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The Relative Costs of Accidents Following the Establishment of the Health, Safety and Environment Management System (HSE-MS) for the Construction Industry in Tehran

Javad Vatani,[1] Gebraeil Nasl Saraji,[1,*] Abolghasem Pourreza,[2] Mahmood Salesi,[3] Iraj Mohammad Fam,[4] and Seyed Abolfazl Zakerian[1]

[1]Department of Occupational Health, School of Public Health, International Campus, Tehran University of Medical Sciences (IC-TUMS), Tehran, IR Iran
[2]Department of Health Management and Economics, School of Public Health, Tehran University of Medical Sciences, Tehran, IR Iran
[3]Truma Research Center, Baqiyatallah University of Medical Sciences, Tehran, IR Iran
[4]Department of Occupational Health, School of Public Health, Hamedan University of Medical Sciences, Tehran, IR Iran

[*]*Corresponding author*: Gebraeil Nasl Saraji, Department of Occupational Health, School of Public Health, International Campus, Tehran University of Medical Sciences (IC-TUMS), Tehran, IR Iran. Tel: +98-9121182069, Fax: +98-2188951390, E-mail: jnsaraji@sina.tums.ac.ir

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Abstract

Background: Accidents in the construction industry are a significant problem in many countries around the world. Occupational accidents result in reduced working hours, loss of life, and other related costs. These accidents result in socio-economic losses such as disability support costs, loss of working time, and increased medical care needs. They also create a lot of waste for communities and labor organizations.
Objectives: Despite extensive studies calculating the cost of accidents, our understanding of these costs is still not clear or practically applicable; consequently, the ultimate aim of the present study is to provide a new framework for the calculation of the (direct and indirect) costs of construction accidents.
Methods: In this paper, using a new and structured seven-step approach, the costs of construction accidents were calculated. In order to calculate the total cost of construction accidents in the city of Tehran for 2013 - 2014, the severity of accident results were first classified into five groups: 1, short-term absences from work; 2, long-term absences; 3, partial disability; 4, total disability; and 5, death. The types of costs resulting from accidents were also categorized: 1, production disturbance costs; 2, human capital costs; 3, medical costs; 4, administrative costs; 5, transfer costs; and 6, other costs. These costs were classified according to the direct or indirect costs resulting from the incident and the imposition of costs on workers, employers and society. Finally, the calculated amount of investment in HSE-MS was analyzed using statistical tests.
Results: The present study indicates that before and after the establishment of HSE-MS that the maximum calculated cost was related to the production disturbance cost (before: $568,000; after: $80,500) and the lowest cost was related to transfer costs (before: $15,000; after: $3,000) and other costs (before: $98,000; after: $28,500). Statistical analyses indicates that there is a significant difference (P = 0.007) between the direct and indirect costs of accidents for before and after the establishment of HSE-MS. In other words, the direct and indirect costs had multiple, significant differences. The present study indicates that the indirect cost is four times greater than the direct costs.
Conclusions: Accidents resulting in death, total disability and partial disability impose huge costs that are borne by society, and employers bear relatively low costs due to the health, treatment and welfare systems provided by society for the treatment and rehabilitation of injured workers and their families. Also, the results of this study show that investment in the HSE-MS is effective and associated with reduced accidents.

Keywords: Accidents, Indirect Costs, Direct Costs, HSE-MS, Construction Industry

1. Background

1.1. Definition of an Accident

1, An unfortunate incident that happens unexpectedly and unintentionally, typically resulting in damage or injury (1).

2, A sudden event (such as a crash) that is not planned or intended and that causes damage or injury (2).

3, An event that is not planned or intended: an event that occurs by chance (2).

The construction industry plays an important role in the economy of many countries; for example, in the UK it represents 10 percent of GDP and more than 1.5 million (3), and there are a large number of occupational accidents in this industry. The most important parts of the costs of occupational accidents are the human costs that result in reduced working years, the loss of life, and other related losses (4, 5). Every year, millions of occupational accidents occur worldwide; some of these accidents are fatal, and others leads to temporary or permanent disability (6). Human contemporary history has recorded multiple disasters with multi-billion dollar financial losses and numerous human casualties including the explosion of the space shuttle Challenger (1986), the nuclear reactor explosion at Chernobyl (1986), the San Juanico accident in Mexico (1984), and the Bhopal plant accident in India (1984) (7). Each year, there are approximately 120 million occupational accidents worldwide, and more than 200 thousand deaths are caused by these accidents (6). In India, annually 7.7 million occupational accidents are reported, which represent an average loss of 3.25 working days per accident occurrence (8). In the year 2007, across 15 European countries the number of occupational accidents with more than three days' absence from work in manufacturing companies was about 942,000 (9). In the US, occupational accidents in the construction industry resulted in

the death of about 17.29 workers out of 100,000 between 1980 and 1992 (10). These accidents have brought great losses for communities, organizations and workers, and related costs along with adverse effects on economic indicators at both the national and household levels are significant.

Accidents in the transportation industry are a major cause of morbidity and mortality of youth worldwide; in developing countries, the rate of deaths due to accidents is quite high, for example in the transport sector in Iran there are 25.8 deaths per 100,000 people in the population, but in developed countries it is only 19.9 deaths (11, 12).

Currently, the worst consequence of occupational accidents is the premature mortality of a notable percentage of the global labor force (3, 4). Work-related injuries are the biggest health problem worldwide, and about 14 deaths per 100,000 are due to occupational accidents. These accidents cause socio-economic losses such as disability, reduction of working time, and increases in health care costs (4). The annual human cost per foot is $3.36 billion, and the total human cost of occupational accidents resulting in death was 3% of GDP (5, 13, 14).

Bahrampur et al. studied the construction workers of Yazd city in Iran and showed that if this trend in accident continues, over the next few years the amount of these accidents will continue to increase dramatically (13).

A study by Feng (15) showed that safety investments in the construction industry will increase safety culture and behavior . Also, other studies showed that investment in safety management reduces the number of accidents and the costs borne by industry, and due to increased employee satisfaction increases the quality of life of workers (15, 16).

One of the most dangerous fields of employment worldwide is the construction industry, but along with the number of accidents leading to death and total disability, its risks and losses remains somewhat unclear (14, 17). The Health, Safety and environment management system (HSE-MS) of Iran is a regular, systematic, comprehensive, and explicit approach to planning, documenting, and changing the methods for managing detrimental factors, safety threats, and risk analyses. Like other management systems, the HSE-MS system was developed in order to maintain a healthy working environment with the minimum amount of job-related incidents and dangers (18, 19).

2. Objectives

Despite many studies on the costs of accidents and investments in the HSE-MS, there is still no clear and scientific method available for calculating the cost of accidents; the ones that are available have some blind spots. The ultimate aim of the present study is to provide a new framework for the evaluation of the HSE-MS management system's implementation. In order to reduce accidents using the new methods, the main goal of the present study is to develop a new method for the calculation of accident costs (direct and indirect), specifically for calculating the costs borne by society, the employer and the injured person, and demonstrate the required analyses of the newly-developed method.

3. Methods

In this paper, the costs of accidents both before and after the establishment of the HSE-MS are calculated by the use of a new, structured seven-step approach: in order to calculate the cost of construction accidents in the city of Tehran in 2013 - 2014, first accidents were classified into five groups according to the severity of the accident results: 1, short-term absences from work; 2, long-term absence; 3, partial disability; 4, total disability; and 5, death. The types of costs resulting from accidents were also categorized: 1, production disturbance costs; 2, human capital costs; 3, medical costs; 4, administrative costs; 5, transfer costs; and 6, other costs. These costs were classified according to the direct or indirect costs resulting from the incident and the imposition of costs on workers, employers and society, calculating the investment value in the HSE-MS system. Finally, using the formulas below the direct and indirect costs of accidents and also the costs borne by workers, employers and society were measured. These procedures are described in detail below.

3.1. Step One

In order to calculate the cost of accidents, first of all accidents were classified into one of five groups according to the severity of the result of accident: 1, short-term absences from work; 2, long-term absence; 3, partial disability; 4, total disability; and 5, death (15, 16, 20). The type of accident, severity of its outcome, and definitions are presented in Table 1.

3.2. Step Two

Accidents were classified based on the types of costs resulting from them: 1, production disturbance costs; 2, human capital costs; 3, medical costs; 4, administrative costs; 5, transfer costs; and 6, other costs. The following definitions were used to calculate each type of costs. Production disturbance costs (PDC) are costs incurred in the short term until the production returns to the level it was at before the accident. Human capital costs (HCC) are long-term costs, including a potential reduction of production, referring to a restructuring of the production level from

Table 1. Definition of Accidents Based on the Severity of the Outcome of Accident

	Type of Accident	Intensity Level	Definition
S1	Short-term absence	Absence of less than 5 working days, after which an employee can return to all regular work tasks	A minor work-related injury or illness that requires an absence of less than 5 working days for recovery, after which the employee is able to continue regular work tasks
S2	Long-term absence	Absence of 5 working days or more, after which an employee can return to all regular tasks	A work-related injury or illness that requires an absence of 5 or more working days but less than 6 months, after which the worker is able to continue regular work tasks
S3	Partial disability	Absence of 6 months or more, after which an employee can return to work with only short-term or reduced tasks; frequently resulting in a lower income than before	A work-related injury or illness that requires more than 6 months' absence from work; after returning to work, the worker's job duties must be modified
S4	Total disability	Permanent disability without return to work	A work-related injury or illness that causes permanent disability and leaves the employee unable to work
S5	Death	Death	A work-related injury or illness that leads to death

the way it was before the accident happened. Medical costs (MEDC) are costs incurred by workers and the society during the medical treatment of workers injured in work-related accidents. Administrative costs (ADMINC) are incurred through the implementation of indemnification projects and accident investigations, and also include legal fees. Transfer costs (TRANC) are deadweight losses associated with the administration of taxes and welfare. Other costs (OTC), including costs not classified elsewhere, cover things such as costs of career retraining, assistance changes and renovations (15, 16, 20).

3.3. Step Three

Each cost group in more detailed classification was classified in cost cases and then a code was allocated to each of the cost sections.

3.4. Step Four

All of the accidents were classified as having direct (D) or indirect (I) costs, then were analyzed based on the costs borne by employers (E), workers (W), and society (S) (15, 16, 20). Table 2 indicates the summary of the above-mentioned classifications.

3.5. Step Five

Finally, using the formulas provided below, the costs of the accident its direct and indirect costs, and also the costs borne by employers, workers, and society were measured (15, 16, 20).

- Total cost of the accident: (PDC1 + PDC2 + PDC3 + PDC4 + PDC5 + PDC6) + (HCC1 + HCC2 + HCC3) + (MEDC1 + MEDC2 + MEDC3 + MEDC4) + (ADMINC1 + ADMINC2 + ADMINC3 + ADMINC4 + ADMINC5 + ADMINC6 + ADMINC7) + (TRANC1) + (OTC1 + OTC2)

- Direct costs of accident: (PDC3) + (HCC3) + (MEDC1 + MEDC3 + MEDC4) + (ADMINC1 + ADMINC5 + ADMINC6 + ADMINC7) + (TRANC1)

- Indirect costs of accident: (PDC1 + PDC2 + PDC4 + PDC5 + PDC6) + (HCC1 + HCC2) + (MEDC2) + (ADMINC2 + ADMINC3 + ADMINC4) + (OTC1 + OTC2)

- Costs borne by employer: (PDC1 + PDC2 + PDC3 + PDC4) + (MEDC1) + (ADMINC1 + ADMINC2)

- Costs borne by worker: (PDC5) + (HCC1) + (MEDC2) + (ADMINC3 + ADMINC4 + ADMINC5) + (OTC1 + OTC2)

- Costs borne by society: (PDC6) + (HCC2 + HCC3) + (MEDC3 + MEDC4) + (ADMINC6 + ADMINC7) + (TRANC1)

3.6. Step Six

Calculation of required investment in HSE-MS: Investment in the HSE-MS includes eight main sectors: 1, administrative costs; 2, educational costs; 3, equipment costs; 4, committee costs; 5, costs of promotion and incentives; 6, cost of new technologies, methods or design tools; 7, costs for identifying, measuring, and controlling risks to health and the environment; 8, costs for investigation, documentation and certification of HSE-MS (15, 16, 18-20)

3.7. Step Seven

Statistical analyses: Cost data were entered into SPSS 16 statistical software and analyzed via statistical tests as follows: First the Kolmogrov Smirnov test was used to determine the normality of the accident cost data. In the case of a normal cost variable, a two-way ANOVA was used to determine the significance of the differences among the type of cost of accidents by the outcome of accidents, accident costs, and costs borne by workers, employers and society both before and after the establishment of the HSE-MS. Results were considered significant at $P < 0.05$.

Table 2. Summary of Classifications of Accidents in Terms of Cost Group, Severity of Result, and Direct/Indirect Costs

Cost Group	Variable	Types of Costs	Costs Borne by	Direct or Indirect Costs	Severity of Accident
Production disturbance	PDC1	Overtime	E	I	-
	PDC2	Additional employer payments	E	I	-
	PDC3	Cost of employee turnover	E	D	-
	PDC4	Employee training and retraining	E	I	S3, S4, S5
	PDC5	Loss of current income	W	I	-
	PDC6	Indemnification	S	I	S3, S4, S5, S2
Human capital	HCC1	Loss of future earnings	W	I	S3, S4, S5
	HCC2	Loss of governmental revenue	S	I	S3, S4, S5, S2
	HCC3	Social welfare payments for lost earning capacity	S	D	-
Medical	MEDC1	Threshold of medical payments	E	D	-
	MEDC2	Medical and rehabilitation	W	I	-
	MEDC3	Rehabilitation	S	D	-
	MEDC4	Health care	S	D	-
Administrative	ADMINC1	Fines and legal sanctions	E	D	-
	ADMINC2	Study	E	I	-
	ADMINC3	Travel	W	I	-
	ADMINC4	Legal fees	W	I	S4, S5
	ADMINC5	Cost of death (funeral)	W	D	-
	ADMINC6	Inspection and examination	S	D	-
	ADMINC7	Travel for workers with total disabilities	S	D	-
	TRANC1	Welfare payments and tax losses	S	D	-
Transfer	OTC1	Care	W	I	S4
Other	OTC2	Help and changes	W	I	S4

4. Results

4.1. A Practical Example of Calculating Costs in the Construction Industry

In order to test the calculation of accident costs in accordance with the above-described steps, this study examined the construction industry in Tehran in 2013 - 2014. The HSE-MS, which was established in 2014, aimed to build 2000 units of residential buildings over 5 years with an investment of $45 million. Thus, this study calculated the number of accidents that occurred and the costs associated with these accidents during 2013 (prior to the establishment of the HSE-MS) and 2014 (after its establishment). In 2013, 22 accidents occurred, of which one was fatal, two resulted in total disability, three resulted in partial disability, four resulted in long-term absence, and 12 resulted in only short-term absence and minor injuries. In comparison, during 2014, just 8 accidents occurred: one resulted in total disability, two resulted in long-term absence, and five resulted in short-term absences. The Kolmogrov Smirnov test indicates the normality of the accident cost data (P = 0.604).

In 2014, the total amount of investment in the HSE-MS was $524,400, which included administrative costs ($34,200), educational costs ($30,000), equipment costs (USD$200,000), committees costs ($33,000), the costs of promotion and incentives ($31,200), the cost of new technologies, methods or design tools ($140,000), the costs for identifying, measuring, and controlling risks to health and the environment ($32,500), and the costs for investigation, documentation and certification of the HSE-MS management system ($23,500).

The present study indicates that before the establishment of the HSE-MS that the maximum calculated costs was related to production disturbances ($568,000) and

Table 3. Calculation of the Required Investment in the HSE-MS

Investment	Amount (US$)
Administrative costs	34,200
Educational costs	30,000
Equipment costs	200,000
Committee costs	33,000
Costs of promotion and incentives	31,200
Cost of new technologies, methods or design tools	140,000
Costs for recognition, measure and control of risks to health and the environment	32,500
Costs for investigation, documentation and certification of HSE-MS	23,500
Total	524,400

human capital ($291,000), and the lowest costs were related to medical care ($139,000), administrative expenses ($98,000), transfers ($15,000) and others ($98,000). Although lower overall, after the establishment of the HSE-MS, the maximum calculated costs were again related to production disturbances ($80,500) and human capital ($78,000), and the lowest costs were similarly related to medical care ($51,000), administrative expenses ($30,000), transfers ($3,000) and others ($28,500). Analyses showed that the difference in the costs of accidents before and after the establishment of the HSE-MS was statistically significant (P = 0.000).

Statistical analyses for the differences between the accident costs borne by society, employers and workers before and after the establishment of the HSE-MS were statistically significant (P = 0.000), i.e., the highest accident costs were borne by society and the lowest were borne by employers. A significant difference was seen among the costs of accidents resulting in death, total disability, partial disability, long-term absence, and short-term absence (P = 0.005) Accidents resulting in long-term absence had highest costs both before ($426,000) and after ($213,000) the establishment of the HSE-MS. Pre-HSE-MS, the lowest costs were for accidents resulting in death ($84,000); after the establishment of the HSE-MS, the lowest costs were for accidents resulting in short-term absences and partial disability (both $0). Statistical analyses indicated that there was also a significant difference (P = 0.007) in the direct and indirect costs of accidents before and after the establishment of the HSE-MS. In other words, direct and indirect accident costs had multiple significant differences.

Figure 1 shows that in terms of both direct and indirect costs, before the establishment of the HSE-MS the most expensive costs are for accidents resulting in total disability and partial disability, the lowest-cost accidents were those resulting in short-term absence; this difference was statistically significant (P = 0.004). But, after the establishment of the HSE-MS accidents resulting in total disability and long-term absence had the most expensive direct and indirect costs, and accidents that resulted in death and partial disability were the least expensive; this difference was also statistically significant (P = 0.004). The present study indicates that the indirect costs are four times greater than the direct costs.

Figure 2 shows that before the establishment of the HSE-MS most of the costs of accidents resulting in death and total disability were borne by society ($86,000 and $206,000, respectively) and workers ($53,000 and $148,000) and the smallest amount of these costs was borne by employers ($41,000 and $72,000). More of the costs of accidents that resulted in partial disability were borne by workers ($129,000) than by society ($102,000) or employers ($96,000). When accidents resulted in long-term absences more of the costs were borne by society ($80,000) and employers ($76,000) and less by workers ($40,000). In the accidents resulting in only short-term absences most of the costs were borne by employers ($48,000), and the remaining costs were borne by workers ($30,000) in this case no costs were borne by society. These differences were all statistically significant (P = 0.041).

Following the establishment of the HSE-MS, all of these costs were markedly reduced. The costs of most of the accidents resulting in total disability were borne by soci-

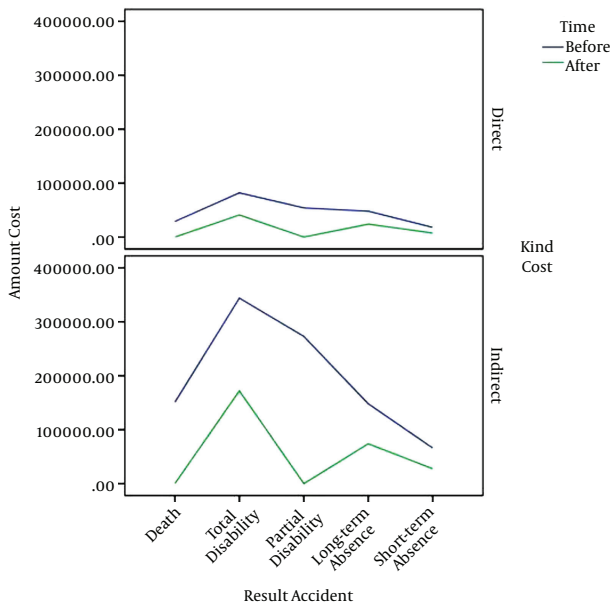

Figure 1. Costs Based on Type and Results of Accidents

Table 4. Analysis of the Calculated Costs of the Accidents in the Construction Industry (US$)

Cost Group		Result of Accident, $					Sum, $	P-Value
		Short-Term Absence	Long-Term Absence	Partial Disability	Total Disability	Death		
Accident costs pre-HSE-MS	PDC	86,000	172,000	168,000	100,000	42,000	568,000	0.000
	HCC	60,000	120,000	75,000	36,000	0	291,000	
	MEDC	5,000	80,000	30,000	12,000	12,000	139,000	
	ADMINC	15,000	26,000	21,000	24,000	12,000	98,000	
	TRANC	3,000	6,000	6,000	0	0	15,000	
	OTC	11,000	22,000	27,000	20,000	18,000	98,000	
Accident costs post-HSE-MS	PDC	0	13,000	0	50,000	17,500	80,500	0.000
	HCC	0	60,000	0	18,000	0	78,000	
	MEDC	0	40,000	0	6,000	5,000	51,000	
	ADMINC	0	13,000	0	12,000	5,000	30,000	
	TRANC	0	3,000	0	0	0	3,000	
	OTC	0	11,000	0	10,000	7,500	28,500	
Who bore costs pre-HSE-MS?	W	53,000	148,000	129,000	40,000	30,000	400,000	
	E	41,000	72,000	96,000	76,000	48,000	333,000	
	S	86,000	206,000	102,000	80,000	0	474,000	
Who bore costs post-HSE-MS?	W	0	74,000	0	20,000	12,500	106,500	
	W	0	36,000	0	38,000	20,000	94,000	
	S	0	103,000	0	40,000	0	143,000	
Type of costs pre-HSE-MS	D	29,000	82,000	54,000	48,000	18,000	231,000	0.007
	I	151,000	344,000	273,000	148,000	66,000	982,000	
Type of Costs post-HSE-MS	D	0	41,000	0	24,000	7,500	72,500	
	I	0	172,000	0	74,000	27,500	273,500	
Total Cost of pre-HSE-MS Accidents		180,000	426,000	327,000	196,000	84,000	121,3000	
Total Cost of post-HSE-MS Accidents		0	213,000	0	98,000	35,000	34,6000	

ety ($103,000) and workers ($74,000) with only $36,000 being borne by employers. But, in the accidents that resulted in long-term absences most of the costs were borne by society ($40,000) and employers ($38,000); workers ($20,000) bore the smallest amount of these costs. In accidents resulting in short-term absences most of the costs were borne by employers ($20,000) and the remainder was borne by workers ($12,500); as before, no costs were borne by society in this case. These differences were also all statistically significant (P = 0.041).

5. Discussion

The present research studied accidents in the construction industry in Tehran during 2013 and 2014. The purpose of the HSE-MS project was to construct a residential building of 2000 units over 5 years with an investment of $45 million. In 2014, the total amount of investment in HSE-MS was $524,400. This study analyzed the number of accidents that occurred during 2013 (prior to the establishment of the HSE-MS) and 2014 (after its establishment) and the costs associated with these accidents.

In 2013, 22 accidents occurred, of which one was fatal, two resulted in total disability, three resulted in partial disability, four resulted in long-term absence, and 12 resulted

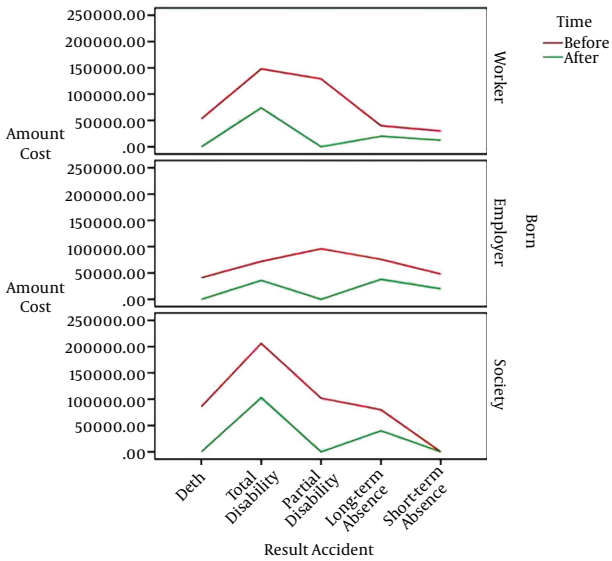

Figure 2. Costs of Accidents in Terms of the Costs Borne by Workers, Employers and Society by the Type of Accident Results

in only short-term absence and minor injuries. In comparison, during 2014, just 8 accidents occurred: one resulted in total disability, two resulted in long-term absence, and five resulted in short-term absences. The greatest reduction in 2014 was in accidents that related in death and partial disability. The decrease in the number of accidents in 2014 compared with 2013, and the $867,000 reduction in the cost of accidents during that time frame, show that investment in the HSE-MS was effective.

The highest cost stemming from construction accidents can be categorized as production disturbance costs and human capital costs, and the lowest fall under medical costs, administrative costs, transfer costs and other costs. This indicates that generally, the costs arising from accidents result from the loss of work, reduced income and additional payments including overtime costs, employee training and retraining costs, loss of current income, and indemnification for loss of future earnings. Most of the costs of accidents resulting in death, total disability and long-term absences are borne by society, and the lowest costs in these cases are borne by the employers. The majority of the costs of accidents leading to partial disability, however, are borne by workers, and the lowest is on employers. In accidents leading to short-term absences, however, most of the costs are borne by employers, and none by society. In other words, accidents with serious consequences such as death, total and partial disability impose a huge cost on society, and employers bear relatively little of these costs, due to the payments provided by the health, treatment and welfare system of society for the treatment and rehabilitation of injured employees and their families; only in low-impact accidents with less severe results such as short-term absence are the greatest portion of the costs borne by employers because of the additional costs of additional and health payments for the injured employees. In long-term absences a large part of the cost is borne by employees in the form of reduced salaries.

According to the present study the amount of accidents leading to total disability, partial disability and death are high, due to the failure to observe basic safety rules and guidelines. The high costs of production disturbance costs and human capital costs in the construction industry are due to indemnifications, the cost of training new workers, loss of efficiency and current money making. In addition to the high incidence of accidents leading to total and partial disability and death in the construction industry, consequently the greatest financial and mental costs are primarily borne by society, and secondly fall on family and the injured workers, which causes increasing financial pressure. Also, this study showed that investment in the HSE-MS is effective and associated with a reduced rate of accidents. Based on the obtained results, the HSE-MS system implementation is strictly advisable because of its benefits.

It is suggested that new research should be conducted to provide a control strategy to reduce the incidents occurring in the construction industry, and to reduce the indirect costs and costs borne by both society and workers, with the aim of increasing welfare and public health.

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Footnotes

Authors' Contribution: Javad Vatani, GebraeilNasl Saraji and Mahmood Salesi, writing the first draft and contribution to final draft and analysis; Abolghasem Pourreza, design of study, collection of data, contribution to final draft; Iraj Mohammad Fam and Seyed Abolfazl Zakerian, collection of data, supervision of group, contribution to first draft, final draft and supervision on analysis of data.

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