Iranian J Publ Health, Vol. 43, No.4, Apr 2014, pp. 507-522

National Report

Risk-based Analysis of Construction Accidents in Iran During 2007-2011- Meta Analyze Study

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(Received 10 Nov 2013; accepted 19 Jan 2014)

Abstract

Background: The present study aimed to investigate the characteristics of occupational accidents and frequency and severity of work related accidents in the construction industry among Iranian insured workers during the years 2007-2011.

Methods: The Iranian Social Security Organization (ISSO) accident database containing 21,864 cases between the years 2007-2011 was applied in this study. In the next step, Total Accident Rate (TRA), Total Severity Index (TSI), and Risk Factor (RF) were defined. The core of this work is devoted to analyzing the data from different perspectives such as age of workers, occupation and construction phase, day of the week, time of the day, seasonal analysis, regional considerations, type of accident, and body parts affected.

Results: Workers between 15-19 years old (TAR=13.4%) are almost six times more exposed to risk of accident than the average of all ages (TAR=2.51%). Laborers and structural workers (TAR=66.6%) and those working at heights (TAR=47.2%) experience more accidents than other groups of workers. Moreover, older workers over 65 years old (TSI=1.97%> average TSI=1.60%), work supervisors (TSI=12.20% >average TSI=9.09%), and night shift workers (TSI=1.89% >average TSI=1.47%) are more prone to severe accidents.

Conclusion: It is recommended that laborers, young workers, weekend and night shift workers be supervised more carefully in the workplace. Use of Personal Protective Equipment (PPE) should be compulsory in working environments, and special attention should be undertaken to people working outdoors and at heights. It is also suggested that policymakers pay more attention to the improvement of safety conditions in deprived and cold western regions.

Keywords: Occupational accidents, Construction safety, Risk-based analysis, Iran

Introduction

Occupational accidents are the cause of about 321,000 mortalities and 317 million injuries worldwide each year (1). This sizeable number of cases has led to severe human and financial impacts in societies (2). Workers in various industries are exposed differently to occupational accidents (3). Construction is known as one of the most dangerous industries all over the world (4). The construction industry has a unique and dynamic nature (5), including continuous changes, use of many different resources, poor working conditions, no steady employment, lack of training (almost all construction workers in Iran are untrained for safety), tough environments (e.g. noise,

vibration, dust, handling of cargo, and direct exposure to weather) (6), low educational level of workers, lack of safety culture, and communication are among such problems (7). The work environment in this industry has a number of characteristics that make it unique and unpredictable. One of these characteristics is the constantly changing environment. Construction projects change on a daily basis, not only in terms of progress in the building process itself, but also in terms of the types of weather, equipment, crews, and materials used (8).

Different aspects of occupational safety in the construction industry are investigated in a number of researches. These analyses include general analysis (9-13), risk or severity of accidents (14, 15), fatal and severe accidents (16-19), fall accidents (20-22), contact with objects or equipment (23), contact with electricity (24), age of workers (25, 26), pattern of seasonal variation (27), and sleep deprivation (28).

According to official statistics in Iran, almost 37 percent of all industrial accidents (including fatalities and lost time accidents) occur in construction projects (29). This is despite the fact that this line of work accounts for only 14 percent of the total employment in the country (30). In spite of the urgency of investigating occupational safety in the construction sector of Iran, this subject is not studied well, and there exists a research gap for a comprehensive analysis in this context. Other studies have been performed in small regions of Iran such as the cities of Yazd and Kerman (12, 13), on a small scale. To the best of our knowledge, the current study is the first of its kind using the most comprehensive database (N=21,864) to conduct construction accident analysis in the country.

The present study aimed to investigate the characteristics of occupational accidents and frequency and severity of work related accidents in the construction industry among Iranian insured workers during the years 2007-2011. The results of this study will help construction policymakers and managers and safety professionals to identify the most hazardous conditions and develop appropriate preventive measures.

Materials and Methods

Workers Characteristics and Accident Data

Since 1975, the Iranian Social Security Organization (ISSO) must be notified of all occupational accidents causing injury to insured workers. Although reporting is mandatory according to the Iranian law, it is possible that some cases remain unreported. In this study, the Social Security Organization provided anonymous data of all workplace accidents among Iranian insured construction workers during the period of 2007-2011. Data were recorded and reported by work inspectors of ISSO all around the country. A total number of 25,057 cases were supplied, but after performing preprocessing and especially removing abundant duplicate cases, 21,864 cases were accepted for the analysis, which included 4158, 4528, 4059, 4270, and 4849 annual samples for each year from 2007-2011, respectively. In the ISSO database, each accident case is characterized by a set of parameters listed in Table 1.

A limited number of characteristics of insured construction workers (including age, sex and the province he/she is working) have also been archived by ISSO since 2011. Hence, for the current analysis, the authors only had access to the workers' characteristics data of the year 2011 (N=312, 492).

Analysis Design

Having obtained the data of the accident cases in the construction industry, and performing the preprocessing step (including removing missing values and duplicate cases, discretizing numerical features and generating appropriate features) on the data, data were analyzed from different perspectives. To that end, the frequency, severity and risk factor of the accidents were analyzed, along with the age of the worker involved in the accident, day of the week, time of day, type of accident, body part affected, seasonal and regional analysis, and finally, the occupation of the worker and construction activity. Thus, the aim of this study is to identify hazardous conditions that have high frequency, severity, and consequently significant risk

factors. The obtained results are discussed comprehensively and compared to the past research. Performing risk factor analysis in this study enabled us to integrate frequency rate and total severity of accidents in each category of the data in a scientific manner. To make the risk factor analysis possible, some indexes were introduced (in the following subsections).

Table 1: Parameters characterizing each accident case, as collected in the ISSO database

The workshop
Data about the construction workshop in which the accident has occurred.
The injured worker
Insurance number
Age
Sex
Marital status
Job
Insurance coverage
Date and time
The date
The time (time and shift)
Place
The place (inside, outside, or during commuting to the workplace)
Province
Accident characteristics
Main cause of the accident
Type of accident
Accident consequences
The part of body affected
Days lost
Final consequence of the accident

Index Definition

The Total Accident Rate (TAR) is obtained by dividing the number of total accidents in the community studied by the number of total accidents analyzed. The Fatal Accident Rate (FAR), Totally Disabling Accident Rate (TDAR), Partially Disabling Accident Rate (PDAR), Fixed Compensation Accident Rate (FCAR), and Completely Recovered Accident Rate (CRAR) are obtained by dividing the number of accidents of each group in the community studied by the number of total accidents of the same category.

In the next step, the Total Severity Index (TSI) is defined to present the severity of each case in a simple number. This index is obtained by allocating weights to the severity rates described in the previous paragraph (i.e. FAR, TDAR, PDAR, FCAR, and CRAR). The approximate number of days lost was estimated for each severity category as a weight criterion.

The lost working days for death cases is taken as 7,500 days by International Labor Organization (ILO) (31). This number is also underlined in regulations and research activities of many countries including Japan (32), South Korea (33), and Italy (34) etc.

Accepting 7,500 lost working days for death cases in Iran seems logical, because it is equal to the compensation of 30 years. The disability compensation for other severity categories are calculated based on the Iranian Social Security Law (1975) and inserted in Column (2) of Table 2. Treatment and wage compensation for every severity degree is also the average of cases lost days in the ISSO accident database (Column 1 of Table 2).

Table 2: Estimated number of days lost as weight criteria for TSI calculation

Severity category	Description	Estimated number of days lost (1)*	(2)**
Death	Death of workers due to occupational accidents.	28	7,500
Total disability	Any damage other than death, which permanently and generally makes workers incapable of doing a useful job, or leads to loss of function of a body organ or its complete loss of both eyes, or an eye and hand or foot. Workers with 66% disability or more are called total disabled (35).	240	7,500
Permanent partial disability	Consists of any damage other than death or permanent total disability, which leads to loss of functional abilities or complete/partial body organ amputation. Workers with between 33% and 66% disability due to occupational accidents are called permanent partial disabled (35).	136	3,750
Fixed compensation	Any damage due to occupational accidents, which leads to loss of functional ability of the worker between 10% and 33%. In this case the worker is eligible for a fixed compensation (35).	82	150
Complete recovery	The injured worker retrieves his/her health completely after the needed treatment.	54	___

*: Treatment + wage compensation
**: Death or disability compensation

By summing up the two values for every severity category, the weight criterion was obtained and applied in the forthcoming analysis.

Risk Factor Calculation

In order to calculate risk factor, Equation [1] was applied, where P stands for "risk incidence probability", and C is the "consequence of risk". This equation identifies items with high likelihoods or high consequences or both, so the chance of high consequence but low likelihood items being ignored is reduced greatly (36). In the current study, TRA and TSI stand for P and C, respectively.

$$\text{Risk Factor} = (P+C) - P \times C \qquad [1]$$

Results

General Characteristics of the Data

The data of 21,864 injured construction workers were analyzed including 21,782 (99.6%) male and 82 (0.4%) female. The mean age ± standard deviation was 33.2 ± 10.9 years. Moreover, 5,991 (27.4%) of them were single, and 15,873 (72.6%) are married.

Table 3 shows that the TSI is slightly reduced from the year 2007 to 2011. It can also be seen that TRA per 1,000 construction workers was 15.5 in 2011 while FRA per 10,000 construction workers was 0.8.

Age of Worker

Fig. 1 shows the TAR for various ages of the construction workers. The number of accidents for every age is based on ISSO accident data in the construction sector of the year 2011, and the total number of workers at risk for every age is derived from the ISSO database of the characteristics of insured construction workers in the same year. In this section, TAR was only calculated for the year 2011, because the insured workers' characteristics of the earlier years were not available. As can be seen in this figure, TAR for ages between 15-19 (teenagers) is maximized and is extremely higher than the average for all ages. Table 4 presents the TAR for the defined age groups. In addition, CRAR, FCAR, PDAR, TDAR, FAR, and TSI are calculated in this table based on accident data of the period 2007-2011. The Risk Factor (RF) of every defined age group is also presented.

Table 3: Annual distribution of occupational accident outcomes, TSI, TRA and FRA

Accident Result	2007		2008		2009		2010		2011	
	n	%	n	%	n	%	n	%	n	%
Death	24	0.6	28	0.6	30	0.7	27	0.6	26	0.5
Total disability	49	1.2	48	1.2	57	1.4	53	1.1	43	0.9
Partial disability	106	2.5	79	2.3	71	1.7	98	1.7	53	1.1
Fixed compensation	203	4.9	205	5.1	191	4.7	219	4.5	228	4.7
Complete recovery	3,776	90.8	4,168	90.7	3,710	91.4	3,873	92.0	4,499	92.8
Total	4,158	100	4,528	100	4,059	100	4,270	100	4,849	100
Total Severity Index (%)	1.52		1.51		1.51		1.33		1.10	
Insured construction workers	168,085		161,451		n/a		114,746		312,492	
Total Accident Rate per 1,000 workers	24.7		26.4		n/a		39.5		15.5	
Fatal Accident Rate per 10,000 workers	1.4		1.7		n/a		2.4		0.8	

n: Number of accidents

Table 4: TAR, TSI and risk factor for different age groups in the Iranian construction industry

Age groups	2011			2007-2011 period							Risk factor (%)
	Number of workers at risk	Number of accidents	TAR (%)	Number of accidents	CRAR (%)	FCAR (%)	PDAR (%)	TDAR (%)	FAR (%)	TSI (%)	
15-19	1,615	217	13.44 ↑	1,157	94.99	3.28	0.86	0.78	0.09	0.82	14.15↑
20-24	21,662	807	3.73 ↑	3,857	93.18	4.04	1.27	1.11	0.39	1.16	4.84↑
25-29	72,658	1064	1.46	4,772	91.93	4.55	1.93	1.03	0.57	1.33	2.77
30-34	69,126	855	1.24	3,695	92.21	4.47	1.49	1.22	0.62	1.34	2.56
35-39	44,897	610	1.36	2,739	90.65	5.48 ↑	1.94 ↑	1.13	0.80	1.47	2.81
40-44	34,375	443	1.29	1,933	89.50	5.69 ↑	2.53 ↑	1.60 ↑	0.67	1.72↑	2.99
45-49	24,751	339	1.37	1,541	90.27	4.67	2.73 ↑	1.56 ↑	0.78	1.77↑	3.12
50-54	20,508	255	1.24	1,018	88.80	5.99 ↑	2.95 ↑	0.88	1.38 ↑	1.80↑	3.02
55-59	13,435	157	1.17	646	90.87	5.73 ↑	2.01 ↑	1.08	0.31	1.28	2.43
60-64	5,612	55	0.98	259	87.64	5.02	3.47 ↑	2.32 ↑	1.54 ↑	2.52	3.48
65-69	1,540	20	1.30	110	90.00	5.45 ↑	0.91	2.73 ↑	0.91 ↑	1.94↑	3.21
Over 70	1,539	24	1.56	84	85.71	9.52 ↑	1.19	1.19	2.38 ↑	2.00↑	3.53
Average			2.51		90.48	5.32	1.94	1.39	0.87	1.60	4.08
Sum	311,718	4,846		21,811							

↑: More than average

Fig. 1: TAR for every age number of the construction workers (vertical axis is displayed using a log 10 based scale)

As can be seen in Table 1, the accident rate in the age range of 15-19 is almost six times and in the range, 20-24 is about double the average of all ages. Therefore, the frequency of accidents among young workers (15 to 24 years old) is dramatically higher than other age groups. It can also be observed that the severity index of accidents increases with the age of the worker.

Worker Occupation and Construction Phases

The job of the injured worker was one of the attributes of the ISSO database. There were 2,102 job codes related to occupations in all industries, but the majority of these codes was not relevant to the construction sector and had not been used in the database. Due to the multiplicity of remaining job codes (551 occupations); it was not possible to analyze all of them as a whole. Hence, eleven groups of occupations and execution in construction phases were created, and each job code was linked to the relevant category. Table 5 demonstrates the number of accidents containing TAR, TSI, and the risk factor for each group.

Table 5: TAR, TSI, and risk factor for occupations and execution phases

Occupations and execution phases	Number of accidents	TAR (%)	CRAR (%)	FCAR (%)	PDAR (%)	FDAR (%)	FAR (%)	TSI (%)	Risk factor (%)
Jobsite supervisors and staff	1,208	5.5	86.3	6.9↑	3.6↑	2.3↑	0.9↑	12.2↑	17.0
Laborers	11,154	51.0↑	92.5↑	4.4	1.5	1.0	0.5	6.6	54.2↑
Welders and ironworkers	2,088	9.5↑	92.5↑	4.7	1.2	1.1	0.5	6.2	15.2
Machine equipment operators	1,091	5.0	90.1	5.1↑	2.7↑	1.4	0.7↑	8.8	13.4
Excavation and drilling groups	295	1.3	87.1	6.8↑	3.4↑	1.4	1.4↑	10.9↑	12.1
Structure and frame execution	3,416	15.6↑	91.8↑	4.6	1.9	0.9	0.7↑	7.2	21.7↑
Finishing groups	893	4.1	93.7↑	3.6	1.6	0.7	0.4	5.6	9.5
Mechanical and electrical utility	664	3.0	90.5↑	5.1↑	3.2↑	0.6	0.6	7.5	10.3
Façade execution groups	187	0.9	89.3	4.3	2.7↑	2.1↑	1.6↑	12.2↑	12.9
Landscaping groups	46	0.2	91.3↑	2.2	2.2	4.3↑	0.0	12.8↑	13.0
Others	822	3.8	87.0	7.8↑	2.6↑	1.9↑	0.7↑	10.0↑	13.4
Average	∑=21,864	9.09	90.2	5.0	2.4	1.6	0.7	9.09	17.5

↑: More than average

As it can be seen, more than half of the injured workers are laborers (51.0%). Working groups executing the structure of buildings are of the second rank (15.6%). Welders and ironworkers are the victims of 9.5% of accidents.

Landscaping groups, jobsite supervisors and staff, façade execution groups, and excavation and drilling groups are more prone to severe accidents than other occupations.

Day of the Week

Results of analyzing 21,864 accident cases, which were registered in the years 2007 to 2011 are presented in Fig. 2 and 3. It should be noted that in the Iranian calendar, the week starts on Saturday and Friday is the weekend; however, in some construction work sites, especially in Tehran province, Thursday is partially closed. As it can be seen from Fig. 2, the TAR on Saturday, Sunday, and Tuesday is slightly more than other working days of the week. Moreover, TAR on Friday is at a minimum. The TSI is presented for days of the week in Fig. 3. Here, we can observe that the severity of accidents occurring on Saturdays is at the minimum and it slightly fluctuates to reach maximum on Thursdays and Fridays. Based on this figure, accidents happening on Thursday and Friday are the most severe accidents.

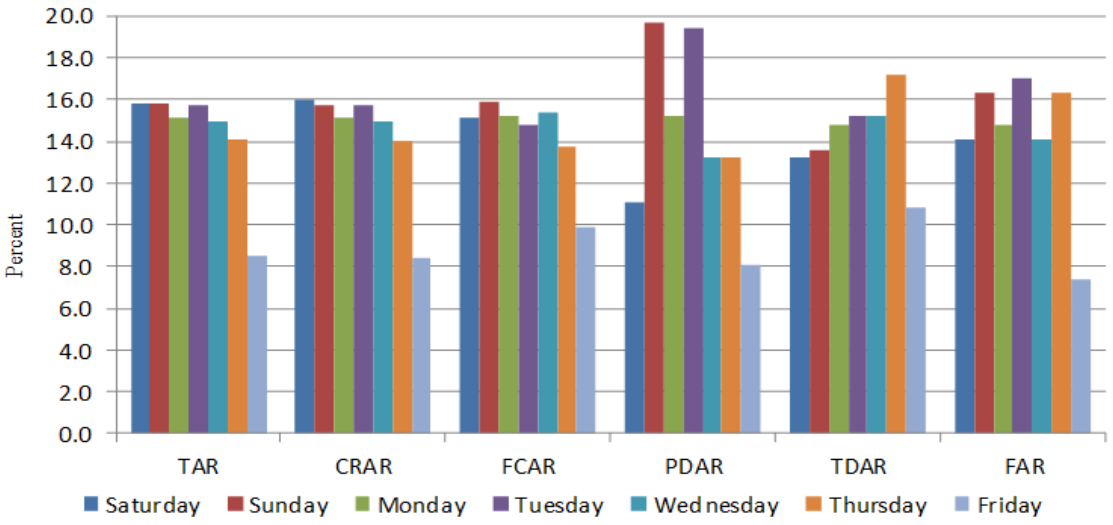

Fig. 2: Accident rates comparing day of the week against severity

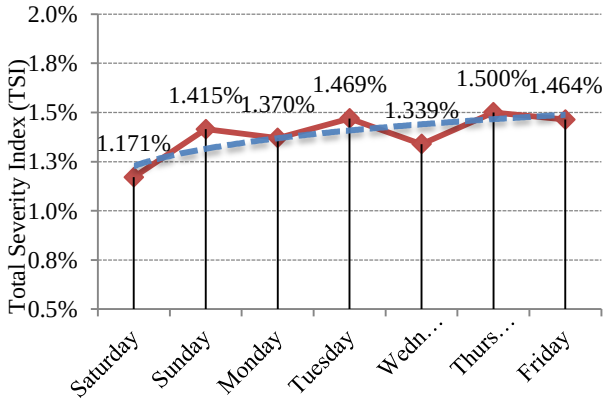

Fig. 3: Calculated TSI against day of the week and the trend line

Time of the Day

Fig. 4 shows that the rate of accidents between 7 PM and 7 AM is very low. It can also be seen that the rate of accidents increases rapidly during 7 AM to 10 AM. Based on the graph, the occurrence of accidents is most probable between 9 AM and 11 AM. It can also be seen from Fig. 5 that between 12:30 PM and 2 PM in which workers are off to rest and have lunch, the rate of accident decreases significantly.

Fig. 5 also shows that the severity of accidents occurring in the lunch period (12:30 PM to 2 PM) and during night hours (9 PM to 7 AM) is higher than other times.

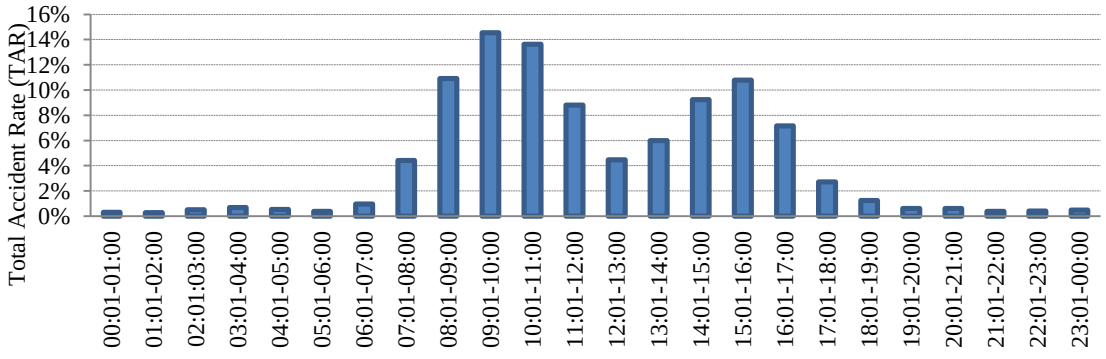

Fig. 4: Accident rate against time of the accident based on 2007-2011 data

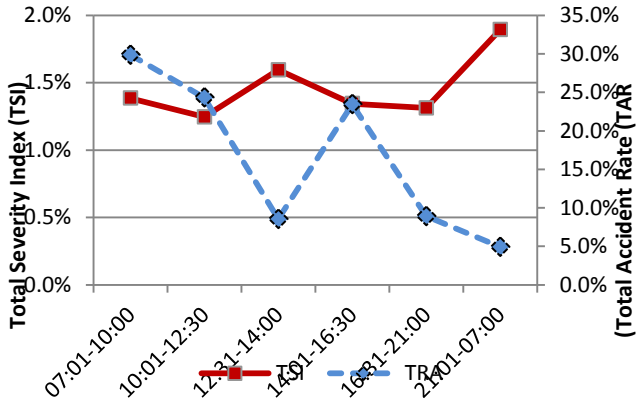

Fig. 5: Rate and severity of accidents occurring in time periods of the day

Seasonal Analysis

The accident rate in different months of the year (beginning with spring) is calculated based on the above-mentioned accident database for the whole country during 2007-2011 (Fig. 6). It is obvious that the frequency of accidents is proportional to proper climatic working conditions. TRA in June is the maximum, too.

As it can be seen in figures 6 and 7, severity of accidents increases in colder months of the year and reaches its maximum at the end of winter (March).

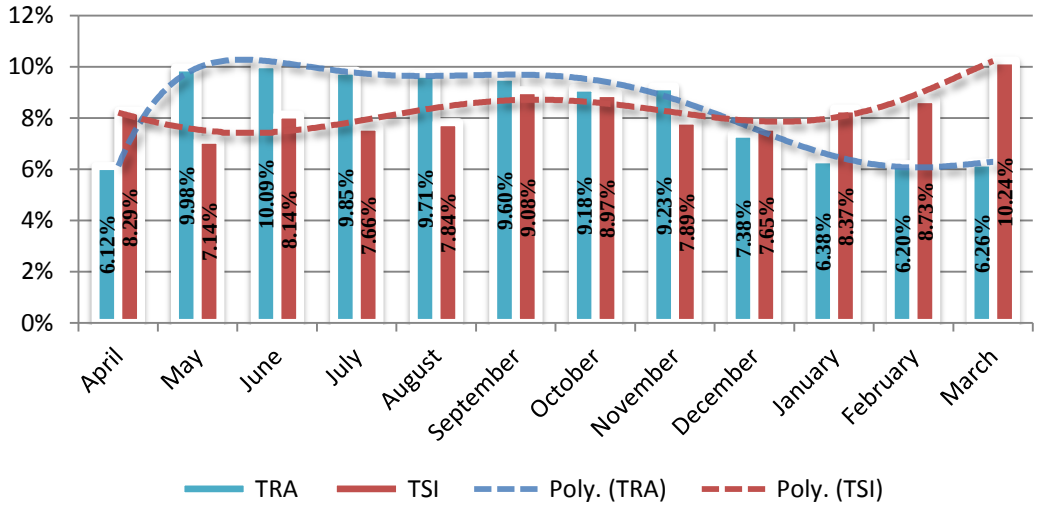

Fig. 6: Trend of TRA and TSI in different months of the year

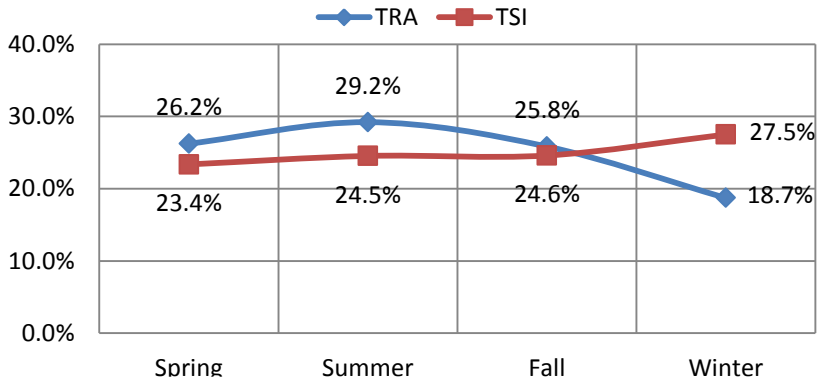

Fig. 7: Trend of TRA and TSI of accidents occurring in different seasons

Regional Analysis

Having extracted the number of workers at risk, and the number of accidents in each of the 31 provinces, TAR, TSI, and the risk factor were calculated and ranked accordingly (Table 6). A graphical map of provinces categorized into high, moderate, and low accident rate is presented in Fig. 8 (a). It can be seen that the accident rate in northern and especially western areas of the country (which are mountainous and receiving high rainfall) is moderate and high. The highest TRA occurred in six provinces of Ilam, ChaharMahaal and Bakhtiari, Lorestan, Kohgiluyeh and Boyer-Ahmad, West Azerbaijan, and Kurdistan, respectively. Fig. 8 (b) demonstrates the distribution of accident severity by province. Based on this figure, most severe construction accidents occur in the northern strip and central regions along with two provinces located in the west of the country.

The obtained risk factor is graphically presented in Fig. 8 (c) by province. It can be seen that the risk of accidents in western and central-western parts of Iran are obviously higher than other regions, excluding Sistan and Baluchestan province.

Accident Type

Table 7 reveals that most frequent accidents in the construction industry of Iran are falling or slipping, falling objects, and sticking inside or between objects. Nevertheless, these accidents are not as severe as they are probable. It can be seen that being hit by vehicles, fire and explosion, electric shock, and collapse in excavation areas are the accident types, which result in more severe consequences than average. Calculating the risk factor of each accident type, it is observed that the risk factor of falling or slipping is extremely high. Falling objects, being hit by vehicles, electric shock, and fire and explosions are also high risks in a construction workplace.

Injured Body Part

Different parts of the worker's body may be affected as a consequence of an accident. The likelihood of a part of the body to be affected and the impact of the injury are obtained based on the ISSO accident database between the years 2007-2011 in Table 8. Furthermore, the risk factor is obtained for every part of the body in this table. Hands and limbs are the most frequently affected parts of the body in accidents. Investigating the severity of these injuries, we can see that injuries affecting the cranium and brain, spine, back and eyes unfortunately had the most unpleasant consequences.

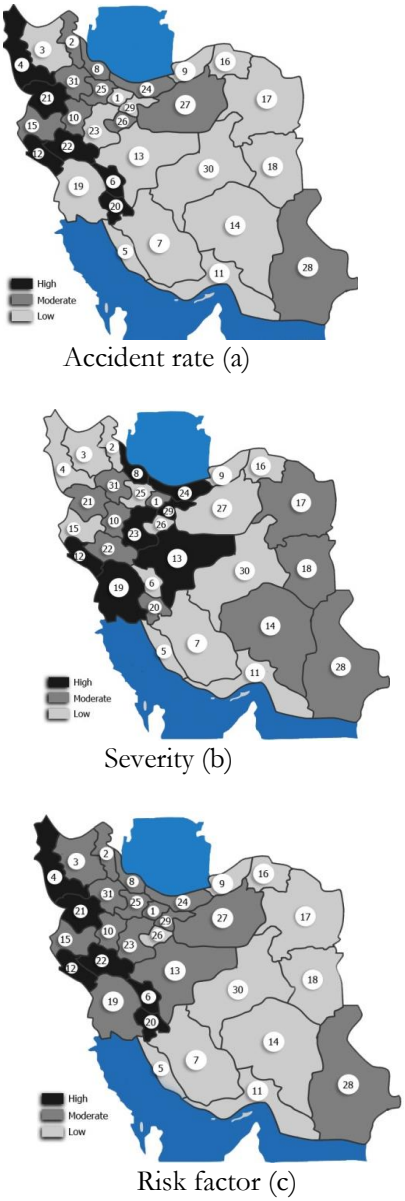

Fig. 8: Accident rate (a), severity (b), and risk factor (c) of construction accidents by province

Table 6: TAR, TSI and risk factor values and ranking for different provinces

Code on map	Province	2011				2007-2011 period			Risk factor (%)	Rank
		Number of workers at risk	Number of acci-dents	TAR (%)	Rank	Number of acci-dents	TSI (%)	Rank		
1	Alborz	10,719	69	0.64	28	371	4.45	9	5.06	21
2	Ardabil	2,268	139	6.13	7	499	2.29	27	8.28	10
3	Azerbaijan, East	12,519	370	2.96	17	1,721	2.69	19	5.56	20
4	Azerbaijan, West	4,476	354	7.91	5	1,452	2.67	20	10.37	6
5	Bushehr	4,827	29	0.60	31	867	1.69	29	2.28	31
6	ChaharMahaal and Bakhtiari	1,354	196	14.48	2	898	2.26	18	16.41	2
7	Fars	12,867	311	2.42	18	1,550	2.56	25	4.92	23
8	Gilan	5,886	248	4.21	13	988	4.54	6	8.56	8
9	Golestan	3,880	59	1.52	23	415	2.09	30	3.58	30
10	Hamadan	2,767	166	6.00	8	775	2.98	17	8.80	9
11	Hormozgān	7,447	58	0.78	26	282	1.95	21	2.71	29
12	Ilam	724	167	23.1	1	402	6.19	1	27.83	1
13	Isfahan	21,249	323	1.52	24	1,504	5.42	4	6.85	16
14	Kerman	7,397	48	0.65	27	203	3.74	12	4.37	24
15	Kermanshah	3,194	177	5.54	10	576	2.53	23	7.94	13
16	Khorasan, North	2,067	40	1.94	20	185	2.67	22	4.55	25
17	Khorasan, Razavi	25,506	160	0.63	30	740	3.04	15	3.65	27
18	Khorasan, South	2,562	46	1.80	21	188	2.95	14	4.70	22
19	Khuzestan	16,630	291	1.75	22	1,606	4.76	8	6.43	17
20	Kohgiluyeh and Boyer-Ah-	877	72	8.21	4	269	3.44	5	11.37	4
21	Kurdistan	2,308	160	6.93	6	612	3.98	11	10.63	5
22	Lorestan	1,023	91	8.90	3	441	3.33	10	11.93	3
23	Markazi	5,501	124	2.25	19	810	4.87	3	7.01	12
24	Mazandaran	9,249	305	3.30	15	1,225	4.73	7	7.88	11
25	Qazvin	3,904	148	3.79	14	669	2.33	28	6.03	19
26	Qom	1,951	62	3.18	16	208	1.24	31	4.38	26
27	Semnan	2,701	133	4.92	11	443	2.78	26	7.57	15
28	Sistan and Ba-luchistan	1,143	65	5.69	9	219	3.55	13	9.04	7
29	Tehran	128,085	206	0.16	29	970	5.30	2	5.46	18
30	Yazd	4,213	41	0.97	25	180	2.71	24	3.66	28
31	Zanjan	3,198	142	4.44	12	596	3.26	16	7.56	14
	Average			4.43			3.32		7.59	
	Sum	312,492	4,849			21,864				

Table 7: TAR, TSI and risk factor for various types of accidents

Type of accident	Number of accidents	TAR (%)	CRAR (%)	FCAR (%)	PDAR (%)	TDAR (%)	FAR (%)	TSI (%)	Risk factor (%)
Falling objects	2,564	17.0	93.84↑	3.71	1.05	0.86	0.55	3.74	20.2↑
Falls or slips	7,105	47.2	91.68↑	4.10	2.15	1.37	0.70	5.40	50.1↑
Stuck inside or between objects	1,263	8.4↑	91.77↑	5.07	1.82	0.71	0.63	4.23	12.3
Accidents while moving	1,049	7.0	93.71↑	4.77	0.86	0.48	0.19	2.64	9.4
Burns	348	2.3	93.39↑	3.74	1.72	1.15	0.00	3.85	6.1
Accidents from toxic materials	39	0.3	84.62	12.82↑	2.56↑	0.00	0.00	3.13	3.4
Fire and explosion	91	0.6	76.92	7.69↑	6.59↑	2.20	6.59↑	17.62↑	18.1↑
Collapse in the excavations	284	1.9	83.45	5.63	2.82↑	4.23↑	3.87↑	14.10↑	15.7↑
Hit by vehicle	438	2.9	77.85	7.31↑	5.02↑	5.94↑	3.88↑	17.98↑	20.4↑
Hit by objects	396	2.6	93.18↑	4.29	1.52	0.51	0.51	3.54	6.1
Mechanical tools	767	5.1	89.70↑	7.30↑	1.69	1.04	0.26	4.16	9.0
Hand tool	488	3.2	95.49↑	3.07	1.02	0.00	0.41	2.35	5.5
Electric shock	211	1.4	81.52	5.21	2.84↑	6.64↑	3.79↑	17.26↑	18.4↑
Average		7.69	88.24	5.75	2.44	1.93	1.65	7.69	14.97

↑: More than average

Table 8: TAR, TSI and risk factor for parts of body affected

Body part affected	Number of accidents	TAR (%)	CRAR (%)	FCAR (%)	PDAR (%)	FDAR (%)	FAR (%)	TSI (%)	Risk factor (%)
Cranium	636	2.91	83.18	2.99	2.67	5.19↑	5.97↑	26.11↑	28.26↑
Eyes	352	1.61	82.10	8.24↑	7.10↑	2.27↑	0.28	13.77↑	15.16
Face	876	4.01	93.84↑	4.11	1.26	0.23	0.57	4.43	8.26
Neck	288	1.32	91.32↑	3.47	2.08	2.78↑	0.35	9.77	10.96
Hand	9,343	42.73	92.69↑	5.16↑	1.38	0.56	0.21	4.55	45.34↑
Trunk	688	3.15	91.86↑	4.51	1.02	1.60	1.02	7.79	10.69
Spine and back	1,304	5.96	84.89	6.83↑	3.91↑	4.06↑	0.31	14.16↑	19.28
Limbs	6,587	30.13	93.52↑	4.14	1.55	0.65	0.14	4.70	33.41↑
Other	1,790	8.19	87.37	4.30	3.30↑	2.23↑	2.79↑	14.73↑	21.71↑
Average	∑=21,864	11.11	88.97	4.86	2.70	2.17	1.29	11.11	21.45

↑: More than average

Discussion

The annual severity index of construction accidents is slightly decreasing. This may be due to more attention to safety management by policy-makers and the involved parties. Moreover, TAR and also FAR of the year 2011 has declined substantially. This may be due to improvement in leg-

islation, training safety professionals, and involvement of Iranian companies in safety programs in recent years. It can be seen that TRA per 1,000 Iranian construction workers was 15.5 in 2011 while it has been 64.3 in Hong Kong and 8.3 in UK construction industry in 2006 (32). This rate has been 4.4 in Turkey in 2010, which explains their improvement in the field of occupational safety (37). From another point of view, FRA per 10,000 construction workers was 0.8, whereas it has been 3.0 in Hong Kong and 0.4 in the UK construction industry in 2006 (32). Here, the rate of Turkey has been 3.3 (38).

In the above comparison, it should be noted that some cases may remain unreported. Hence, the calculated rates are possibly lower than actual accident rates. However, this issue is not limited to Iran, and has been reported in other countries (5, 11, 39).

The frequency of accidents among young workers (15 to 24 years old) is dramatically higher than other age groups. This is probably because younger workers are less educated and experienced and more venturesome. They are also more vulnerable to professional stress. The majority of laborers, which are also mostly untrained for safety, are included in this group (40, 41). It can also be observed that the severity index of accidents increases with the age of the worker. This is probably due to the more physical stamina of younger workers. This is seen in similar research, for example, Sawacha et al. (25) showed that workers between the ages of 16–20 were more likely to be exposed to accidents than others. Further analysis indicated that the level of accidents tends to decline steadily after the age of 28 to reach a low point in the mid-40s. In a similar manner, Salminen (42) concluded that young workers had a higher injury rate than older workers; however, the injuries of young workers were reported as less often fatal than those of older workers. Halvani et al. (12) identified the highest accident frequency in the range of 20-29 years old.

Nearly half of the accident victims in the construction sector are laborers. Workers executing the structure of the buildings are also prone to accidents. People who work outdoors and at heights are more exposed to severe accidents. These findings are greatly consistent with the past studies such as Rozenfeld et al. (43) that concluded activities performed outdoors and at heights are more risky.

TAR on Friday is at a minimum, because Friday is a weekend in Iran, and therefore, most construction workplaces are closed. Accidents happening on weekends are the most severe accidents. Frequency of accidents on the first day of the week is maximum in comparison to other weekdays. This might be because workplaces are mostly closed on these two days of the week and the supervising personnel are not present at work; therefore, those few workers performing their planned job in different points of the workplace are at high risk of accident. In similar research, Brogmus (44) found an increased rate of Lost Time (LT) accidents for Mondays (beginning of the workweek in Georgian calendar) compared to all other days of the week, which is consistent with the results of this study. Banik (45) observed that the least number of fatal events occurred on Mondays, excluding weekends. This observation is in line with the lowest TSI value for Saturday in our study.

The rate of accidents between 7 PM and 7 AM is very low. This is because in normal conditions it is rare that workers work during this time period. The most probable time for accidents is between 9 AM and 11 AM. It can also be seen that between 12:30 PM. and 2 PM in which workers are off to rest and have lunch, the rate of accident decreases severely. These findings are consistent with the findings of past researchers, for example a diagram similar to Fig. 3 was found by Camino López et al. (46). However, the severity of accidents occurring during the lunch period (12:30 PM to 2 PM) and during night hours (9 PM to 7 AM) is higher than other hours. Similar studies advocate these findings. For instance, Camino López et al. (46) observed that a higher percentage of severe and fatal accidents occur in the lunch period and 9 PM as compared to other hours. It is also pointed out that fatal occupational accidents are 50% more frequent at night hours (12 midnight to 6 AM) than during the day (47). It is obvious that the frequency of accidents is propor-

tional to proper climatic working conditions. For example, in most regions of the country, from April to November, the climatic condition is proper for construction. There are exceptions too, for instance in Khuzestan (a southern province), due to hot weather in the spring and summer; the most suitable period for construction is from November to May. Conversely, Ardabil is almost the coldest province of Iran; hence, the working period is limited to June to November. The low accident rate in April is due to the Iranian New Year holidays, which lasts for almost 15 days. TRA in June is the maximum, which is in line with the results found by Rashidi (48). Furthermore, accident severity increases in winter. This phenomenon may be due to unpredictable wet weather conditions causing falls from heights or electric shock (27). In similar studies, it is revealed that working on or after rainy days results in more fatalities and severe events (49).

The highest TRA occurred in six provinces of Ilam, ChaharMahaal and Bakhtiari, Lorestan, Kohgiluyeh and Boyer-Ahmad, West Azerbaijan and Kurdistan, respectively. These regions are located in the Zagros mountain chain and have cold weather. Moreover, all these six provinces are in the category of deprived provinces in the country. In this regard, Song et al. (50) have shown the correlation between economic cycles and occupational safety in China. It can be seen that the risk of accidents in western and central-western parts of Iran are obviously higher than other regions, excluding Sistan and Baluchestan province. This distribution is consistent with the finding of Camino et al. (11) who reveal that the most mountainous areas, with rugged terrain and high rainfall register the greatest percentages of severe accidents.

Falls or slips (10, 12, 18, 19), falling objects and being stuck inside or between objects (9) are the most frequent types of accidents. Conversely, most severe accidents are collapsing in excavation areas, fire or explosion, electric shock, and being hit by a vehicle. Some studies such as Ale et al. (9) and Im et al. (19) advocate this finding.

Hands and limbs are the most frequently affected parts of the body in accidents (51). Investigating the severity of these injuries, we can see that injuries affecting the cranium and brain, spine, back, and eyes unfortunately had the most unpleasant consequences. Conversely, when the cranium and brain, spine and back or eyes are injured, severe consequences are expected. These findings are consistent with past research including as Jeong (52).

Limitations of the Study:

It has only been six years that the occupational accident attributes are archived digitally in the Iranian Social Security Organization (ISSO), and is still not in accordance with comprehensive classifications and formats. Moreover, the quality of gathering accident information by work inspectors is not yet satisfactory.

This study indicates several precautions and steps to be taken for mitigating the risk of occupational accidents in construction industry, including more carefully supervising young workers, workers executing the structure of the buildings and people who work outdoors and at heights, and particularly planning special safety training for young workers and laborers; in the case of planned work for the weekends, enough supervisory staff should be present and working alone should be prevented; construction managers should also plan for accurate inspection and preventive activities during working hours (especially between 8 AM and 12 AM) and prohibit working alone especially when the supervising personnel are not present at the site (in accordance with book 12 of the Iranian National Building Regulations); providing sufficient light for night work can also be useful; it is recommended to interrupt hazardous activities (such as erecting and installing steel structures) in winter even if schedule pressure exists; policymakers should also pay more attention to the improvement of safety conditions in deprived provinces; special attention should be made to prevent accidents affecting the hands, limbs, cranium, and brain; wearing hard hats (which can significantly reduce traumatic head injuries), taking preventive actions such as tools safeguarding (to reduce the risk of hand injuries) and installing protective shields around open spaces and making sure that

workers wear safety shoes (to diminish the risk of limb injuries) are some of the main precautions. Future research can be performed to identify factors affecting the frequency and severity of accidents in different provinces. As a result, it can help policy makers to perform preventive actions and strategies.

Conclusion

The findings of the current study are totally in line with the past research. Hence, this study can help policy makers to perform preventive actions and strategies in order to improve safety condition in the construction industry.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

The authors wish to thank Dr. Nikpour, Mr. Arji and Tabrizi, the respected members of statistics and social - economic calculations office of the Iranian Social Security Organization (ISSO), for providing access to the accident database used in this study. The authors declare that there is no conflict of interests.

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