International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 5 (2018) pp. 2545-2550

Effects of the Number of Workers Exposed to Industrial Machines and the Level of Workers' Safety Behavior on the Occurrence of Industrial Accidents

Kwan Woo Kim[1,*] and Yoon Ho Cho[2]

[1]*Occupational Safety and Health Training Institute, Korea Occupational Safety & Health Agency (KOSHA)*
400 Jongga-ro, Jung-gu, Ulsan 44429, Korea.
E-mail: mazindo11@gmail.com

[2]*Occupational Safety and Health Research Institute, Korea Occupational Safety & Health Agency (KOSHA)*
400 Jongga-ro, Jung-gu, Ulsan 44429, Korea.
E-mail: uno@kosha.or.kr (Corresponding author)*

Abstract

This study was conducted to analyze the association of the occurrence of industrial accidents with the number of workers exposed to industrial machines, and the level of workers' safety behavior. Our aim was to confirm if the number of workers exposed to industrial machines is positively associated with the occurrence of industrial accidents, and if the level of workers' safety behavior moderates the relationship between the number of workers exposed to industrial machines and the occurrence of industrial accidents. Logistic regression analysis was performed using the occurrence of industrial accidents as the dependent variable; the number of workers exposed to industrial machines as the independent variable; the level of workers' safety behavior as the moderating variable, and the number of workers as well as the presence of risk factors, a safety management organization, safety and health education, a labor union, and safety culture as the control variables. A total of 2,000 manufacturing workplaces from the 2015 Occupational Safety and Health Company Survey were sampled. Analysis results showed that the number of workers exposed to industrial machines (Wald=9.498, p<.01) and the level of workers' safety behavior (Wald=11.985, p<.01) affected the occurrence of industrial accidents. The occurrence of industrial accidents increased as the number of workers exposed to industrial machines increased, and decreased as the level of workers' safety behavior increased. The number of workers (Wald=10.064, p<.01), risk factors (Wald=10.808, p<.01) and the presence of a labor union (Wald=4.932, p<.05) also affected the occurrence of industrial accidents. Therefore, measures to prevent workers' exposure to industrial machines, and increase the level of workers' safety behavior must be taken to reduce the number of industrial accidents. The results of this study are meaningful in that they provide implications for the establishment and implementation of safety and health policies, at the government and workplace level.

Keywords: Industrial machine, worker, safety behavior, industrial accident, Korea

INTRODUCTION

The reduction in the number of industrial accidents is currently the focus of efforts taken by the government, as well as employers, in Korea. Industrial accidents not only cause financial loss for employers, but also economic and psychological pain for the workers involved in the accidents and their families. However, no significant decrease has been observed in the number of workers who died in industrial accidents, in the last five years, in Korea (1,134 in 2012, 1,090 in 2013, 992 in 2014, 955 in 2015, and 969 in 2016) [1]. Accordingly, the government has endeavored to reduce the number of industrial accidents by providing funds for workplace improvements, and through system reform. The government of the United Kingdom has established a definitive guideline for health and safety offences, corporate manslaughter, and food safety and hygiene offences, which calls for workplaces to take rigorous responsibility for safety and health policies violations, so as to reduce the number of industrial accidents [2].

Death or injury caused by industrial machines is a commonly observed consequence of industrial accidents [3]. To reduce the number of deaths or injuries due to industrial machines, the Korean Industrial Safety and Health Act (KISHA) stipulates that the manufacturers and users of industrial machines take safety precautions. Safety measures for industrial machines that have been put forth in Korea include safety certification, and safety inspection. As part of safety certification, precautions are taken before industrial machines are put into use. Safety certification includes mandatory safety certification, voluntary safety certification, and reporting on voluntary safety verification. Mandatory safety certification requires that manufacturers of industrial machines, as defined under the KISHA, have the safety of these machines certified before they are shipped. This kind of certification involves a written review of whether the safety of the industrial machines has been considered from the design stage, an audit of the technical ability and production system to evaluate the ability to properly incorporate the safety items considered in the design stage into the product, and product inspection to check the safety of the manufactured products. Voluntary safety certification differs from mandatory safety certification, in that the former entails autonomously receiving safety certification for all products, except for industrial machines that are subject to the latter. Reporting on voluntary safety verification requires manufacturers to self-assess the safety of their industrial machines, and to submit relevant documents to the certification authorities. Since industrial machines require continuous safety management during their use, inspection agencies conduct safety inspections on industrial machines at regular intervals. For this reason, extensive research has been conducted on the risk assessment of industrial machines, and the effects of safety certification [3, 4]. However, additional analyses of the relationship between the number of workers exposed to industrial machines and the occurrence of industrial accidents are also necessary. For instance, if 10 of 1,000 workers exposed to pressure vessels and 20 of 1,000 workers exposed to presses are involved in industrial accidents, presses are considered more hazardous than pressure vessels, and may become the primary factor for consideration in the formulation of preventive measures against industrial accidents.

Even if the number of workers exposed to industrial machines is large, the occurrence of industrial accidents may vary depending on the level of safety behaviors among the workers. Studies have investigated various aspects of the effects of workers' safety behavior. Safety climate, which pertains to the common perception among workers, in terms of workplace safety, is reported to affect workers' safety behavior [5, 6], in addition to organizational commitment [7]. Organizational commitment is the tendency for an individual to identify him/herself as being part of the organization [8]. Organizational commitment can be classified as 'affective', 'continuance', and 'normative'. It has been confirmed that affective and normative organizational commitment affects workers' safety behavior [9, 10]. The factors that affect workers' safety behavior include safety climate, organizational commitment, and safety motivation [11]. It is necessary to analyze not only the factors that affect workers' safety behavior, but also how the level of workers' safety behavior affects industrial accidents.

METHODS

In this study, data from the Occupational Safety and Health Company Survey (OSHCS), conducted by the Korea Occupational Safety and Health Agency, in 2015, were used. Manufacturing workplaces with over 50 employees, construction workplaces with construction expenses of over $10 million, and other workplaces with over 50 employees were investigated. Researchers visited each workplace, and interviewed the safety and health managers. The sample size was 5,000 workplaces, including 2,000 manufacturing workplaces, 1000 construction workplaces, and 2,000 others. Considering that industrial machines are more frequently used in manufacturing workplaces than in other types of workplaces, the 2,000 manufacturing workplaces were used as the sample population of this study.

The purpose of this study was to analyze the association of the occurrence of industrial accidents with the number of workers exposed to industrial machines, and the level of safety behaviors among workers. The following hypotheses were made in this study. First, the number of workers exposed to industrial machines positively affects the occurrence of industrial accidents. Second, the level of workers' safety behavior moderates the relationship between the number of workers exposed to industrial machines, and the occurrence of industrial accidents. The research model used in the analysis is shown in Figure 1.

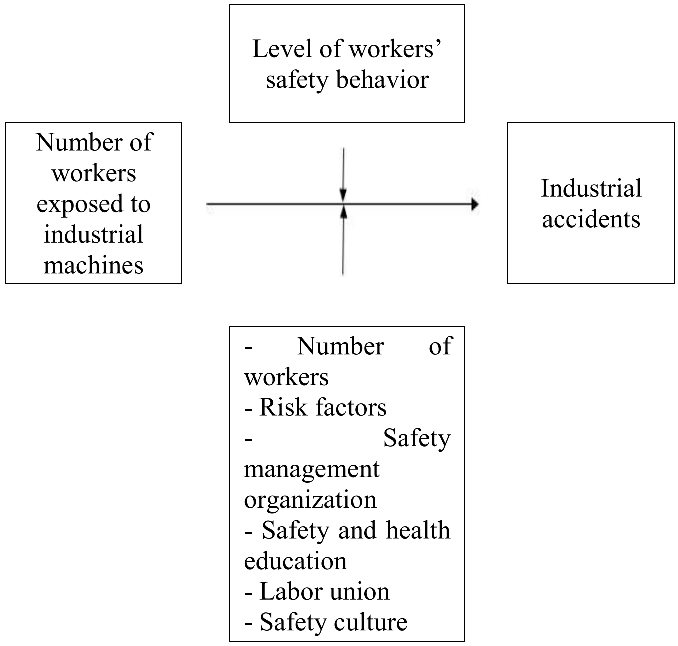

Figure 1. Research model

The dependent variable was the occurrence of industrial accidents, and the independent variable, the number of workers exposed to industrial machines. The moderating variable was the level of workers' safety behavior. However, since other factors can affect the occurrence of industrial accidents too, the number of workers, as well as the presence of risk factors, a safety management organization, safety and health education, a labor union, and safety culture were used as the control variables. All the aforementioned variables are defined in Table1.

Table 1. Definition of the variables

Variable	Definition
Industrial accidents	Occurrence of industrial accidents at the workplace
Number of workers exposed to industrial machines	The number of workers exposed to industrial machines at the workplace
Level of workers' safety behavior	The level of workers' safety behavior at the workplace
Number of workers	The number of workers at the workplace
Risk factors	Risk factors related to chemicals and hazardous workplaces, as well as physical, ergonomic, biological, and psychological risk factors
Safety management organization	Having a safety management organization at the workplace

Safety and health education	Regular safety and health education for office workers and non-office workers, supervisor education, collective and on-site training for new employees, education on changes regarding existing tasks, special safety and health education, and others
Labor union	The presence of a labor union at the workplace
Safety culture	The level of safety awareness within the workplace, as perceived by a safety and health manager

The variable "industrial accidents" was assigned a value of 1 if an industrial accident occurred, and 0 if no accidents occurred. The level of workers' safety behavior in the workplace was measured by the following items.

- The worker performs his duties in a safe manner.
- The worker uses all the necessary safety equipment when working.
- The worker complies with all safety precautions when working.
- The worker works in safe conditions.

The level of workers' safety behavior was rated using a Likert scale; 1 point was assigned for "strongly disagree," 2 points for "disagree," 3 points for "neutral," 4 points for "agree," and 5 points for "strongly agree." The mean score of the four items was used as the final score. The total score of six items, that is, the presence of chemical, physical, ergonomic, biological, and psychological risk factors, and hazardous workplaces, was used to denote the variable "risk factors." If the corresponding risk factor was present, a value of 1 was assigned, and if not, 0. The variable "safety management organization" was assigned a value of 1 if a safety management organization was present, and 0 if it was not. The variable "safety and health education" was defined as the mean score on eight questions, including those about whether regular safety and health education for office workers and non-office workers, supervisor education, collective and on-site training for new employees, education on changes regarding existing tasks, special safety and health education, and other forms of education were provided at the workplace. If the corresponding type of education was provided, a value of 1 was assigned, and if not, 0. The variable "labor union" was assigned a value of 1 if a labor union was present, and 0 if it was not. The value of the variable "safety culture" was the mean score on eight questions. Each question was rated on a 5-point Likert scale, in which a score of 1 was assigned for "strongly disagree", and 5 for "strongly agree".

The eight questions related to "safety culture" were:

- Are various measures and actions related to workplace safety and health required?
- Is the CEO concerned about workers' safety and health?
- Are workplace safety and health emphasized in the business goals?
- Are safety and health prioritized in the business?
- Does the CEO believe that safety and health will become important issues in the future?
- Are sufficient measures and actions being taken against accidents?
- Are measures and actions related to safety and health systematically established?
- Have measures and actions, related to safety and health, been well-implemented, effective, and useful?

3. RESULTS

Table 2 shows the characteristics of each variable related to the 2,000 manufacturing workplaces. Industrial accidents occurred in 27% of all the workplaces analyzed. The mean number of workers in the workplaces was 130, and the mean number of workers exposed to industrial machines was 17. The mean level of workers' safety behaviors was four out of five. Workers were exposed to two of the six risk factors, on average. About 78% of the workplaces had a safety management organization, and 23% had a labor union. The manufacturing workplaces provided seven of the eight safety and health education programs. The mean score for "safety culture" was 4 out of 5.

Table 2. Characteristics of the variables in the manufacturing workplaces

Variable	Mean	Standard deviation
Industrial accidents (%)	.270	.444
Number of workers exposed to industrial machines	16.970	40.510
Level of workers' safety behaviors	4.067	.614
Number of workers	130	193
Risk factors	2.310	1.201
Safety management organization (%)	.780	.416
Safety and health education (%)	.887	.192
Labor union (%)	.230	.420
Safety culture	3.961	.617

Logistic regression analysis was performed to analyze the moderating effects of the level of workers' safety behaviors on the relationship between the number of workers exposed to industrial machines (independent variable) and the occurrence of industrial accidents (dependent variable). The results are shown in Table 3. The dependent variable was the occurrence of industrial accidents in 2014. Three models were used in the analysis. Model 1 analyzed the relationships between the control variables and the occurrence of industrial accidents. Model 2 analyzed the same relationships with the addition of the number of workers exposed to industrial machines to Model 1 as the independent variable. Model 3 was formed by introducing the level of workers' safety behaviors to Model 2, and analyzed its relationship with the occurrence of industrial accidents. In Model 3, which included all the variables, the number of workers (Wald=10.064, p<.01), risk factors (Wald=10.808, p<.01), and presence of a labor union (Wald=4.932, p<.05) (control variables); the number of workers exposed to industrial machines (Wald=9.498, p<.01) (independent variable); and the level of workers' safety behaviors (Wald=11.985, p<.01) (moderating variable) were significantly associated with the occurrence of industrial accidents.

Conclusively, the occurrence of industrial accidents increased as the number of workers exposed to industrial machines increased, in Model 1, 2, and 3, and decreased as the level of workers' safety behaviors increased. Based on the odds ratio in Model 3, the likelihood of industrial accidents increased 1.176-fold as the value of the number of workers exposed to industrial machines increased by 1, and decreased by a factor of 0.714 as the value of the level of workers' safety behaviors increased by 1. The likelihood of industrial accidents increased 1.262-fold as the value of the number of workers in a workplace increased by 1, and increased 1.164-fold when the value of the risk factors increased by 1. Lastly, the likelihood of industrial accidents increased in the presence of a labor union.

Table 3. Influence of the number of workers exposed to industrial machines and the level of workers' safety behavior on the occurrence of industrial accidents

Variable		Industrial accident								
		Model 1			Model 2			Model 3		
		B	Wald	Exp(B)	B	Wald	Exp(B)	B	Wald	Exp(B)
CV	Number of workers	.274	15.493***	1.315	.231	10.521***	1.260	.233	10.604***	1.262
	Risk factors	.216	24.054***	1.241	.177	15.240***	1.194	.152	10.808***	1.164
	Safety management organization	.035	.067	1.035	.029	.046	1.029	.063	.215	1.065
	Safety and health education	.162	.272	1.176	.111	.128	1.118	.079	.064	1.082
	Labor union	.336	7.359**	1.400	.291	5.387**	1.338	.280	4.932**	1.323
	Safety culture	-.204	5.321**	.816	-.207	5.453**	.813	-.055	.301	.947
IV	Number of workers exposed to industrial machines				.170	10.535***	1.186	.162	9.498***	1.176
MV	Level of workers' safety behavior							-.337	11.785***	.714

* p<0.1, ** p<0.05, *** p<0.01, CV: control variable, IV: independent variable, MV: moderating variable

Table 4. Status of the industrial machines in the manufacturing workplaces

Industrial machine	Number	Ratio (%)
Total	89,305	100
Pressure vessel	16,994	19.0
Industrial lift	14,464	16.2
Machine tool	10,763	12.1
Conveyor	9,379	10.5
Press and shearing machine	5,222	5.9
Industrial robot	4,435	5.0
Injection moulding machine	3,173	3.6
Mixer and crusher	2,827	3.2
Chemical and drying equipment	2,710	3.0
Food processing machine	790	0.9
Car lift	541	0.6
Roller machine	304	0.3
Centrifugal machine	210	0.2
Machine for processing timber	162	0.2
Others	17,331	19.4

Table 4 shows the industrial machine possession status of the manufacturing workplaces analyzed. The industrial machines listed in Table 4 require adequate safety measures, according to the KISHA.

Logistic regression analysis was performed to investigate if the industrial machines listed in Table 4 affected the occurrence of industrial accidents, in 2014. The results are shown in Table 5. Presses and shearing machines (Wald=5.764, p<.05), mixers and crushers (Wald=4.358, p<.05), and industrial lifts (Wald=14.488, p<.01) affected the occurrence of industrial accidents, in 2014, in the order of decreasing magnitude.

Additionally, regression analysis was performed to investigate which industrial machines affected the number of those injured by industrial accidents, in 2014. Industrial lifts (β=.092, t=3.320, p<.01), pressure vessels (β=.077, t=3.137, p<.01), machines for processing timber (β=.071, t=3.033, p<.01), car lifts (β=.070, t=3.023, p<.01), injection moulding machines (β=.060, t=2.330, p<.01), and presses and shearing machines (β=.050, t=2.045, p<.05) affected the number of those injured by industrial accidents, in 2014, in the order of decreasing magnitude.

Table 5. Relationship between industrial machines and the occurrence of industrial accidents

Variable	Industrial accident			Number of persons injured		
	B	Wald	Exp(B)	β	t	VIF
Press, shearing machine	.015	5.764**	1.015	.050	2.045**	1.091
Industrial lift	.013	14.488***	1.013	.092	3.320***	1.431
Pressure vessel	.001	.521	1.001	.077	3.137***	1.115
Roller machine	.068	2.702	1.070	-.006	-.265	1.008
Injection moulding machine	.004	.472	1.004	-.008	-.324	1.029
Industrial robot	.001	.275	1.001	.023	.945	1.090
Food processing machine	.005	.126	1.005	.009	.385	1.028
Conveyor	-.001	.578	.999	-.001	-.021	1.237
Car lift	.018	2.688	1.018	.070	3.023***	1.001
Machine tool	-.003	.963	.997	.060	2.330**	1.245
Machine for processing timber	.078	1.234	1.081	.071	3.033***	1.004
Centrifugal machine	-.171	3.819	.843	-.038	-1.563	1.097
Chemical and drying equipment	-.005	.501	.995	-.015	-.659	1.010
Mixer and crusher	.014	4.358**	1.014	-.002	-.091	1.083
F						5.746
R^2						.043

* p<0.1, ** p<0.05, *** p<0.01, VIF: variance inflation factor

DISCUSSION AND CONCLUSION

The number of workers exposed to industrial machines was associated with the occurrence of industrial accidents. Of the industrial machines possessed by the manufacturing workplaces analyzed in this study, the ratios of those that were associated with the number of individuals injured in industrial accidents in 2014 were 19.0% (pressure vessels), 16.2% (industrial lifts), 12.1% (injection moulding machines), 5.9% (presses and shearing machines), 0.6% (car lifts), and 0.2% (machines for processing timber); these machines accounted for 54% of all the industrial machines in the manufacturing workplaces in 2014. This suggests that the likelihood of industrial accidents is high in workplaces that contain large numbers of industrial machines.

As seen under Model 3, in Table 3, the number of workers at a workplace, risk factors, and the presence of a labor union affected the occurrence of industrial accidents, in addition to the number of workers exposed to industrial machines and the level of workers' safety behaviors. Although the likelihood of industrial accidents was found to increase in workplaces that had labor unions, it is reported that the better the labor-management relations, the lower the likelihood of the occurrence of industrial accidents [12]. While the occurrence of industrial accidents was not significantly correlated with whether workers were provided safety and health education, another study reported that the likelihood of industrial accidents decreased when the said education was provided to workers [13].

In this study, the likelihood of industrial accidents increased as the number of workers exposed to industrial machines increased. Since workplaces cannot reduce the number of industrial machines essential to production, in order to prevent industrial accidents, measures must be taken to reduce workers' exposure to the risk factors associated with industrial machines. Based on the results of this study and those of previous studies, the level of workers' safety behaviors affects the likelihood of the occurrence of industrial accidents. Therefore, efforts to increase the level of safety behaviors among workers, using various approaches, are necessary [11, 14-16].

It is necessary to use data that have been accumulated over several years to perform accurate analyses of the causal relationships between various variables and the occurrence of industrial accidents. In that sense, a limitation of this study is that it is based on data obtained from the OSHCS conducted in 2015. However, its results may still be used as basic data in the development and implementation of safety and health policies by the government and workplaces.

REFERENCES

[1] Korea Ministry of Employment and Labor, 2017, An Analysis of 2016 Industrial Accidents. Retrieved from http://www.moel.go.kr/info/publicdata/majorpublish/majorPublishView.do?bbs_seq=20171200131.

[2] Sentencing Council, 2016, "Definitive Guideline for Health and Safety Offences, Corporate Manslaughter and Food Safety and Hygiene Offences." Retrieved from https://www.sentencingcouncil.org.uk/wp-content/uploads/HS-offences-definitive-guideline-FINAL-web.pdf.

[3] Choi, G. H., and Loh, B. G., 2016, "Risk Assessment of Industrial Machines and Devices and Appropriateness of Their Safety Certification and Self-Declaration of Conformity," J. Korean. Soc. Saf., 31(1), pp. 1-6.

[4] Choi, G. H., 2016, "Effectiveness and Balance of Compulsory and Voluntary Safety Certification of Industrial Machines and Devices," J. Korean. Soc. Saf., 31(1), pp. 7-12.

[5] Guldemound, F. W., 2000, "The Nature of Safety Culture: A Review of Theory And Research," Safety. Sci., 34(1-3), pp. 215-225.

[6] Dedobbeler, N., Beland, F., and German, P., 1990, "Is there a Relationship Between Attributes of Construction Sites and Workers Safety Practices and Climate Perception?", Advances in Industrial Ergonomics and Safety II, Vol. 11, pp. 725-732.

[7] Moon, K. S., Lee, J. H., and Oh, S. Z., 2011, "The Effect of Organizational Commitment on Safety Behaviors: Moderating Effects of Safety Climate," KJIOP., 24(1), pp. 51-73.

[8] Mowday, R. T., Steers, R. M., and Porter, L. W., 1979, "The Measurement of Organizational Commitment," J. Vocat. Behav., 14(2), pp. 233-247.

[9] Allen, N. J., and Meyer, J. P., 1990, "The Measurement and Antecedents of Affective, Continuance, and Normative Commitment to the Organization," J. Occup. Organ. Psychol., 63(1), pp. 1-8.

[10] Oh, S. Z., Lee, J. H., and Moon, K. S., 2011, "The Effect of Organizational Commitment on Safety Behaviors: Moderating Effects of Safety Climate," KJIOP., 24(1), pp. 51-73.

[11] Neal, A., and Griffin, M. A., 2006, "A Study of the Lagged Relationships Among Safety Climate, Safety Motivation, Safety Behavior, and Accidents at the Individual and Group Levels," J. Appl. Psycho., 91(4), pp. 946-953.

[12] Park, Y. S., and Na, I. G., 2010, "Effect of Union and Labor Relations Climate on Workplace Injury," Korean Journal of Industrial Relations, 20(4), pp. 115-132.

[13] Jang, K. H., and Ha, K., 2016, "The Effect of Occupational Safety and Health Education on Occupational Accidents," J. Korean. Soc. Occup. Environ. Hyg., 26(1), pp. 90-98.

[14] Clarke, S., 2010, "An Integrative Model of Safety Climate: Linking Psychological Climate and Work Attitudes to Individual Safety Outcomes Using Meta-Analysis," J. Occup. Organ. Psychol., 83(3), pp. 553-578.

[15] Griffin, M. A., and Neal, A., 2000, "Perceptions of Safety at Work: A Framework for Linking Safety Climate to Safety Performance, Knowledge, and Motivation," J. Occup. Health. Psychol., 5(3), pp. 347-358.

[16] Hofmann, D. A., and Morgeson, F. P., 1999, "Safety-related Behavior as a Social Exchange: The Role of Perceived Organizational Support and Leader-Member Exchange," J. Appl. Psychol., 84(2), pp. 286-296.