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Original Article

Effectiveness of Direct Safety Regulations on Manufacturers and Users of Industrial Machines: Its Implications on Industrial Safety Policies in Republic of Korea

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ABSTRACT

Background: Despite considerable efforts made in recent years, the industrial accident rate and the fatality rate in the Republic of Korea are much higher than those in most developed countries in Europe and North America. Industrial safety policies and safety regulations are also known to be ineffective and inefficient in some cases.

Methods: This study focuses on the quantitative evaluation of the effectiveness of direct safety regulations such as safety certification, self-declaration of conformity, and safety inspection of industrial machines in the Republic of Korea. Implications on safety policies to restructure the industrial safety system associated with industrial machines are also explored.

Results: Analysis of causes in industrial accidents associated with industrial machines confirms that technical causes need to be resolved to reduce both the frequency and the severity of such industrial accidents. Statistical analysis also confirms that the indirect effects of safety device regulation on users are limited for a variety of reasons. Safety device regulation needs to be shifted to complement safety certification and self-declaration of conformity for more balanced direct regulations on manufacturers and users. An example of cost-benefit analysis on conveyor justifies such a transition.

Conclusion: Industrial safety policies and regulations associated with industrial machines must be directed towards eliminating the sources of danger at the stage of danger creation, thereby securing the safe industrial machines. Safety inspection further secures the safety of workers at the stage of danger use. The overall balance between such safety regulations is achieved by proper distribution of industrial machines subject to such regulations and the intensity of each regulation. Rearrangement of industrial machines subject to safety certification and self-declaration of conformity to include more movable industrial machines and other industrial machines with a high level of danger is also suggested.

1. Introduction

Despite considerable efforts made in recent years, the industrial accident rate (defined as the number of injuries and deaths per 100 workers or employees) and the fatality rate (defined as the number of deaths per 100,000 workers or employees) in the Republic of Korea are much higher than those in most developed countries in Europe and North America [1]. Statistical analysis further revealed that 76.92% of all industrial accidents associated with industrial machines (hereafter referred to as "items") were caused by technical reasons in the Republic of Korea. For ease of interpretation, the term "industrial accidents" was used to indicate all industrial accidents that involved injuries or deaths or both in this study.

Fig. 1 depicts a flow chart for cause analysis of industrial accidents associated with items. Causes of industrial accidents are first classified into technical ones, managerial ones, and educational ones at the highest level. These causes are further classified at subsequent levels. In 2009, 28,441 cases of industrial accidents associated with items were analyzed to classify their causes according to the flow chart in Fig. 1. Most of the industrial accidents caused by technical reasons were mainly due to defects of items, items without safety devices, or malfunctioning of safety devices attached to them, as shown in Table 1. Malfunction or defects of personal protection equipment account for only a small portion of those cases. Statistical analysis also showed that 59.66% (16,968 cases) among them were preventable. Managerial causes and

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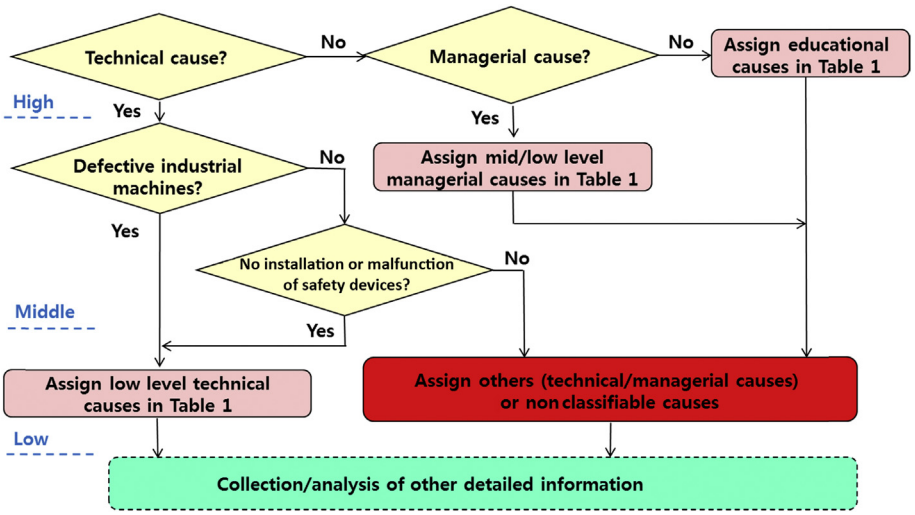

Fig. 1. Flow chart for cause analysis of industrial accidents associated with industrial machines, Journal of Korean Society of Safety, 2013 [2].

educational causes were responsible for only 21.03% and 0.44% of all cases, respectively. Most of the technical causes can be resolved at the stage of manufacture, and subsequent elimination of sources of danger appear to be more effective than any other means for prevention of industrial accidents associated with items. Safety certification is, therefore, thought to play a key role in preventing industrial accidents associated with items.

The importance of safety function of industrial machines was also important in other countries. A 2014 survey commissioned by the European Union Occupational Safety and Health Agency in collaboration with the Health and Safety Executive in the UK, e.g., explores how health and safety risks are managed at the workplace. The most common reported workplace risk was "machines or tools." Compared with what we know about causes of injury, one in five of all fatal injuries in the sector over the past 5 years were due to contact with machinery and it accounts for over 10% of employer-reported nonfatal injuries within the manufacturing sector [3]. Around 5% of employer-reported fatal and nonfatal injuries were due to contact with machinery within the construction sector [4].

However, as explained in a subsequent section, current direct regulations on industrial machines used in the workplace in the Republic of Korea are mainly focused on users. Safety device regulation on users, which is unique, in the Republic of Korea is a good example. Limited responsibility of manufacturers may lead to a situation where effective elimination of sources of danger at the stage of manufacture are not realizable. There also arises a question as to whether such a direct regulation is efficient enough to lower the industrial accident rate associated with industrial machines to the level in most developed countries in the near future with limited resources put on.

The effectiveness of safety certification and inspection in the Republic of Korea which is based on European Conformité Européene (CE) marking have been evaluated elsewhere [2,5,6]. In other countries such as Taiwan where industrial safety systems are similar to the Republic of Korea, effectiveness of CE marking-compatible safety certification and its impact on competitiveness of items have been reported [7]. Another report also confirmed the effectiveness of CE marking on industrial machines [8]. No quantitative evaluation of direct regulation on users such as safety device regulation has ever been made in the Republic of Korea and its effectiveness is still in question.

Table 1
Causes of industrial accidents associated with industrial machines in 2009, Journal of Korean Society of Safety, 2014 [1]

Classification level			No. of cases (%)
High	Middle	Low	
Technical causes	Defective industrial machines & PPEs	Mechanical causes	9,845 (34.62)
		Electrical causes	334 (1.20)
		No installment of safety devices as required	351 (1.23)
		Others	6,299 (22.14)
	Malfunction of safety devices after installation		139 (0.48)
	Others		4,909 (17.26)
	Subtotal		21,877 (76.92)
Managerial causes	Noncompliance of operating procedures		544 (1.91)
	Removal, shut-off, or alteration of safety devices after installation		57 (0.20)
	Maintenance while industrial machine is operating	Maintenance without power-off while industrial machine is operating	545 (1.92)
		Others	450 (1.58)
	Simple misconduct during operation		3,346 (11.77)
	Others		1,038 (3.64)
	Subtotal		5,980 (21.03)
Educational causes			126 (0.44)
Not classified			458 (1.61)
Total			28,441 (100.00)

PPE, personal protection equipment.

This study first discusses the quantitative evaluation of the effectiveness of direct safety regulations such as safety certification, self-declaration of conformity, and safety inspection of items in the Republic of Korea. Statistical analysis to assess the indirect effects of another direct safety regulation on users, i.e., safety device regulation then follows. Implications on industrial safety policies to reduce both the frequency and the severity of industrial accidents associated with items are explained in view of the effectiveness of direct safety regulations. Quantitative analysis for rearrangement of items subject to safety certification and self-declaration of conformity to include more movable items and other items with a high level of danger is also given.

2. Materials and methods

In order for the safe items to be manufactured and used in a safe fashion, safety-securing direct regulations need to be implemented independently at each level where danger is created or used. Fig. 2 indicates the mechanism where current direct safety regulations such as safety certification, self-declaration of conformity, and safety inspection with proper levels of intensity are independently enforced on manufacturers and users [9]. It is also important to maintain a balance among direct safety regulations. The level of intensity of each direct safety regulation, for example, will depend on the characteristics of items.

Korea Occupational Safety and Health Agency classified all items used in the Republic of Korea into 121 items [10]. These items were categorized into three groups: (1) items subject to safety certification (8 items as of 2009, hereafter “safety certification items”); (2) items subject to self-declaration of conformity (3 items, hereafter “self-declaration of conformity items”); and (3) the rest (110 items, hereafter “nonsafety certification items”).

Many items including some of the safety certification items are subject to another direct safety regulation on users in the Republic of Korea, which is called “Safety Device Regulation”. Safety devices are, for example, required to be installed on many items by users. This regulation is to complement safety certification or self-declaration of conformity as the number of safety certification items and self-declaration of conformity items are limited [11]. As seen in Fig. 3, the effects of such safety device regulation are viewed as indirect in that users typically ask manufacturers to install safety devices on items when they are purchased [9]. In 2009, 73 items (60.3%) among all 121 items were subject to installation of safety devices on them (hereafter “safety device items”) and the rest 47 items (39.7%, hereafter “nonsafety device items”) were free from such installation.

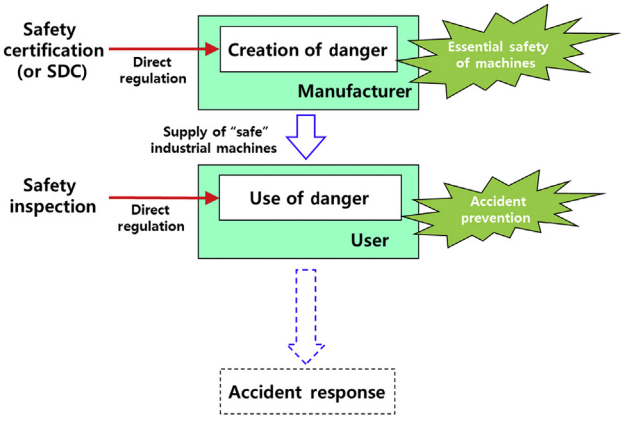

Fig. 2. Direct safety regulations on manufacturers and users of industrial machines. SDC, self-declaration of conformity.

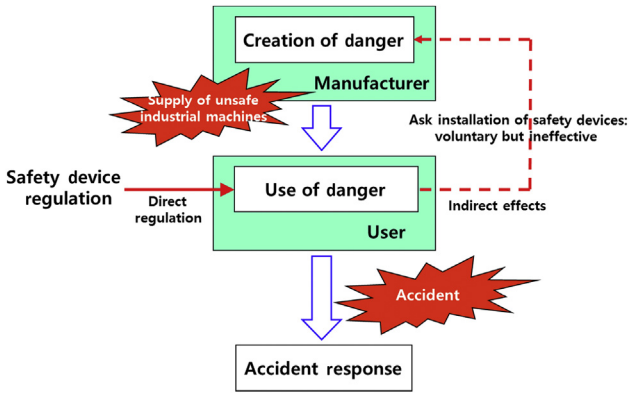

Fig. 3. Safety device regulation on users of industrial machines.

The effectiveness of current direct safety regulations on either manufacturers or users in Korea can be quantitatively evaluated based on industrial accident data associated with industrial machines.

3. Results

3.1. Effectiveness of direct safety regulations on manufacturers: safety certification and self-declaration of conformity

In Fig. 4, the share of the number of industrial accidents associated with each group in 2008 is compared with the share of the number of items in each group. Note that the old certification system where only a single method of testing and examination was used took effect until 2008 and the current safety certification and self-declaration of conformity that are compatible with European CE marking was first introduced in 2009 in the Republic of Korea. Items in each group were, therefore, not subject to current safety certification and self-declaration of conformity in 2008.

The ultimate goal of safety certification is to reduce both the frequency (as defined by the number of industrial accidents) and the severity (as defined by the number of deaths in industrial accidents) associated with safety certification items below those associated with nonsafety certification items or to zero in the end. The number of safety certification items comprised only 6.61% of all items, whereas nonsafety certification items accounted for the rest, 90.9%. In 2008, industrial accidents associated with safety certification items comprised 23.0% of all industrial accidents associated with items. Unit frequency of industrial accidents associated with

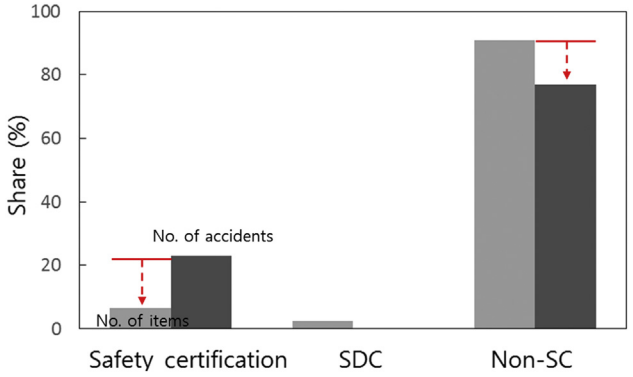

Fig. 4. Comparison of the shares of the number of items and the number of industrial accidents associated with items in 2008. Items are categorized into three groups: (1) safety certification items; (2) self-declaration of conformity items; and (3) nonsafety certification items, Safety and Health, 2012 [12]. Non-SC, nonsafety certification; SDC, self-declaration of conformity.

safety-certification items as defined in Eq. (1) was more than four times higher than that associated with nonsafety certification items in 2008.

$$[Unit\ frequency]_{Safety\ Certification\ Item} = \frac{\left[\frac{Number\ of\ industrial\ accidents\ associated\ with\ safety\ certification\ items}{Number\ of\ all\ industrial\ accidents\ associated\ with\ items}\right]}{\left[\frac{Number\ of\ safety\ certification\ items}{Number\ of\ all\ items}\right]} \quad (1)$$

The share of the industrial accidents associated with safety-certification items decreased, on the average, since the introduction of current safety certification in 2009, showing 17.02% in 2009, 22.86% in 2010, and 18.43% in 2011 as shown in Table 2. Unit frequency also decreased from 3.48 in 2008 to 2.79 in 2011. This statistical analysis justifies the selection of safety certification items.

Table 3 shows the frequency and the severity associated with each safety certification item over the past 4 years. The overall improving trends are seen except for the year 2008 when the international monetary crisis hit the country. Severity, for example, decreased from 102 in 2008 to 75 in 2011, which is also a manifestation of the positive effect of current safety certification in contrast to the old safety certification. Considering the fact that those items that exhibit high levels of frequency and severity in industrial accidents were selected for safety certification, such a selection of safety certification items appear to be appropriate.

Table 4 shows the frequency and the severity of industrial accidents associated with each self-declaration of conformity item over the past 4 years. Share of the number of industrial accidents associated with self-declaration of conformity items was only 0.22% of all industrial accidents associated with items in 2008, 0.09% in 2009, 0.19% in 2010, and 0.32% in 2011. The number of self-declaration of conformity items comprises 2.4% of all items.

Little conclusions may be drawn from the quantitative analysis of industrial accidents associated with items. (1) Selection of safety certification items based on the level of danger (both the frequency and the severity of industrial accidents associated) leads to the effectiveness of safety certification. (2) Overall effectiveness of safety certification is, however, inherently limited since only a few items are subject to safety certification. (3) Further reduction in industrial accidents is possible as more items are subject to safety certification. (4) Frequency and severity of industrial accidents associated with self-declaration of conformity items being low, a question arises as to the effectiveness of self-declaration of conformity or the selection of self-declaration of conformity items.

Table 2
Comparison of the shares of the number of items and the number of industrial accidents associated with items in the past 4 years. Items are categorized into three groups: (1) safety certification items; (2) self-declaration of conformity items; and (3) nonsafety certification items

Y	(1) Safety certification items		(2) Self-declaration of conformity items	
	Share of items (%)	Share of industrial accidents (%)	Share of items (%)	Share of industrial accidents (%)
2008	6.61	23.00	2.48	0.22
2009	6.61	17.02	2.48	0.09
2010	6.61	22.86	2.48	0.28
2011	6.61	18.43	2.48	0.32

Y	(3) Nonsafety certification items		(4) Unit frequency		
	Share of items (%)	Share of industrial accidents (%)	SC items	SDC items	Non-SC items
2008	90.9	76.78	3.48	0.09	0.84
2009	90.9	82.89	2.57	0.04	0.91
2010	90.9	76.86	3.46	0.11	0.85
2011	90.9	81.25	2.79	0.13	0.89

Non-SC, nonsafety certification; SDC, self-declaration of conformity.

Table 3
Frequency (F) and severity (S) of industrial accidents associated with each safety certification item in the past 4 years, Journal of Korean Society of Safety, 2013 [2]

	2008		2009		2010		2011	
	Frequency*	Severity†	F	S	F	S	F	S
Total	5,718	102	4,678	87	4,724	90	4,151	75
Press/shearing machine	2,667	10	2,274	5	1,939	8	1,727	4
Crane	2,465	77	1,940	66	1,991	48	1,803	53
Lift	209	10	188	14	439	27	312	11
Pressure vessel	24	2	1	0	39	0	45	2
Roller	95	0	65	1	96	0	62	0
Injection molding machine	254	3	210	1	209	1	194	5
Elevated work platform	4	0	0	0	11	6	8	0

* Frequency implies the number of industrial accidents that involved injuries or death or both.
† Severity implies the number of industrial accidents that involved deaths.

3.2. Effectiveness of direct safety regulations on users

3.2.1. Safety inspection of industrial machines

In Fig. 5, the share of the number of industrial accidents associated with items subject to safety inspection (hereafter, "safety inspection" items) among all industrial accidents associated with items in 2008 is compared with the share of the number of safety inspection items among all items. The current safety inspection introduced in 2009 virtually had no difference from the old periodic safety inspection which took effect until 2008.

Twelve safety inspection items comprise 9.9% of all items, whereas nonsafety inspection items accounts for the rest, 90.1%. In 2008, industrial accidents associated with safety inspection items comprised of 19.6% of all industrial accidents associated with items. Unit frequency of industrial accidents associated with safety inspection items as defined in Eq. (2) is more than twice that associated with nonsafety inspection items.

$$[Unit\ frequency]_{Safety\ Inspection\ \ Item} = \frac{\left[\frac{Number\ of\ industrial\ accidents\ associated\ with\ safety\ inspection\ \ items}{Number\ of\ all\ industrial\ accidents\ associated\ with\ \ items}\right]}{\left[\frac{Number\ of\ safety\ inspection\ \ items}{Number\ of\ all\ items}\right]} \quad (2)$$

This statistical analysis justifies the selection of safety inspection items. The share of the number of industrial accidents associated

Table 4
Frequency (F) and severity (S) of industrial accidents associated with each self-declaration of conformity item in the past 4 years, Journal of Korean Society of Safety, 2013 [2]

	2008		2009		2010		2011	
	Frequency*	Severity†	F	S	F	S	F	S
Total	57	4	25	1	58	1	73	3
Gondola	21	3	14	1	13	0	19	1
Centrifugal machine	1	0	0	0	7	0	0	0
Air compressor	35	1	11	0	38	1	54	2

* Frequency implies the number of industrial accidents that involved injuries or death or both.
† Severity implies the number of industrial accidents that involved deaths.

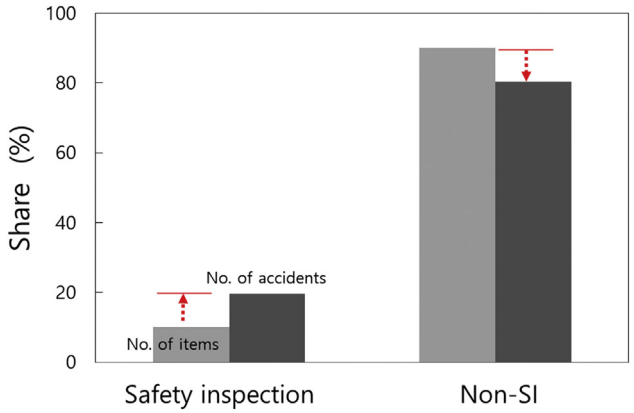

Fig. 5. Comparison of the shares of the number of industrial accidents associated with items and the share of the number of items in 2008. Items are categorized into two groups: (1) safety inspection (SI) items and (2) nonsafety inspection items (Non-SI), Occupational Safety and Health Research Institute, 2010 [13].

with safety-inspection items decreased to 15.5% in 2009. Since there was no rearrangement of safety inspection items and inspection methods, meaningful improvement was not seen.

3.2.2. Safety device regulation

The shortcomings of safety device regulation are that users often lack the specific knowledge and experiences about items and the safety devices needed and installed on them. Asking users to judge the performance of safety devices is in most cases beyond the capacity of them particularly when items used are commodity products. It is also often difficult or impossible for government (Ministry of Employment and Labor) or Korea Occupational Safety and Health Agency to intervene by safety regulations the deal between users (buyers) and manufacturers of items. It is not guaranteed for all safety devices installed on items to be functional as required by the regulations.

Among 28,441 cases of industrial accidents associated with items in 2009, 15,298 (53.8%) cases were associated with safety device items, whereas the rest of the 13,143 (46.2%) cases were associated with nonsafety device items. Unit frequency of industrial accidents associated with safety device items as defined in Eq. (3) was $53.8/60.3 = 0.89$, whereas those associated with nonsafety device items was $46.2/39.7 = 1.16$ in 2009. These numbers were $60.48/60.3 = 1.00$ for safety device items and $39.52/39.7 = 1.00$ for nonsafety device items in 2008. Safety devices as required by safety device regulation appear to have a limited effect in the prevention of industrial accidents.

$$[\mathit{Unit\ frequency}]_{\mathit{Safety\ Device\ Item}} = \frac{\left[\frac{\mathit{Number\ of\ industrial\ accidents\ associated\ with\ safety\ device\ items}}{\mathit{Number\ of\ all\ industrial\ accidents\ associated\ with\ \ items}}\right]}{\left[\frac{\mathit{Number\ of\ safety\ device\ \ items}}{\mathit{Number\ of\ all\ items}}\right]} \tag{3}$$

No further regulatory methods are available to restrict the use of unsafe items without safety devices at the right time. Upon industrial accidents, safety device regulation works only to judge the responsibility involved in the accidents. As seen in Table 5, the share of small-sized enterprises with less than 10 employees is nearly 90% of all enterprises in the Republic of Korea. The level of their understanding about industrial safety is low and they are vulnerable to the compliance of applicable safety regulations.

Statistical analysis raises another question. Table 6 shows the number of industrial accidents associated with 12 safety inspection items in the Republic of Korea. All safety inspection items except local ventilation equipment are subject to the installation of safety devices by users (safety device regulation). Installed safety devices are then inspected by periodic safety inspection. Many safety inspection items were, however, found to be used without safety devices installed as required. Installed cases were less than half (45.17%) of all cases, which causes only a slight improvement in industrial accidents associated with safety inspection items. Again, little conclusions may be drawn: (1) safety inspection items without safety devices installed on them were not properly inspected; and (2) safety devices installed by users may not be as functional as those installed by the manufacturers of items at the stage of manufacture. Only limited effects are, therefore, expected by safety device regulation on users.

Table 5
Industrial accident rate (IAR) by the number of employees in the Republic of Korea, Korea Occupational Safety and Health Agency, 2011 [10]

No. of employees	IAR	No. of companies
<5	1.55	1,234,158
5–9	1.00	248,910
10–29	0.75	182,788
30–49	0.54	34,524
50–99	0.40	21,698
100–299	0.26	12,638
300–499	0.18	1,812
500–999	0.13	1,110
<1,000	0.19	558
Average/total	0.65	1,738,196

4. Discussion

4.1. Need for transition from safety device regulation to more balanced regulations on both manufacturers and users

Managerial and educational causes accounting for only 22.64% of all industrial accidents associated with industrial machines in

Table 6
Number of industrial accidents associated with 12 safety inspection items in 2009 [2]

Industrial machines	Installed cases, share (%)*
1. Press	629 (43.98)
2. Shearing machine	306 (36.25)
3. Tower crane	30 (41.09)
Crane & hoist	398 (61.04)
4. Lift for construction site	9 (47.36)
Lift for general use	51 (30.17)
5. Pressure vessel	1 (100)
6. Gondola	2 (14.28)
7. Local ventilation equipment†	0 (0)
8. Centrifuge	0 (0)
9. Chemical equipment with supplements	18 (69.23)
10. Drying equipment with supplements	5 (21.73)
11. Roller for rubbers & synthetic resins	15 (23.07)
Roller for general use	55 (50.45)
12. Injection molding machine	123 (58.57)
Total, average (%)	1,462 (45.17)

* "Installed cases" implies the number industrial accidents associated with safety inspection items where safety devices were properly installed as required by safety device regulation. The share (%) represents the relative portion of the cases with safety devices properly installed among all industrial accidents associated with safety inspection items.

† All safety inspection items are required to install safety devices except local ventilation equipment.

Table 1, and the number of safety inspection items and the effectiveness of safety device regulation on users being limited, industrial safety policies need to be directed towards eliminating the sources of danger at the stage of danger creation, thereby securing the safe items. Safety inspection complements either safety certification or self-declaration of conformity, further securing the safety of workers at the stage of danger use. The overall balance between such direct safety regulations is achieved by proper distribution of items in their item lists and the intensity of each regulation. Selection of items for a particular safety regulation will also depend on the characteristics of each item.

Unlike the cases in the Republic of Korea where users of industrial machines in the workplace have more responsibilities for maintaining the safety of machines, the safety of industrial machines is secured at the stage of manufacture in most developed countries. Machine guarding regulation in the USA, for example, requires every mechanical power press to be equipped with Presence Sensing Device for certification [14]. Only when attachment of machine guarding is not possible at the stage of manufacture, the employer (user in our context) has the responsibility to secure the machine guarding elsewhere for the safety of employees [15]. Mechanical or hydraulic press in Germany is subject to CE marking and certification standards also require Presence Sensing Device to be attached on the machine at the stage of manufacture [16,17]. Such a regulation to remove the source of danger at the stage of manufacture is very effective even for industrial machines where the levels of danger associated are high. Recent industrial accident data announced by the Federal Institute for Occupational Safety and Health in Germany confirms that the number of deaths associated with presses has been kept to zero or near zero [2]. Such a safety device or function on presses is, however, subject to the user's installation as required by safety device regulation in the Republic of Korea. As more responsibility is put on users of industrial machines by safety device regulation in the Republic of Korea, a transition from such a direct regulation on users to more balanced direct regulations on both manufacturers and users appears to be the next steps to take for more effectiveness of regulations.

4.2. *Effectiveness of balanced regulations on both manufacturers and users*

A step towards realizing such a transition is the expansion of safety certification items and proper selection of them. Fig. 6 shows the relationship between the frequency and the severity of industrial accidents associated with all 121 items in 2009. Items (dots) in the right upper corner are, in general, to be safety certified and items in the left lower corner are free from such regulation. Safety certification items indeed show a higher level of frequency and severity than non-safety certification items. Despite the effectiveness of current safety certification, however, there are more non-safety certification items that cause severe injuries and deaths in workplaces. Beginning in the year 2013, three items were added to the list of safety certification items and cost-benefit analysis justified such additions [5]. Self-declaration of conformity items in Fig. 6 shows no distinct frequency and severity compared with nonsafety certification items. For this reason, there has been continuous demand for the rearrangement of self-declaration of conformity items and 11 items were added to the list of self-declaration of conformity items in 2013. More items with a higher level of frequency and the severity of related industrial accidents (white dots in Fig. 6) than those items newly selected are still not subject to safety certification or self-declaration of conformity. Further careful evaluation of essential safety of nonsafety certification items and addition on the list of safety certification items are, therefore, needed.

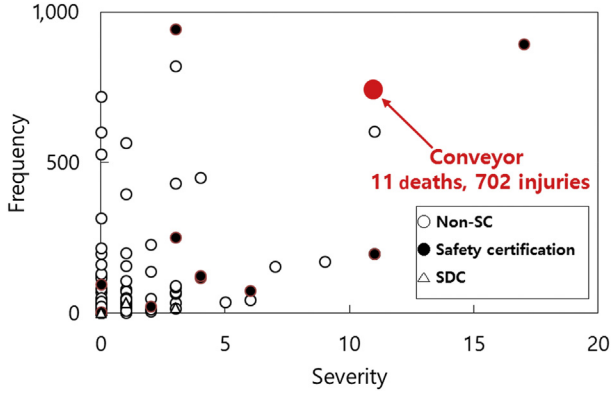

Fig. 6. Relationship between the frequency and the severity of industrial accidents associated with items in 2009. Non-SC, nonsafety certification; SDC, self-declaration of conformity.

One thing to note is that the mobility of items is a key factor for inclusion in the list of safety certification. Statistical analysis was performed to see any influence of the mobility of items on safety of workers. All items can be classified as the fixed items or the movable items. Fixed items are defined as items that are used as fixed on specific locations. Sixty-one items (50.4% of all 121 items) are classified as fixed items. Movable items can be moved to any location where installation or usage of them takes place. Movable items include 53 items (43.8% of all items). Seven items (5.8% of all items) were not classifiable.

Frequency, severity, and intensity of the industrial accidents associated with the fixed or the movable items in the past 4 years is given in Table 7. Only the classifiable accidents were considered in the calculation of the share. Intensity of the industrial accidents is defined as the ratio of the severity to the frequency. No noticeable difference in frequency is seen in the figure. Severity associated with the movable items, however, appears to be much higher than that with the fixed items. Intensity of the industrial accidents with the movable items is three times higher than that with the fixed items.

Movable items move around while in use and are inherently dangerous in that consistent safety measures, either hard or soft, are not easy to apply. Furthermore, workers are easily exposed to danger as it is difficult to install safety devices on the movable items. According to the statistical data in Germany, movable items such as crane, lift, pressure vessel, hand-held tools, fork-lift, and ladder may be classified as dangerous items which can cause death [2]. On the contrary, the number of deaths can be kept to zero even when the levels of danger of fixed items in use are high. This is because safety measures are clearly defined and applied in a consistent way on the fixed items. Such analytical results indicate

Table 7
Comparison of frequency, severity, and intensity of the industrial accidents associated with the fixed items and the movable items in the past 4 years

	Y	Total	Fixed items, share (%)	Movable items share (%)
Frequency for fixed items (A) or movable items (B)	2008	18,499	9,705 (52.46)	8,794 (47.54)
	2009	20,357	9,019 (44.30)	11,338 (55.70)
	2010	20,142	10,592 (52.59)	9,550 (47.41)
	2011	19,997	9,957 (49.79)	10,040 (50.21)
Severity for fixed items (A′) or movable items (B′)	2008	333	70 (21.73)	263 (78.27)
	2009	267	67 (25.09)	200 (74.91)
	2010	314	75 (23.89)	239 (76.11)
	2011	303	85 (28.05)	218 (71.95)
Intensity for fixed items (A′/A) or movable items (B′/B)	2008		0.41	1.65
	2009		0.57	1.35
	2010		0.45	1.61
	2011		0.56	1.43

that more strong safety measures on movable items needs to be taken. Five movable items (2 items in safety certification items and 3 items in self-declaration of conformity items) account for only 35.7% of all 14 items newly added to either safety certification or self-declaration of conformity in 2013. Therefore, more movable items need to be included in the list of safety certification or self-declaration of conformity in the future.

4.3. Efficiency of balanced regulations on both manufacturers and users

Efficiency of proposed transition of regulations can be justified by cost-benefit analysis. Conveyor is a good example that exhibits the benefit of a transition from safety device regulation on users to more balanced direct regulations on both manufacturers and users. Conveyor was a typical safety device item and no safety certification or self-declaration of conformity was enforced until the year 2012 in the Republic of Korea. Conveyor was, however, newly added to the list of self-declaration of conformity items in 2013 and is no more a safety device item. The cost and benefit when a conveyor is subject to self-declaration of conformity can be estimated as follows [6]: it is assumed that 76.92% of all conveyor-associated accidents were due to defective conveyors or malfunctioning of safety devices installed on them. Further assumption is that these accidents and related injuries and deaths would have been prevented by self-declaration of conformity of conveyor. Any benefit over cost arising from reduction in injuries and deaths by 76.92% on the average can be regarded as the effect of transition from safety device regulation on users to self-declaration of conformity on manufacturers. 21.03 % and 0.44% of industrial accidents arising from the managerial causes and the educational causes respectively need to be resolved by other safety regulations on users such as labor inspection, education of workers, and others.

Fig. 7 shows the accumulated net benefit (cost-subtracted benefit) for conveyor when it is subject to self-declaration of conformity. One-year transition period, 10% annual replacement ratio of existing conveyors, 2% annual increment ratio of conveyors in use, and 3.27% annual inflation ratio of consumer price were assumed in the simulation. From the 1st year after self-declaration of conformity takes effect, more benefit than cost is expected. The accumulated net benefit after 11 years is estimated to be Korean Won (KRW) 275.6 billion (approximately US$250 million). In the year 2022 alone, the net benefit is estimated to be KRW35.4 billion (approximately US$33 million). Fig. 8 shows the accumulated net benefit if safety inspection of conveyors is assumed to complement

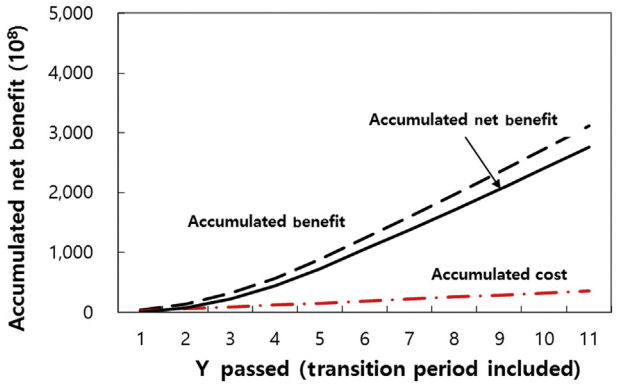

Fig. 7. Accumulated net benefit for conveyors (transition period: 1 year, annual replacement ratio of existing conveyors: 10%, annual increment ratio of conveyors in use: 2%, annual inflation ratio of consumer price: 3.27%), Journal of Korean Society of Safety, 2013 [2].

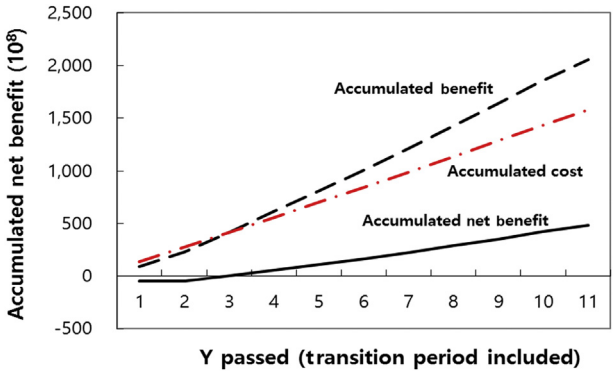

Fig. 8. Accumulated net benefit for conveyors when benefit and cost of safety inspection are included (transition period: 1 year, annual replacement ratio of existing conveyors: 10%, annual increment ratio of conveyors in use: 2%, annual inflation ratio of consumer price: 3.27%).

self-declaration of conformity. According to a survey conducted in 2012, 230,436 conveyors are estimated to be in use in the Republic of Korea. Considerable cost for safety inspection of these conveyors causes more cost than benefit for the 1st 2 years. The net benefit is expected thereafter. Cost-benefit analysis for typical safety device items other than conveyor in Table 6 again revealed appropriateness and efficiency of such transition [2].

Statistical analysis of industrial accidents associated with industrial machines confirmed the effectiveness of direct safety regulations such as safety certification and safety inspection. Since the current safety certification that are consistent with CE marking in Europe in their process and testing/examination methods took effect in 2009, gradual reduction in industrial accidents associated with industrial machines was found in the Republic of Korea. Self-declaration of conformity, however, was proved to be ineffective in prevention of industrial accidents. In order to reduce both the frequency and the severity of industrial accidents associated with industrial machines technical causes needs to be resolved. Quantitative evaluation also suggests that indirect effects of safety device regulation on users are not enough to further secure the safety of workers. Small-sized enterprises with less than 10 employees comprising nearly 90% of all enterprises and being vulnerable to compliance of applicable safety regulations, major target of safety regulations associated with industrial machines in the Republic of Korea needs to be shifted from a skewed safety device regulation to more balanced direct safety regulations on both manufacturers and users.

Industrial safety activities must then be directed towards eliminating the sources of danger at the stage of danger creation, thereby securing the safe industrial machines. Safety inspection complements safety certification in securing the safety of workers at the stage of danger use. The overall balance between such direct safety regulations is achieved by proper distribution of industrial machines subject to such regulations and the intensity of each regulation. An example of cost-benefit analysis on conveyor clearly justifies such a transition. This will also work to guarantee the overall effectiveness of the industrial safety system. Rearrangement of the list of safety certification and self-declaration of conformity items to include more movable industrial machines and other industrial machines with a high level of danger is also suggested for the effectiveness of direct safety regulations in the future.

Conflicts of interest

The author has nothing to disclose.

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