sustainability

MDPI

Article

Trend Analysis of Construction Industrial Accidents in Korea from 2011 to 2015

Byung Wan Jo, Yun Sung Lee *, Jung Hoon Kim and Rana Muhammad Asad Khan

Department of Civil and Environmental Engineering, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Korea; joycon@hanmail.net (B.W.J.); junghoon3301@hotmail.com (J.H.K.); masadkhan87@gmail.com (R.M.A.K.)

* Correspondence: unsaboa@hanyang.ac.kr; Tel.: +82-2220-0327

Received: 29 May 2017; Accepted: 22 July 2017; Published: 25 July 2017

Abstract: The purpose of this study is to analyze the results of construction accidents occurred from 2011 to 2015 in Korea. The annual reports from the Ministry of Employment and Labor, Korea (MOEL), and the annual reports from the Statistics Korea were used for the analysis in this study. The gender, age, company size and accident types were chosen as a category to analyze the trend of various occupational accidents. In order to analyze the characteristics of construction accidents, incidence rates (IRs) and mortality rates (MRs) were calculated. Further, T-tests and ANOVA analysis were performed to discover the relationships among IRs, MRs, and chosen categories. Male workers' IRs and MRs were significantly higher than those of female workers. Construction workers over 40 years of age suffered the most from occupational injuries. In terms of company size, as company size increases, both IRs and MRs tended to decrease. Occupational injuries caused by falls were higher than other accident types each year. This paper will be able to provide information on occupational accidents for establishing strategies to reduce the accident rate in construction sectors of Korea.

Keywords: construction accidents; incidence rates; mortality rates; ANOVA; occupational injuries

1. Introduction

Industrial occupational accidents cause permanent disabilities, deaths, and work delays; in fact, each of these has long-term negative impacts on the economy, employers, employees, and their families. Thus, occupational accidents are a serious global public health issue [1]. The industrial occupational accidents are influenced by a wide range of factors such as personal, business, and social variables. Chang and Tsai [2] showed an association between the employment growth rate and severity of injuries in the Taiwan manufacturing industry. Similarly, Fabiano et al. [3] found affiliation between the economic cycle and incidence rates in the Italian industry. Dong et al. [4] discovered that out of many types of fatal injuries in the U.S. construction industry, there is a correlation between falls from the roof and economic cycles. Lin et al. [5] conducted a study to identify the difference in incidence rates according to gender. Some researchers analyzed the relationship between day [6], time [7], and occupational injuries. Accident analysis is helpful to identify main factors contributing to incidence rates as well as to develop occupational accidents prevention programs. Dodsworth et al. [8] analyzed relationship to a significant association between organizational culture and occupational injuries. They suggested relative risk ranking method for effective risk management in industry. Many studies have been published focusing on the correlation between different industries and their incidence rates. Usnar and Sut [9] presented that occupational fatalities of the construction industry were much higher than in any other industry in Turkey from 2000 to 2005. Fabiano et al. [10] analyzed trends in the rates of occupational injuries in Italian industries from 2000 to 2004. Their study showed that, among other industries, the building industry is one of the highest risk sectors in Italy. Additionally, Macedo and Silva [11] presented that the numbers of fatal accidents of the construction industry are highest compared to other industries of Portugal. Construction is a hazardous industry in which occupational accidents occur frequently [12]. Therefore, there have been many studies to investigative factors to prevent accidents.

For example, Jackson and Loomis [13] analyzed the occupational fatality trends of the construction industry in North Carolina (USA) from 1978 to 1994. Colak et al. [14] evaluated the characteristics of occupational injuries for construction employees in the Kocaeli Province (Turkey), suggesting that small companies should be checked more systematically and should be encouraged to properly train their workers with regard to safety. Cheng et al. [15] focused on analyzing the accident patterns of small construction enterprises in Taiwan and discovered that most of the accidents in small construction companies occurred in non-governmental projects with contract prices below 5 million NTD (New Taiwan Dollars). Suárez-Cebador et al. [16] conducted a study regarding the characteristics of construction accidents in Spain caused by electrical contact. In addition, recently, many articles covering the various topics dealing with the prevention of construction accidents have been published [17,18]. Similarly, in Korea's construction industry, an occupational accident is an important issue. According to Korea's Ministry of Employment and Labor (MOEL) annual report in 2015, 25,132 workers (fatalities, 493) from construction accidents required more than 4 days of medical care and incident rates of Korea's construction industry remained the highest from 2012 to 2015 (only superseded by manufacturing sector in 2011) [19]. Mortality rates of construction stayed the highest among all the other economic sectors from 2011 to 2015, yet it remained a major concern of Korea government. Therefore, there is a need to observe occupational accident trends so that policies and laws can be reformed for the construction industry of Korea. The aim of this study is to evaluate the characteristics of construction accidents in Korea and to gain insight into construction accidents. For this purpose, the following study analyzed the trend of industrial accidents to explore the relationship among the various occupational accident factors from 2011 to 2015. This paper is able to provide information on occupational accidents for establishing strategies to reduce the accident rate in construction sectors of Korea.

2. Materials and Methods

2.1. Data Sources

The accident data during the period of 2011 to 2015 have been analyzed and evaluated in terms of various criteria's. In recent years, Korea has improved the provisions of safety standards, risk forecasting, accident reporting, and other facets through improvement or development of laws and regulations. In this study, the statistical yearbooks regarding the status of industrial accidents regularly published by the Ministry of Employment and Labor (MOEL) were used for the analysis [19]. MOEL is law-based administration, responsible for the establishing and coordinating employment, labor policies, labor standards, occupational safety, and health to name a few. Being a public institution MOEL has been annually gathering and releasing comprehensive data on the total number of occupational accidents in Korea. It is mandatory for each registered enterprise to report every accident to the involved local or provincial governments. From these bodies, MOEL collects all data, the accidents data gathered by MOEL include occupational injuries for those that require medical treatment over 4 days or those who were deceased. The periodic reports published by MOEL include reported occupational accidents in the construction sector as well. In Korea, the industrial accident insurance system was initially enacted in 1963, when the modernization of industry began in earnest. In accordance with the enforcement ordinance of the industrial accident compensation insurance act in July 2000, industrial accident insurance was implemented in all workplaces with one or more workers. Industrial accident compensation insurance is a necessary insurance program by which the nation ensures the post-accidental livelihood of employees and their families. The total number of construction workers were based on the yearbooks of analysis of industrial accidents by the MOEL and the annual report on the economically active population survey by statistics Korea [20].

2.2. Data Analysis

The analytical method used in this study follows the procedure as described:

(i) Occupational injuries were classified into two different groups—total injuries (fatal and non-fatal) and fatal injuries.

(ii) The study variables were selected in order to analyze in terms of various concepts related to occupational injuries in the construction sector. These study variables were classified into four groups: (a) gender, (b) age (c) company size, and (d) accident type. In the total datasets of recorded accidents in the construction industry of Korea, there are 118,532 occupational injuries and 2663 fatal injuries from 2011 to 2015.

(iii) The two occupational injury rates (incidence and mortality rates) were calculated for trend analysis of construction industrial accidents in Korea. In this case, instead of worked hours which represent actual exposed time from the hazard, the number of injuries to the number of workers were used. The incidence rates were calculated as the number of injuries per 100 workers employed in the construction industry. Gender, age, company size, and accident types-specific mortality rates were calculated as fatalities per 100,000 workers.

$$\text{IRs (incidence rates)} = \frac{\text{Total number of occupation injuries per category}}{\text{Total number of workers per category}} \times 10^2$$

$$\text{MRs (mortality rates)} = \frac{\text{Total number of fatal occupation injuries per category}}{\text{Total number of workers per category}} \times 10^5.$$

(iv) Significant differences between the gender groups were compared statistically using T-tests. The other groups were compared using ANOVA tests and further compared between individual categories using the post-hoc tests. p-values below 0.05 were considered statistically significant.

(v) Finally, the authors analyzed and evaluated trends of a total number of occupational injuries in the construction sector of Korea from 2011 to 2015. In this study, the statistical analysis was carried out using SPSS (Statistical Package for Social Sciences) version 21.

3. Results

3.1. Frequency Analysis of Occupational Injuries

Table 1 describes the number of workers, occupational injuries, and fatal injuries in Korea's construction industry from 2011 to 2015. There is an overall increasing trend in the number of companies and workers in the construction industry since 2013. During the study period, the mean number of workers in the construction industry is 3,009,810, while mean occupational injuries and fatal occupational injuries are 23,957 and 561. The total number of occupational injuries in Korea's construction industry increased from 2011 to 2014. The incidence rates increased from 2011 to 2013, but have been decreasing since 2014. From the same table, a number of fatal occupational injuries have shown a fluctuation, decreasing and increasing from 2011 to 2015. The mortality rates in Korea's construction industry started to decrease after 2013. In Korea's construction industry, the number of companies and workers showed the lowest in 2013. On the other hand, both incidence and mortality rates (IRs = 0.92/100 workers, MRs = 22.09/100,000 workers) showed the highest figure in 2013. In addition, the incidence and mortality rates in Korea's construction industry sharply decreased from 2013 to 2014.

Table 1. The number of occupational injuries in construction sector in Korea from 2011 to 2015.

Year	Companies (n)	Workers (n)	Total OIs *		Total FOIs **	
			Numbers (n)	IRs ***	Numbers (n)	MRs ****
2011	283,861	3,087,131	22,782	0.74	621	20.12
2012	217,316	2,786,587	23,349	0.84	496	17.80
2013	216,320	2,566,832	23,600	0.92	567	22.09
2014	329,061	3,249,687	23,669	0.73	486	14.96
2015	380,944	3,358,813	25,132	0.75	493	14.68
Mean	309,107	3,009,810	23,957	-	561	-

* OIs: occupational injuries; ** FOIs: fatal occupational injuries; *** IRs: incidence rates; **** MRs: mortality rates.

Table 2 describes the number of occupational injuries in respect to gender, age, company size, and accident type from 2011 to 2015. In the case of gender, the total number of OIs of male workers increased from 2011 to 2015. The total number of female workers' OIs has shown a fluctuation, increasing and decreasing from 2011 to 2015. The number of female worker's OIs and FOIs were much lower than those of male workers in the study period. Over 95% of the total number of OIs and FOIs were male workers' injuries. The age group was divided into five categories. The trend analysis of occupational injuries in the construction industry shows that workers with ages of <29 showed the lowest number of OIs and FOIs from 2011 to 2015. In contrary, the highest number of OIs and FOIs occurs in the age group of 50–59. From 2011 to 2015, there is an overall decreasing trend in the number of OIs and FOIs for age groups of 30–39 and 40–49. On the other hand, the increasing trends of OIs in the 50–59 and >60 age groups are dominant. Most of the OIs and FOIs in Korea's construction industry belong to the age groups of over 40. The size of the company is the number of workers. In total, nine categories of companies were defined depending on the total number of workers employed in the company. Analysis of OIs and FOIs in the construction industry shows that the company with <5 workers recorded the highest number of occupational injuries. Contrarily, the companies with more than 1000 workers showed the lowest injury numbers among all the other company size groups. The second highest number of injuries group is the company with 10–29 workers, followed by the group of 5–9 employees. There is an overall increasing trend in the number of OIs for a company with 10–29 workers since 2013. From 2011 to 2015, there is an overall decreasing trend in the number of FOIs for a company with 5–9 workers. Results of the analysis indicated that companies with more workers are more likely to decrease numbers of occupational injuries. In total, ten subgroups of accidents were defined based on the different nature of accidents. The highest number of OIs and FOIs in the construction industry occurred by "fall from a higher level," and the second highest number showed by "fall on the same level." Thus, the "fall" type as a whole in Korea's construction industry is the most dominant factor for the injuries. The number of OIs for those who "fall from a higher level," were "struck by objects excluding falling objects," and were "cut" have all been increasing since 2013. The number of OIs and FOIs of types "narrowness" and "cut" decreased from 2013 to 2015.

Table 2. The total number of OIs and FOIs in Korea's construction industry from 2011 to 2015.

Category	OIs					FOIs				
	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Gender										
Male	22,213	22,776	23,050	23,081	24,600	612	493	561	475	486
Female	569	573	550	588	532	9	3	6	11	7
Age										
<29	411	388	388	403	422	20	8	8	12	8
30–39	2199	2020	1856	1724	1718	59	43	36	29	39
40–49	6379	6248	5992	5698	5551	146	135	128	103	116
50–59	9277	9763	9925	9821	10,485	235	189	241	202	178
Over 60	4516	4926	5439	6023	6953	161	121	154	140	152
Unknown	-	4	-	-	3	-	-	-	-	-

Table 2. *Cont.*

Category	OIs					FOIs				
	2011	**2012**	**2013**	**2014**	**2015**	**2011**	**2012**	**2013**	**2014**	**2015**
Company size										
<5 workers	8549	8014	9340	8358	10,054	186	149	192	148	172
5–9	4638	4780	4015	4529	4467	74	72	54	55	46
10–29	5037	5673	5091	5162	5458	113	98	95	86	100
30–49	1628	1808	1709	1899	1871	52	33	52	39	33
50–99	1329	1474	1561	1601	1427	58	48	62	43	49
100–299	1045	1026	1213	1278	1147	69	64	73	59	53
300–499	271	304	322	362	328	29	10	19	29	16
500–999	229	202	259	331	238	20	13	14	21	13
Over 1000	146	68	90	149	142	20	9	6	6	11
Accident type										
Fall from a higher level	7489	7734	7682	7908	8259	311	248	266	256	257
Fall on the same level	4191	4081	4431	4146	4360	32	27	35	29	28
Struck by objects excluding falling objects	1917	1820	1763	2045	2219	22	41	36	35	46
Struck by falling objects	3123	3226	3024	3002	3168	33	35	45	29	28
collapse	452	411	468	308	327	50	31	36	29	27
Narrowness	1856	1952	2006	1960	1958	23	20	19	15	12
Cut	1912	2145	2106	2218	2625	1	3	-	-	3
Electric shock	176	188	176	144	138	22	20	15	14	9
Explosion//fire	136	188	139	162	148	14	14	15	7	11
Others	1530	1604	1805	1776	1930	113	57	100	72	72

OIs = occupational injuries; FOIs = fatal occupational injuries.

3.2. Analysis of Incidence and Mortality Rates

Table 3 depicted the trend of IRs and MRs in respect to gender, age, company size, and accident type for the study period. When we consider gender, IRs and MRs of the male workers are much higher relative to female workers. Initially, IRs for male workers increased from 2011 to 2013 then it decreased until 2015. On the other hand, generally, the MRs of male workers decreased from 2011 to 2015 with an exception of 2013. In 2013, male workers' MRs was higher than other years of this study. Comparatively, the IR trend of female workers generally decreased in the period of 2013–2015 with the highest value in the year of 2013, and MRs for female workers was the highest in 2014. In the case of age, among all the age groups, the highest number of IRs and MRs occurred in workers >60 years old, followed by workers aged 50–59. The IRs of workers >60 initially increased until 2013 then decreased until 2015. Apart from this, there was a decrease in MRs of the age group of >60 from 2011 to 2015, with the highest value in the year of 2011. Similarly, the IRs and MRs of the 50–59 age group also decreased for the study period with some notable exceptions. In addition, the IRs and MRs for the age groups <29, 30–39, and 40–49 generally decreased from 2011 to 2015. However, 2013 showed the higher IRs for all three groups, while for age group <29 and 30–39, much higher MRs were observed for 2011. Moreover, for the age group of 40–49 significantly higher MRs were depicted in 2013. The highest amounts of IRs and MRs were found in companies with <5 workers followed by the 5–9 workers company size. The IRs for <5 workers company size was initially increased until 2013 then lessened till 2015, but the overall trend was slightly decreased from 2011 to 2015. For the MRs of <5 workers, there was a reduction over the study period, an exception can be observed for the year of 2013. Over the study period, the IRs and MRs of the 5–9 workers group followed a decreasing trend, about 50% was observed in the MRs. IRs of 300–499, 500–999, and over 1000 remained almost constant, on the contrary, MRs of these groups were constantly decreased over the study period. Generally, IRs and MRs of 10–29, 30–49, and 50–99 decreased from 2011 to 2015. For the 100–299 workers, the IRs remained almost constant and MRs decreased over the study period. IRs and MRs for the groups of accident type have also been illustrated in Table 3. The highest indices of IRs, as well as MRs, involved "falls from a higher level," followed by "falls on the same level" type. The third highest indices of IRs and

MRs were involved being "struck by falling objects." For "falls from a higher level" and "struck by objects excluding falling objects," general trends of IRs increased until 2013 and started to decrease until 2015, but the overall trend remained almost constant. Meanwhile, MRs of falls from a higher level decreased over the study period; contrarily, the MRs of being struck by objects, excluding falling objects, increased from 2011 to 2015. IRs for falls on the same level slightly decreased, and MRs of this group decreased from 2011 to 2015. IRs of all the other groups, except for cuts, either decreased or remained constant with some variation over the years, while the IRs of cuts increased during the study period. MRs of being struck by falling objects, collapses, narrowness, electric shock explosion, and other incidences decreased substantially. However, there was a considerable increase in the MRs of cuts.

Table 3. The IRs and MRs in Korea's construction industry from 2011 to 2015.

Category	IRs					MRs				
	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Gender										
Male	0.79	0.89	0.98	0.78	0.80	21.76	19.29	23.74	15.96	15.80
Female	0.21	0.25	0.27	0.22	0.19	3.27	1.30	2.94	4.03	2.47
Age										
<29	0.18	0.18	0.22	0.18	0.21	8.58	3.79	4.58	5.50	4.05
30–39	0.34	0.36	0.38	0.30	0.30	8.99	7.75	7.42	5.01	6.87
40–49	0.61	0.67	0.69	0.54	0.52	13.87	14.38	14.80	9.76	10.83
50–59	1.02	1.16	1.25	0.95	0.93	25.86	22.40	30.35	19.45	15.73
Over 60	1.91	2.07	2.19	1.68	1.78	68.08	50.79	62.08	39.05	38.88
Company size										
<5 workers	2.85	3.57	4.13	2.50	2.81	62.63	66.33	84.97	44.19	48.07
5–9	2.07	2.32	1.94	1.76	1.69	33.07	33.94	26.14	21.39	17.39
10–29	1.24	1.42	1.32	0.98	0.99	27.74	24.54	24.54	16.36	18.18
30–49	0.80	0.91	0.87	0.70	0.72	25.46	16.54	26.37	14.38	12.68
50–99	0.48	0.57	0.62	0.47	0.43	20.99	18.62	24.53	12.67	14.91
100–299	0.20	0.20	0.25	0.21	0.20	12.99	12.76	15.19	9.91	9.29
300–499	0.10	0.12	0.13	0.12	0.11	10.45	3.89	7.52	9.47	5.19
500–999	0.07	0.07	0.10	0.11	0.08	5.79	4.57	5.46	6.70	4.18
Over 1000	0.03	0.01	0.03	0.05	0.03	3.82	1.97	1.95	1.96	2.70
Accident type										
Fall from a higher level	0.24	0.28	0.30	0.24	0.25	10.07	8.90	10.36	7.88	7.65
Fall on the same level	0.14	0.15	0.17	0.13	0.13	1.04	0.97	1.36	0.89	0.83
Struck by objects excluding falling objects	0.06	0.07	0.07	0.06	0.07	0.71	1.47	1.40	1.08	1.37
Struck by falling objects	0.10	0.12	0.12	0.09	0.09	1.07	1.26	1.75	0.89	0.83
Collapse	0.01	0.01	0.02	0.01	0.01	1.62	1.11	1.40	0.89	0.80
Narrowness	0.06	0.07	0.08	0.06	0.06	0.75	0.72	0.74	0.46	0.36
Cut	0.06	0.08	0.08	0.07	0.08	0.03	0.11	-	-	0.09
Electric shock	0.01	0.01	0.01	0.00	0.00	0.71	0.72	0.58	0.43	0.27
Explosion//fire	0.00	0.01	0.01	0.00	0.00	0.45	0.50	0.58	0.22	0.33
Others	0.05	0.06	0.07	0.05	0.06	3.66	2.05	3.90	2.22	2.14

3.3. Result of T-Test and ANOVA Analysis

A T-test and ANOVA analysis were conducted to compare the significant association with each category for incidence and mortality rates. The results are shown in Tables 4 and 5. There was a significant difference in IRs on gender at the $p < 0.001$ level. The IRs of male workers' (mean = 0.848, SD = 0.086) were much higher than female workers' (mean = 0.228, SD = 0.032). In addition, the age (F = 175.206, $p < 0.001$), company size (F = 90.832, $p < 0.001$), and accident types (F = 193.144, $p < 0.001$) of construction workers were significantly different in IRs. Post-hoc comparisons indicated that the <29 age group (mean = 0.194, SD = 0.019) and 30–39 age group (mean = 0.336, SD = 0.036) were lower than the >60 age group (mean = 1.926, SD = 0.208). The highest IRs occurred in the >60 age group (mean = 1.926, SD = 0.208), while the <29 age group appeared to be the lowest (mean = 0.194, SD = 0.019). From the results of the relationship between the company size and the IRs, the incident rates increased as the company size decreased. The company size with over 1000 workers showed the lowest rate (mean = 0.03, SD = 0.014), while the company size with less than 5 workers showed the highest (mean = 3.172, SD = 0.663). From the analysis of accident type, fall from a higher level (mean = 0.262, SD = 0.027) were much higher than fall on the same level (mean = 0.144, SD = 0.017).

Table 4. Result of T-test and ANOVA analysis (incidence rates).

Category	Mean (SD)	No.									
		(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Gender (t = 15.135, $p < 0.001$)											
(1) Male	0.848 (0.086)										
(2) Female	0.228 (0.032)										
Age (F = 175.206, $p < 0.001$)											
(1) <29	0.194 (0.019)	-	*	*	*	**					
(2) 30–39	0.336 (0.036)	*	-	*	*	**					
(3) 40–49	0.606 (0.076)	*	*	-	*	**					
(4) 50–59	1.062 ± 0.138	*	*	*	-	*					
(5) Over 60	1.926 ± 0.208	**	**	**	*	-					
Company size (F = 90.832, $p < 0.001$)											
(1) <5 workers	3.172 (0.663)	-		*	*	*	*	*	*	*	
(2) 5–9	1.956 (0.252)		-	*	*	*	*	*	*	*	
(3) 10–29	1.190 (0.198)	*	*	-		*	*	*	*	*	
(4) 30–49	0.800 (0.091)	*	*		-	*	*	*	**	**	
(5) 50–99	0.514 (0.078)	*	*	*	*	-	*	*	*	*	
(6) 100–299	0.212 (0.021)	*	*	*	*	*	-	*	**	**	
(7) 300–499	0.116 (0.011)	*	*	*	*	*	*	-		**	
(8) 500–999	0.086 (0.018)	*	*	*	**	*	**		-	*	
(9) Over 1000	0.030 (0.014)	*	*	*	**	*	**	**	*	-	
Accident type (F = 193.144, $p < 0.001$)											
(1) Fall from a higher level	0.262 (0.027)	-	*	*	**	**	**	**	**	**	**
(2) Fall on the same level	0.144 (0.017)	*	-	*		**	*	*	**	**	*
(3) Struck by objects excluding falling objects	0.066 (0.005)	*	*	-	*	**			**	**	
(4) Struck by falling objects	0.104 (0.015)	**		*	-	*	*		*	**	*
(5) Collapse	0.012 (0.004)	**	**	**	*	-	**	**			*
(6) Narrowness	0.066 (0.009)	**	*		*	**	-		**	**	
(7) Cut	0.074 (0.009)	**	*			**		-	**	**	
(8) Electric shock	0.006 (0.005)	**	**	**	*		**	**	-		**
(9) Explosion//fire	0.004 (0.005)	**	**	**	**		**	**		-	**
(10) Others	0.058 (0.075)	**	*		*	*			**	**	-

* Indicates a significant difference, p-value < 0.05; ** Indicates a significant difference, p-value < 0.001.

The analysis results confirm that the gender (t = 10.114, $p < 0.001$), age (F = 41.507, $p < 0.001$), company size (F = 33.349, $p < 0.001$), and accident types (F = 122.069, $p < 0.001$) of construction workers were significantly different with MRs. Compared to female workers' (mean = 2.802, SD = 1.014) MRs, those of male workers (mean = 19.310, SD = 3.506) were approximately seven times higher. Similar to previous IRs, the highest MRs occurred in the >60 age group (mean = 51.7760, SD = 13.240) while <29 years group appeared to be the lowest (mean = 5.30, SD = 1.947). From the results of the relationship between the company size and the MRs, the company size with over 1000 workers showed the lowest rate (mean = 2.48, SD = 0.815) while the company size with less than 5 workers showed the highest (mean = 61.238, SD = 16.241). From the analysis of accident type, fall from a higher level (mean = 8.972, SD = 1.233) showed the highest mean value.

Table 5. Result of T-test and ANOVA analysis (Mortality rates).

Category	Mean (SD)	No.									
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Gender (t = 10.114, $p < 0.001$)											
(1) Male	19.310 (3.506)										
(2) Female	2.802 (1.014)										
Age (F = 41.507, $p < 0.001$)											
(1) <29	5.300 (1.947)	-		*	*	*					
(2) 30–39	7.208 (1.454)		-	*	*	*					
(3) 40–49	12.728 (2.277)	*	*	-		*					
(4) 50–59	22.758 (5.651)	*	*		-	*					
(5) Over 60	51.776(13.240)	*	*	*	*	-					
Company size (F = 33.349, $p < 0.001$)											
(1) <5 workers	61.238(16.241)	-		*	*	*	*	*	*	*	
(2) 5–9	26.586 (7.477)		-					*	*	*	
(3) 10–29	22.272 (4.793)	*		-				*	*	*	
(4) 30–49	19.086 (6.390)	*			-					*	
(5) 50–99	18.344 (4.726)	*				-		*	*	*	
(6) 100–299	12.028 (2.421)	*					-		*	*	
(7) 300–499	7.304 (2.773)	*	*	*		*		-			
(8) 500–999	5.340 (1.001)	*	*	*		*	*		-	*	
(9) Over 1000	2.480 (0.815)	*	*	*	*	*	*		*	-	
Accident type (F = 122.069, $p < 0.001$)											
(1) Fall from a higher level	8.972 (1.233)	-	*	*	*	*	*	*	*	*	*
(2) Fall on the same level	1.018 (0.207)	*	-					*		*	
(3) Struck by objects excluding falling objects	1.206 (0.315)	*		-				*		*	
(4) Struck by falling objects	1.160 (0.370)	*			-			*			
(5) Collapse	1.164 (0.344)	*				-		*			
(6) Narrowness	0.606 (0.183)	*					-	*			
(7) Cut	0.046 (0.051)	*	*	*	*	*	*	-	*	*	*
(8) Electric shock	0.542 (0.192)	*						*	-		*
(9) Explosion//fire	0.416 (0.142)	*	*	*				*		-	*
(10) Others	2.794 (0.906)	*						*	*	*	-

* indicates a significant difference, p-value < 0.05; ** indicates a significant difference, p-value < 0.001.

4. Discussion

In this paper, we analyzed the trend of occupational injuries that occurred in Korea's construction industry from 2011 to 2015. The analysis results of construction workers' genders indicate that the male workers (mean; IRs = 0.848/100 workers, MRs = 19.310/100,000 workers) were more likely to suffer from occupational accidents than female workers (mean; IRs = 0.228/100 workers, MRs = 2.802/100,000 workers). According to Lin et al. [5], in Taiwan construction, male workers (31.8/100,000 workers) had almost 1.8 times higher mortality rates than female workers (17.2/100,000 workers). Lipscomb et al. [21] presented the rates of treated injuries from the emergency department in U.S. construction sector were significantly higher among male workers (230/10,000 full-time workers) than that of female workers (65/10,000 full-time workers). In addition, male workers showed a high percentage (more than 90%) of injuries in several studies including frequency survey of occupational injuries [22–26]. Males are more likely to be employed in outdoor jobs or dangerous tasks compared to females [24,26]. These differences arise from the possibility that the construction industry is a male-dominated industry, yet research on the construction accidents due to gender differences are still lacking. Tables 4 and 5 shows that, as workers age, IRs (mean; <29 = 0.194, 30–39 = 0.336, 40–49 = 0.606, 50–59 = 1.602, >60 = 1.926/100 workers) and MRs (mean; <29 = 0.5.300, 30–39 = 7.208, 40–49 = 12.728, 50–59 = 22.758, >60 = 52.776/100,000 workers) increase in Korea's construction industry. Similarly, Arquillos et al. [27] and Dumark et al. [25] reported that the severity of an accident increase as the age of the construction worker increases. Generally, older workers are more likely to be injured compared to younger workers because of their declining mental and physical abilities [12,28]. With older workers becoming more prevalent within the construction industry, there is a growing need for the health and safety of such workers. Due to physical limitations of the aged group, which comprises more than a half of the total workers, the safety regulations should be revised. Tables 4 and 5 indicate that occupational injuries for the companies with <5 workers (mean; IRs = 3.172/100 workers, MRs = 61.238/100,000 workers) are more likely to occupational and fatal injuries. Generally, in most countries, because the large-sized construction companies invest more in safety management than small construction enterprises do, small-sized construction companies suffer more accidents than large-sized construction companies do [15,29,30]. In addition, workers for small construction companies tend to use old equipment and devices that lack safety measures or ways to prevent injury. It is difficult to ensure internal knowledge regarding safety management for small companies, which have limited budgets for systematic safety measure [31]. It is thus necessary to develop approaches for worker health and safety for small construction companies. For small construction enterprises, it is important to focus on simple and economic solutions [32]. In addition, the workers with a short service period rarely receive instructions regarding the prevention of occupational accidents. For this reason, construction workers are more likely to experience occupational injuries when they have a lack of education and work experience [31,33]. Safety and health education are important elements that can reduce the frequency of occupational injuries and diseases [34–36]. Such safety and health education include topics such as confined space entry, working under extreme weather, traffic control, and various types of occupational accident prevention [36]. Tables 4 and 5 shows the trend of occupational injuries in Korea's construction industry according to accident types. Among the accidents, fall (mean; IRs = 0.262/100 workers, MRs = 8.972/100,000 workers) represent the most common accident types in Korea. Similarly, the most frequent accident types in the Iranian construction industry are falls or slips (47.2%) [22]. In Turkey, 52.9% of non-fatal accidents and 54.1% of fatal accidents were due to falls [37]. In the construction industry, falls are the leading cause of serious injuries and fatalities [38]. According to a study by Haslam et al. [33], fall accidents could be the result of the inappropriate usage of safety equipment and poor communication within the work team. In addition, fall from a higher level is more likely to occur when construction workers perform hazardous tasks, and the work complexity may divert workers' attention at significant heights, potentially leading to accidental falling [38]. In order to prevent falling, Ling et al. [39] recommended that it be mandatory for workers to put on anti-fall equipment and set up an anchorage point before work. Table 6 compares the MRs of Korea's construction industry with that of U.S. from 2011 to 2015 [40]. From 2011 to 2015, MRs in Korea's construction industry is 1.5 or 2 times more than the MRs in the U.S. construction industry for the years of 2011 and 2015. During 2013 to 2015, the MRs in the U.S. construction industry shows an upward trend, with minimum MRs at 2013 and maximums in the year 2015. On the contrary, the MRs in Korea's construction industry follows a decreasing trend in the same period. It indicates the consistent efforts of Korea's construction industry to improve construction safety.

Table 6. Mortality rates in construction industry (U.S. and Korea).

Category	2011	2012	2013	2014	2015
U.S.	9.1	9.9	9.7	9.8	10.1
Korea	20.12	17.80	22.09	14.96	14.68

5. Conclusions

This study is related to the trend analysis of the occupational and fatal injuries in Korea's construction industry from 2011 to 2015, using the incidence rate and mortality rate. T-tests and ANOVA analysis were conducted to compare the significant association with each category for incidence and mortality rates. The results confirm that the gender, age, company size, and accident types of construction workers were significantly different in incidence rates and mortality rates.

Compared to female workers, male workers' IRs were approximately four times higher (male workers' mean = 0.848, female workers' mean = 0.228), and male workers' MRs were almost seven times higher than that of female workers' (male workers' mean = 19.310, female workers' mean = 2.802). Relatively, a high number of incidence and mortality rates are associated with the workers of >40 years of age. Occupational injuries of companies over 1000 employees were lower than that of small-sized companies, while most of the construction accidents occurred in the companies with <5 workers. Like other countries, "falls from a higher level" and "falls on the same level" are the leading types of accidents covering more than half of the proportion of construction sites. In addition, IRs and MRs related to falls are higher than those of any other accident type. Therefore, for establishing strategies to reduce the accident rate in the construction sector, the Korean government should focus on male workers >40 years of age in small- to medium-scale companies. Additionally, a special consideration should be given to falling at construction sites.

6. Limitation and Future Research

Limitations of this study are as follows: (i) As the source of data used for analyzing the trends of construction accidents, those industrial accident victims who received at least 4 days of medical care benefits were only counted; thus, the workers who received less than 4 days of medical care were not considered in this analysis. This may contribute to lower the total number of incidence rates. (ii) In addition, at the time of bidding in Korea, pre-qualification assessment includes accident rates; therefore, it is possible for some companies to hide their incidence records, which ultimately can influence the total number of accident rates in the construction field.

Some factors should be studied more in-depth in future research to obtain a better solution. For example, in this study, only total incidence rates were analyzed. However, for establishing effective strategies to reduce the accident rate in the construction field, the accident rates according to construction types need to be analyzed.

Acknowledgments: The authors would like to thank the anonymous reviewers for their constructive comments and suggestions on improving this paper.

Author Contributions: In this paper, Byung wan jo and Yun sung Lee designed experimental method, carried out the interpretation, and wrote the manuscript; Jung Hoon Kim collected the related data and managed data; Rana Muhammad Asad Khan gave important advice about the content and writing.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zhou, W.; Whyte, J.; Sacks, R. Construction safety and digital design: A review. *Autom. Constr.* **2012**, *22*, 102–111. [CrossRef]
2. Chang, D.-S.; Tsai, Y.-C. Investigating the long-term change of injury pattern on severity, accident types and sources of injury in Taiwan's manufacturing sector between 1996 and 2012. *Saf. Sci.* **2014**, *68*, 231–242. [CrossRef]
3. Fabiano, B.; Parentini, I.; Ferraiolo, A.; Pastorino, R. A century of accidents in the Italian industry: Relationship with the production cycle. *Saf. Sci.* **1995**, *21*, 65–74. [CrossRef]
4. Dong, X.S.; Choi, S.D.; Borchardt, J.G.; Wang, X.; Largay, J.A. Fatal falls from roofs among US construction workers. *J. Saf. Res.* **2013**, *44*, 17–24. [CrossRef] [PubMed]
5. Lin, Y.-H.; Chen, C.-Y.; Luo, J.-L. Gender and age distribution of occupational fatalities in Taiwan. *Accid. Anal. Prev.* **2008**, *40*, 1604–1610. [CrossRef] [PubMed]
6. Campolieti, M.; Hyatt, D.E. Further evidence on the "monday effect" in workers' compensation. *Ind. Labor Relat. Rev.* **2006**, *59*, 438–450. [CrossRef]
7. Lopez, M.A.C.; Fontaneda, I.; Alcantara, O.J.G.; Ritzel, D.O. The special severity of occupational accidents in the afternoon: "The lunch effect". *Accid. Anal. Prev.* **2011**, *43*, 1104–1116. [CrossRef] [PubMed]

8. Dodsworth, M.; Connelly, K.; Ellett, C.; Sharratt, P. Organizational climate metrics as safety, health and environment performance indicators and an aid to relative risk ranking within industry. *Process Saf. Environ. Prot.* **2007**, *85*, 59–69. [CrossRef]
9. Unsar, S.; Sut, N. General assessment of the occupational accidents that occurred in Turkey between the years 2000 and 2005. *Saf. Sci.* **2009**, *47*, 614–619. [CrossRef]
10. Fabiano, B.; Currò, F.; Reverberi, A.P.; Pastorino, R. A statistical study on temporary work and occupational accidents: Specific risk factors and risk management strategies. *Saf. Sci.* **2008**, *46*, 535–544. [CrossRef]
11. Macedo, A.C.; Silva, I.L. Analysis of occupational accidents in portugal between 1992 and 2001. *Saf. Sci.* **2005**, *43*, 269–286. [CrossRef]
12. Choi, S.D. Aging workers and trade-related injuries in the US construction industry. *Saf. Health Work* **2015**, *6*, 151–155. [CrossRef] [PubMed]
13. Jackson, S.A.; Loomis, D. Fatal occupational injuries in the north carolina construction industry, 1978–1994. *Appl. Occup. Environ. Hyg.* **2002**, *17*, 27–33. [CrossRef] [PubMed]
14. Colak, B.; Etiler, N.; Bicer, U. Fatal occupational injuries in the construction sector in Kocaeli, Turkey, 1990-2001. *Ind. Health* **2004**, *42*, 424–430. [CrossRef] [PubMed]
15. Cheng, C.-W.; Leu, S.-S.; Lin, C.-C.; Fan, C. Characteristic analysis of occupational accidents at small construction enterprises. *Saf. Sci.* **2010**, *48*, 698–707. [CrossRef]
16. Suárez-Cebador, M.; Rubio-Romero, J.C.; López-Arquillos, A. Severity of electrical accidents in the construction industry in Spain. *J. Saf. Res.* **2014**, *48*, 63–70. [CrossRef] [PubMed]
17. Zhou, Z.; Goh, Y.M.; Li, Q. Overview and analysis of safety management studies in the construction industry. *Saf. Sci.* **2015**, *72*, 337–350. [CrossRef]
18. Skibniewski, M.J. Research trends in information technology applications in construction safety engineering and management. *Front. Eng. Manag.* **2015**, *1*, 246–259. [CrossRef]
19. Ministry of Employment and Labor. Yearbooks of Analysis of Industrial Accidents, 2011–2015. Available online: http://www.kosha.or.kr/board.do?menuId=554 (accessed on 29 May 2017).
20. Statistics Korea. Annual Report on the Economically Active Population Survey, 2011–2015. Available online: http://kosis.kr/ups/ups_01List.jsp?pubcode=WA (accessed on 29 May 2017).
21. Lipscomb, H.J.; Schoenfisch, A.L.; Shishlov, K.S. Non-fatal contact injuries among workers in the construction industry treated in US emergency departments, 1998–2005. *J. Saf. Res.* **2010**, *41*, 191–195. [CrossRef] [PubMed]
22. Amiri, M.; Ardeshir, A.; Zarandi, M.H.F. Risk-based analysis of construction accidents in Iran during 2007–2011-meta analyze study. *Iran. J. Public Health* **2014**, *43*, 507–522. [PubMed]
23. Cattledge, G.H.; Hendricks, S.; Stanevich, R. Fatal occupational falls in the US construction industry, 1980–1989. *Accid. Anal. Prev.* **1996**, *28*, 647–654. [CrossRef]
24. Ore, T. Women in the US construction industry: An analysis of fatal occupational injury experience, 1980 to 1992. *Am. J. Ind. Med.* **1998**, *33*, 256–262. [CrossRef]
25. Dumrak, J.; Mostafa, S.; Kamardeen, I.; Rameezdeen, R. Factors associated with the severity of construction accidents: The case of south Australia. *Australas. J. Constr. Econ. Build.* **2013**, *13*, 32–49. [CrossRef]
26. Chi, C.-F.; Chang, T.-C.; Ting, H.-I. Accident patterns and prevention measures for fatal occupational falls in the construction industry. *Appl. Ergon.* **2005**, *36*, 391–400. [CrossRef] [PubMed]
27. Arquillos, A.L.; Romero, J.C.R.; Gibb, A. Analysis of construction accidents in Spain, 2003–2008. *J. Saf. Res.* **2012**, *43*, 381–388. [CrossRef] [PubMed]
28. Dong, X.S.; Wang, X.; Daw, C.; Ringen, K. Chronic diseases and functional limitations among older construction workers in the United States: A 10-year follow-up study. *J. Occup. Environ. Med.* **2011**, *53*, 372–380. [CrossRef] [PubMed]
29. Hasle, P.; Kines, P.; Andersen, L.P. Small enterprise owners' accident causation attribution and prevention. *Saf. Sci.* **2009**, *47*, 9–19. [CrossRef]
30. Yoon, S.J.; Lin, H.K.; Chen, G.; Yi, S.; Choi, J.; Rui, Z. Effect of occupational health and safety management system on work-related accident rate and differences of occupational health and safety management system awareness between managers in South Korea's construction industry. *Saf. Health Work* **2013**, *4*, 201–209. [CrossRef] [PubMed]
31. Pinto, A.; Nunes, I.L.; Ribeiro, R.A. Occupational risk assessment in construction industry—Overview and reflection. *Saf. Sci.* **2011**, *49*, 616–624. [CrossRef]

32. Hasle, P.; Limborg, H.J. A review of the literature on preventive occupational health and safety activities in small enterprises. *Ind. Health* **2006**, *44*, 6–12. [CrossRef] [PubMed]
33. Haslam, R.A.; Hide, S.A.; Gibb, A.G.; Gyi, D.E.; Pavitt, T.; Atkinson, S.; Duff, A. Contributing factors in construction accidents. *Appl. Ergon.* **2005**, *36*, 401–415. [CrossRef] [PubMed]
34. Kinn, S.; Khuder, S.A.; Bisesi, M.S.; Woolley, S. Evaluation of safety orientation and training programs for reducing injuries in the plumbing and pipefitting industry. *J. Occup. Environ. Med.* **2000**, *42*, 1142–1147. [CrossRef] [PubMed]
35. Johnson, K.A.; Ruppe, J. A job safety program for construction workers designed to reduce the potential for occupational injury using tool box training sessions and computer-assisted biofeedback stress management techniques. *Int. J. Occup. Saf. Ergon.* **2002**, *8*, 321–329. [CrossRef] [PubMed]
36. Hinze, J.; Gambatese, J. Factors that influence safety performance of specialty contractors. *J. Constr. Eng. Manag.* **2003**, *129*, 159–164. [CrossRef]
37. Gürcanli, G.E.; Müngen, U. Analysis of construction accidents in Turkey and responsible parties. *Ind. Health* **2013**, *51*, 581–595. [CrossRef] [PubMed]
38. Nadhim, E.A.; Hon, C.; Xia, B.; Stewart, I.; Fang, D. Falls from height in the construction industry: A critical review of the scientific literature. *Int. J. Environ. Res. Public Health* **2016**, *13*, 638. [CrossRef] [PubMed]
39. Ling, F.Y.Y.; Liu, M.; Woo, Y.C. Construction fatalities in Singapore. *Int. J. Proj. Manag.* **2009**, *27*, 717–726. [CrossRef]
40. Bureau of Labor Statistics. Available online: https://www.Bls.Gov/iif/oshcfoi1.Htm# (accessed on 1 July 2017).