE) problems and challenges in this industry as a major threat to labor, workforce and industry can be very hazardous and harmful. Some studies indicated that construction sites and projects are the most dangerous workplaces; additionally, the risk of occupational accidents, human injuries is reportedly high (Tam et al., 2004; Lee et al., 2006; Im et al., 2009; Soltanzadeh et al., 2014). Occupational accidents in construction industry have not only influenced safety and health, but also have negative impacts on economics (Silverstein et al., 1998; Hinze et al., 2006; Lee et al., 2006; Dong et al., 2007). In fact, it has been shown that the frequency and severity rate of occupational injuries and their costs in the construction industry is more than that of all industries (Dong et al., 2007; Soltanzadeh et al., 2014); besides, Silverstein et al. (1998) estimated that the rate of cure and compensation expenses in the construction industry is 4-times the other industries.

In the construction industry, workers do different activities which has its own dangers. One of the most important points of safety issues in the construction sites is that all working groups such as workers, technicians, foremen, and supervisors who are responsible for project management and control, are directly exposed to the dangers of work (Baradan and Usmen, 2006; Pinto et al., 2011). Therefore, analyzing and troubleshooting these types of occupational accidents is very important (Asan and Akasah, 2015; Li et al., 2015).

According to findings of some researchers, various factors and their combination play important role in poor safety performance and occupational accidents in the construction industry. These factors were including: continuous change in construction projects, using a lot of materials, poor housekeeping, non-continuous employment and cross-seasonal work, and other pollutants (noise, vibration, dust, and direct exposure to the outside weather) (Tam et al., 2004; Cameron et al., 2008; Im et al., 2009; Cheng et al., 2010; Sertyesilisik et al., 2010). Moreover, because of construction job nature, the risk of accidents such as falling, throwing objects, collision and crash, chemicals, manual handling, and abrasion with equipment exist in all construction activities (Tam et al., 2004; Haslam et al., 2005; Cheng et al., 2010; Arquillos et al., 2012).

Accident analysis aimed at determining accidents' contributing factors is a good and practical way to prevent occupational accidents and reduce accident frequency and severity rate (Huang and Hinze, 2003; Colak et al., 2004; Tam et al., 2004; Cheng et al., 2010). So, the present study was implemented with the purpose of analyzing occupational accidents and to determine contributing factors of human injuries induced by construction accidents in the big construction industries and sites.

METHODOLOGY

The present analytical cross-sectional investigation was implemented in 13 Iranian big construction sites during five years (2009 to 2013). Occupational accident cases in this study were chosen in the census and all construction accidents which caused human injuries have been analyzed.

Data gathering

To begin with, all recorded reports of different occupational accidents in construction sites were gathered, thereafter accident investigation was done on the basis of predefined pattern; also, additional data about the accidents was gathered using interviews or checklists. It should be mentioned that after data gathering, researchers reviewed them precisely; thereafter, accidents with incomplete information were excluded from the study. Eventually, 500 human injuries construction accidents qualified for the investigation. In addition, the overall studied factors were considered as independent factors. Besides, analyzed data in this study includes;

(i) Construction project features: job title or types of work involved, construction activity, number of workers.
(ii) Demographical factors of injured personnel: means of age and job experience, education level.
(iii) Information of accident time and place: accident place, accident time includes day-time, month, and year.
(iv) Injured organ: head, face, eyes, hands, feet, and spine.
v) Work conditions: failure in machinery, equipment, hand tools, electricity, and chemicals.
(vi) Unsafe acts and conditions: predisposing conditions, human errors, and hazardous acts.
(vii) Accident type: falling, throwing objects, slipping, crash, electrocution, and chemicals.
(viii) Accident nature: death, amputation, burning, fracturing, bruising, cutting.
(ix) HSE control measures: personal protective equipment (PPE).
(x) Workers awareness of hazards of working sites and items of HSE training process in construction industry.
(xi) Housekeeping in the construction industry, workers knowledge and the role of housekeeping in preventing and reducing occupational accidents.

Accident frequency and severity rate (AFR and ASR)

Accident frequency rate (AFR) and accident severity rate (ASR) are basic accident indices that are considered as dependent factors in many accident analysis studies (Onder et al., 2014; Feng et al., 2015). AFR and ASR can be mentioned as quantity and monitoring indices of accident analysis. Moreover, these indices are used to assess HSE performance and safety problems in the industry. According to OSHA, accident indices can be calculated as follow (Sari et al., 2009; OSHA, 2012):

$$AFR = \frac{\text{total number of occured accidents} \times 200000}{\text{total number of hours worked}}$$

$$ASR = \frac{\text{total number of working days lost due ti accidents} \times 200000}{\text{total number of hours worked}}$$

Statistical analysis

In this study, data analysis was done using IBM SPSS v22.0 and the level of significance was set at p=0.05. Accident analysis has been carried out by means of some statistical tests including independent sample T-test, linear regression, and one-way ANOVA. To investigate accident indices relation with quantity

Table 1. Descriptive and analytical analysis of demographical and organization factors with accidents indices.

Factors	M±SD/ frequency (%)	AFR(P-Value)	ASR(P-Value)
Age	29.18±7.67	0.001†	0.001†
Job experience	4.67±3.90	0.032†	0.011†
Education			
Sub Diploma	203 (40.6%)	0.021††	0.003††
Diploma	209 (41.8%)		
Academic	88 (17.6%)		
Job title			
Construction Workers	362 (72.4%)	0.025††	0.014††
Technicians	124 (24.8%)		
Drivers	14 (2.8%)		
Activity type			
Construction Work	333 (66.6%)		
Mechanical	39 (7.8%)	0.048††	0.034††
Installation	117 (23.4%)		
Electricity	11 (2.2%)		

† Linear regression; †† One-way ANOVA; ‡Independent sample t-test.

factors such as age and job experience, linear regression was used; independent sample T-test and one-way ANOVA are used to investigate accident indices with respect to quality factors.

RESULTS AND DISCUSSION

In the descriptive and analytical study, 500-human injuries induced by occupational accidents were investigated. The primary findings showed that 739 workers were injured through the occupational accidents. The results of accident indices' calculation showed that the mean of AFR and ASR were 4.71±3.29 and 216.28±83.46, respectively.

Table 1 includes the results of descriptive analysis of demographical and organization factors and also their relation with accident indices. As the results showed, the average age and job experience of injured workers were 29.18±7.67 and 4.67±3.9 years respectively and only one-fifth (17.6%) of them have academic educations. Furthermore, over 70% of injured personnel were simple workers and about 25% of them were technicians. Additionally, it can be concluded that about 25% of accidents have happened during installation works while the other 70% happened during the construction tasks. Comparing individual factors of injured personnel like; age, job experience, and educations have shown that there is a significant statistical difference with respect to accident indices ($p<0.05$). Besides the relation between organization factors, job type and activities which lead to human accidents, and accident indices were reported significant ($p<0.05$).

Table 2 contains the related result of factors analysis of accidents such as accident type, work conditions and equipment, unsafe acts and unsafe conditions, injuring accidents nature, and the investigated relations of these factors with accident indices. As accident type analysis showed, almost all factors including falling, throwing objects, slipping, collision and crash, abrasion and loading have an important role in accident happening. Also the results of equipment and work condition analysis have proved that unsafe acts, unsafe conditions, equipment and machinery have the most important role in occupational accidents in the construction industry. Other factors such as failure in electricity current, working with unsafe and inappropriate hand tools, and chemicals have also been studied but each importance was under 10%. Moreover, accident nature analysis results indicated that the percentage of accidents which lead to death and amputation are 3.8 and 3.2% respectively. Besides, the most injuries were due to bruising and fracturing (each one 33%), cuts and punctures (28%), and hernia (15.6). It is also noticeable that results of burning accidents have got 11.8% of all. Statistical analysis have proved that there is a significant relation between accident indices and all factors (accident type, equipment and work conditions, unsafe acts and unsafe conditions) ($p<0.05$). Furthermore, the relation between ASR and all factors related to accident nature has been found significant ($p<0.05$).

These results showed that some factors of accidents

Table 2. Descriptive and analytical analysis of the accidents related factors.

Factors	Frequency (%)	AFR(P-Value)	ASR(P-Value)
Accident type factors			
Fall	113 (22.6%)	0.005‡	0.013‡
Throwing objects	113 (22.6%)	0.005‡	0.002‡
Slipping	108 (21.6%)	0.009‡	0.002‡
Collision and crash	86 (17.2%)	0.014‡	0.002‡
Abrasion	76 (15.2%)	0.018‡	0.027‡
Electrical shock	48 (9.6%)	0.033‡	0.001‡
Chemicals	36 (7.2%)	0.041‡	0.002‡
Manual handling	74 (14.8%)	0.020‡	0.004‡
Equipment-related factors			
Machines	59 (11.8%)	0.032‡	0.040‡
Equipment	105 (21.0%)	0.001‡	0.004‡
Power	45 (9.0%)	0.039‡	0.002‡
Hand tools	39 (7.8%)	0.014‡	0.024‡
Chemicals	36 (7.2%)	0.048‡	0.002‡
Unsafe condition and act			
Unsafe conditions	161 (32.2%)	0.001‡	0.004‡
Unsafe acts	311 (62.2%)	0.001‡	0.003‡
Nature of accidents			
Death	19 (3.8%)	0.172‡	0.005‡
Maim	16 (3.2%)	0.234‡	0.009‡
Burn	59 (11.8%)	0.048‡	0.001‡
Fracture	165 (33.0%)	0.031‡	0.002‡
Hernia	78 (15.6%)	0.044‡	0.002‡
Strains	165 (33.0%)	0.031‡	0.001‡
Crush	40 (8.0%)	0.053‡	0.004‡
Cuts and perforation	140 (28.0%)	0.036‡	0.001‡

‡Independent sample t-test and linear regression.

nature do not have a significant relation with AFR; these factors are death, maim, and crash.

Table 3 contains the analytical results of HSE training factor, Housekeeping and HSE control measures, and also their relation with accident indices in construction industries. Analytical HSE training factors showed that the role of these factors at the beginning and during the work, and after the accident were 48, 22, and 17.6% respectively, showing a decreasing pattern. Additionally, the results of duration and training course content indicated that there is 26.4 and 14.2% satisfaction of these factors respectively. Housekeeping analysis has indicated that only 5.8% of housekeeping cases has been followed and 3.2% of injured personnel know about housekeeping role in prevention and reduction of accidents and their consequences. In addition, analysis related to the control measures proved that only 21% of injured workers have been trained on how to use PPE and in 10.2% of cases such equipment were used. Other percentages of control measure components including inspection and audit as well as TBM implementation were reported as 8.2 and 10.6% respectively. Statistical analysis have been shown that there is a significant relation between accident indices and all related factors to HSE training, housekeeping and HSE control measures.

Investigated results of accident time and place and their relation to accident indices showed that the amount of occupational accidents is much more in tropical climate area than other places. Moreover, accident analysis related to the accident time showed that most accidents happened at the beginning and ending of the work; also, investigation of seasonal-work indicated that the most accidents occur in the first two seasons of the year

Table 3. Descriptive and analytical findings of HSE training and control measures.

Factors	Frequency (%)	AFR(P-Value)	ASR(P-Value)
HSE training factors			
Pre-employment training	240 (48.0)	0.004‡	0.040‡
Periodic training	110 (22.0)	0.009‡	0.004‡
Training after accident	88 (17.6)	0.017‡	0.002‡
Duration of training	132 (26.4)	0.006††	0.028††
Content of the training	71 (14.2)	0.029††	0.025††
Housekeeping			
Housekeeping knowledge	16 (3.2)	0.001‡	0.002‡
Housekeeping establishment	29 (5.8)	0.001‡	0.002‡
HSE control measures			
Awareness of PPE	105 (21.0)	0.001‡	0.024‡
control measures such as PPE	51 (10.2)	0.031‡	0.002‡
HSE inspection and audit	41 (8.2)	0.001‡	0.003‡
Tool box meeting	53 (10.6)	0.030‡	0.006‡

‡Independent sample t-test and linear regression; †† One-way ANOVA.

Table 4. Results of temporal and locational influence on construction accidents.

Factors	Frequency (%)	AFR(P-Value)	ASR(P-Value)
Place factors			
Hot place	249 (49.8)	0.005††	0.042††
Desert place	98 (19.6)		
Cold place	153 (30.6)		
Time factors			
Day-time			
Morning (7-10)	179 (35.8)	0.017††	0.009††
Noon (11-14)	116 (23.2)		
Afternoon (15-18)	205 (41.0)		
Season			
Spring	119 (23.8)		
Summer	199 (39.8)	0.006††	0.001††
Fall	121 (24.2)		
Winter	61 (12.2)		

†† One-way ANOVA and linear regression.

(spring and summer). According to Table 4 there is a statistical significant relation between accident time and place and accident significance of construction occupational accidents ($p<0.05$).

Generally, the findings of this study showed that construction accidents were a combination of different factors including individual and organization factors, accident type, equipment and work conditions, unsafe acts, accident nature, HSE training factors, a collection of HSE controlling measures like using different kinds of personal protective equipment, housekeeping, apply TBM programs and also accident time and place. In other words, construction accidents were due to one failure in the interaction between workers and work place, materials, and equipment involved (Haslam et al., 2005; Arquillos et al., 2012).

In addition to the findings of some studies, it can be said that construction industry and its related sites are a dangerous and high risk place which its consequences can lead to adverse and catastrophic accidents; therefore, identifying and analyzing the factors can help to identify hazards and risks of projects, analyze and manage them. It also can reduce the rate of accidents and occupational damages in the construction sites (Tam et al., 2004; Lee et al., 2006; Cheng et al., 2010; Pinto et al., 2011; Grant and Hinze, 2014).

Accident frequency and severity rate are part of reactive and effective indices in the construction analysis of accidents. While accident frequency rate was acceptable in this study, the rate of accident severity was high (Raouf and Dhillon, 1994; Teo and Feng, 2010).

Studied results of individual and demographical features as well as organization factors of injured workers has revealed that those injured personnel were young and with low working experience. Moreover, most of the injured ones were construction workers and technicians, who are exposed to dangers in a direct or indirect way (Cheng et al., 2010; Pinto et al., 2011). Studies showed that some of the important and effective factors of occupational injuring accidents are related to the workers or work-team (70%) (Haslam et al., 2005). The important role of individual and organization variables in the construction industry in comparison with other industries is that workers themselves are responsible for their own and organization safety. Thus, the role of these factors for each job and activity involved is significant (Haslam et al., 2005; Cheng et al., 2010; Pinto et al., 2011).

Analysis of accident types showed that almost all kinds of expected accident such as falling, throwing objects etc. has happened and according to statistical reports, falling and throwing objects get the largest number of accidents. Grant and Hinze reported that 68% of accidents were as a result of falling (Grant and Hinze, 2014). Work-related conditions and equipment factor analysis indicated that unsafe acts, unsafe conditions, equipment, machinery, failure in electrical current, using unsafe and inappropriate hand tools, and chemicals have the most important role in occupational accidents in the construction sites as it was mentioned in other studies (Abdelhamid and Everett, 2000; Mitropoulos et al., 2005).

One of the other factors that affect the accident occurrence and its consequences are training process and its related factors (Cheng et al., 2010; Pinto et al., 2011). In view of how dangerous construction industry is, HSE training and the correct application of it can help reduce the frequency and severity of occupational accidents in the construction sites. Besides, following designed steps such as pre-employment training, periodic training, and training after an accident, housekeeping, and PPE training can lead to safe acts and conditions in construction sites (Abdelhamid and Everett, 2000; Mitropoulos et al., 2005; Cheng et al., 2010; Pinto et al., 2011).

As revealed in this study and other ones, inadequacy and lack of risk control equipment like PPE (56%) and lack or failure in applying risk control measures (84%) are significant contributory factors of construction accidents. Factors such as housekeeping and performing actions like TBM in the construction industry are important to prevent the accidents and reduce its consequences. Poor housekeeping is an effective issue and factor which has been found in half of the construction accidents (Haslam et al., 2005; Gibb et al., 2014; Chi et al., 2015).

However, lots of factors and their roles in construction accidents have been investigated in this study, it should be noticed that construction accidents were due to failure in the interaction between workers and workplace, materials, and equipment involved (Haslam et al., 2005; Arquillos et al., 2012). Therefore, for causal analysis of these accidents and investigation of their connections, more steady steps should be taken in the future.

Conclusion

The results of this investigation indicated that the frequency and severity of construction human injury accidents are caused by combination of failures in the factors including; demographics and organization factors, type of occurred accidents, factors related to the work conditions and equipment, unsafe acts and unsafe conditions such as poor housekeeping, nature of accidents, failure in HSE training and HSE control measures, and temporal and locational influences. Thus, to prevent frequency rate of the construction accidents and reduce the severity rate of these injuries, all these factors and a precise combination of them should be considered.

Conflict of Interests

Authors have no conflicts of interest.

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