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# A Framework for the Calculation of Direct and Indirect Costs of Accidents and Its Application to Incidents Occurring in Iran's Construction Industry in 2013

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## Abstract

**Background:** Occupational accidents represent one of the major problems in developing and developed countries. Deaths caused by occupational accidents result in loss of life, lost working hours, and related costs. These accidents create a lot of waste for the community and labor organizations. Moreover, they result in socioeconomic losses such as disability, loss of work time, and increased medical care expenses.

**Objectives:** Despite the existence of extensive studies, a practical method for calculating the cost of accidents is still not clear; consequently, the aim of the present study is to provide a new framework for the calculation of the (direct and indirect) costs of accidents in construction.

**Materials and Methods:** In this paper, the cost of accidents in the construction industry in Tehran, Iran in 2013 were calculated using a new, structured, six-step approach. First, the results were classified into five groups according to the intensity of accident, as follows: 1, short-term absences; 2, long-term absence; 3, small inability; 4, total disability; and 5, death. Moreover, the six following groups of imposed costs were identified: 1, production disturbance costs; 2, human capital costs; 3, medical costs; 4, administrative costs; 5, transfer costs; and 6. other costs. These groups were classified according to the direct or indirect costs resulting from the incident and the costs imposed on workers, employers, and society. Finally, the data were analyzed using statistical tests.

**Results:** Significant proportions of the cost of construction accidents involve production disturbance costs, human capital costs, medical costs, administrative costs, transfer costs, and other costs. The highest cost is imposed on the community and employee, with the least being imposed on employers. Much of the cost of accidents relates to total disability (\$ 4,260,000) and partial disability (\$ 3,270,000); meanwhile, the lowest costs are associated with death (\$ 1,800,000), long-term absences (\$ 1,960,000), and short-term absences (\$ 840,000). A significant difference was seen between the type of cost (e.g., production disturbance cost, human capital costs;  $P = 0.0001$ ). Statistical analysis of the direct and indirect costs of accidents indicated a significant difference ( $P = 0.019$ ). Moreover, a significant difference was seen between the cost of accidents resulting ( $P = 0.005$ ).

**Conclusions:** Accidents resulting in death, total disability, and partial disability impose a huge cost burden on society, whereas the employer will bear a relatively low cost. This is because of society's health, treatment, and welfare systems available for treatment and rehabilitation of injured employees and their families.

**Keywords:** Accidents, Direct Costs of Accidents, Indirect Costs of Accidents, Construction

## 1. Background

Occupational accidents represent a major problem in both developing and developed countries. The most important part of these costs are human costs. Deaths caused by occupational accidents result in the loss of life and years of work, as well as related costs (1,2). Every year, millions of occupational accidents occurs worldwide; some are fatal, while others leads to temporary and permanent disability (3). Human contemporary history has recorded several

disasters with multi-billion-dollar financial losses and human casualties, including the explosion of the Challenger shuttle (1986), the nuclear reactor explosion at Chernobyl (1986), the accident in Mexico (1985), and the Bhopal plant accident in India (1981) (4). Each year, approximately 120 million occupational accidents and more than 200,000 deaths caused by accidents occur worldwide (3). In India, there are 120 million workers; 7.7 million occupational accidents are reported annually, representing a loss of

3.25 working days for the occurrence of any accident (5). In 2007, the number of occupational accidents involving more than 3 days' absence from work in manufacturing companies in 15 European countries was about 942,000 (6).

Various industries play an important role in the economies of countries around the world; the construction industry is particularly important in the United Kingdom, this industry represents with 10% of the gross domestic product (GDP) and more than 1.5 million (7). In the United States, occupational accidents in the construction industry resulted in the deaths of about 17.29 workers out of 100,000 between 1980 and 1992 (8). Accidents in the transportation industry also represent a major cause of morbidity and mortality of youth worldwide; in developing countries such as Iran, there is a high rate of deaths due to accidents in the transport sector, at 25.8 deaths per 100,000 people, whereas in developed countries, this rate is 19.9 deaths (9, 10).

Occupational accidents have brought about great losses and related costs for the community, organizations, and workers, along with adverse effects on economic indicators at the national and household levels. Such accidents represent obstacles to obtaining predetermined objectives.

Currently, the worst consequence of occupational accidents is premature mortality in the labor force (1, 7). Work-related injuries are an important health problem worldwide, and about 14 deaths per 100,000 are due to occupational accidents. Such accidents also cause socioeconomic losses such as disability, reductions in working time, and increased healthcare costs (1). The annual human cost per foot is 3.36 billion dollars, and the total human cost of occupational accidents resulting in death represents 3% of the GDP (2, 11, 12). Bahrampour et al. studied on the building workers of Yazd, Iran and showed that if the current trend in accidents continues, the number accidents will increase dramatically after several years; the major cause of such accidents will be falls from a height (11). One of the most dangerous occupations is working the construction industry, but along with the accidents leading to death and total disability at an international level, its risks and losses remains somewhat unclear (12-18).

## 2. Objectives

Unlike many studies on the costs of accidents, there is still no clear and scientific method to calculate the cost of accidents; those that are available have some blind spots, the ultimate aim of the present study is to provide a new structure in the cost calculation of accidents (direct and in-

direct) and calculate the costs imposed on society, the employer and the injured person and required analyses.

## 3. Materials and Methods

In this paper, the cost of accidents was calculated using a new, structured, six-step approach. First, the results were classified into five groups according to the intensity of accident, as follows: 1, short-term absences; 2, long-term absence; 3, small inability; 4, total disability; and 5, death. Moreover, the six following groups of imposed costs were identified: 1, production disturbance costs; 2, human capital costs; 3, medical costs; 4, administrative costs; 5, transfer costs; and 6, other costs. Finally, using the developed formulas the direct and indirect costs of accidents and the imposed costs on employees, employers, and the community were measured. The steps of the procedure are described in detail below:

### 3.1. Step 1

In order to calculate the cost of accidents, first, the results were classified into five groups according to the intensity of accident, as follows: 1, short-term absences; 2, long-term absence; 3, small inability; 4, total disability; and 5, death (19, 20). The types of accident, levels of intensity, and definitions are presented in Table 1.

### 3.2. Step 2

The accident is classified into one of six groups, as follows: 1, production disturbance costs; 2, human capital costs; 3, medical costs; 4, administrative costs; 5, transfer costs; and 6 other costs. The following definitions are used to determine the cost groups of an accident:

**Production disturbance costs (PDC):** costs incurred in the short term until the product reaches its pre-accident level.

**Human capital costs (HCC):** long-term costs and the potential reduction of production after a restructuring of the production level that existed before the accident occurred.

**Medical costs (MEDC):** costs incurred by the workers and the community during the medical treatment for workers injured in work-related accidents.

**Administrative costs (ADMINC):** costs incurred in the implementation of indemnification projects, accident investigations, and legal fees.

**Transfer costs (TRANC):** deadweight losses associated with the administration of tax and welfare.

**Other costs (OTC):** includes costs not classified elsewhere, such as costs related to employees' careers, assistance changes, and renovations (19, 20).

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

	Type of Accident	Intensity level	Definition
S1	Short-term absence	Under 5 working days	A minor injury or work-related illness where the employee is absent for under 5 working days or is unable to complete normal and routine tasks, and the employee is able to continue his work after recovery
S2	Long-term absence	Five working days or more of rest and returning to work on regular duty	A minor injury or illness related to work, which consists 5 or more working days but less than 6 months off work, after which the worker is able to continue working and has completely recovered
S3	Partial disability	Five or more days of rest and return to work with short-term tasks or low income	Work-related injury or illness resulting in the return of worker for the first time after leaving work with more than 6 months of absenteeism
S4	Total disability	Permanently disability and inability to return to work	Work-related injury or illness to the employee causing permanent inability to perform his or her tasks
S5	Death	Death	Work-related injury or illness that leads to death

3.3. Step 3

Each cost group is divided using a more detailed classification and a code is allocated to each of the cost sections.

3.4. Step 4

All of the accidents are classified into direct (D) and indirect (= I) sections, then analyzed based on the cost imposed on the employer, the employee, or society (19-21). Table 2 summarizes the cases mentioned above.

3.5. Step 5

Using the provided formulas, the cost of the accident and its direct and indirect costs can be measured, including the costs imposed on the employee, employer, and society (19-21):

Calculation of the total cost of the accident:

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

Calculation of the direct cost of the accident:

$$\text{Direct cost of accident: } (PDC3) + (HCC3) + (MEDC1 + MEDC3 + MEDC4) + (ADMINC1 + ADMINC5 + ADMINC6 + ADMINC7) + (TRANC1)$$

Calculation of the indirect costs of the accident:

$$\text{Indirect cost of accident: } (PDC1 + PDC2 + PDC4 + PDC5 + PDC6) + (HCC1 + HCC2) + (MEDC2) + (ADMINC2 + ADMINC3 + ADMINC4) + (OTC1 + OTC2)$$

Calculation of the accident costs imposed on the employer:

$$\text{Cost to employer: } (PDC1 + PDC2 + PDC3 + PDC4) + (MEDC1) + (ADMINC1 + ADMINC2)$$

Calculation of the accident costs imposed on the worker:

$$\text{Costs to worker: } (PDC5) + (HCC1) + (MEDC2) + (ADMINC3 + ADMINC4 + ADMINC5) + (OTC1 + OTC2)$$

Calculation of the accident costs imposed on society:

$$\text{Costs to society: } (PDC6) + (HCC2 + HCC3) + (MEDC3 + MEDC4) + (ADMINC6 + ADMINC7) + (TRANC1)$$

3.6. Step 6

For statistical analysis, cost data are entered into SPSS 16 statistical software and analyzed via statistical tests. In this study, first, the Kolmogorov-Smirnov test was used to determine the normality of the accident cost data. In the case of the normality of the cost variable, two-way analysis of variance (ANOVA) was used to determine the significance of the cost differences between the types of accidents (PDC, HCC, MEDC, ADMINC, TRANC, and OCT) in relation to the outcomes (death, total disability, partial disability, and long-term and short-term absence), accident costs (direct and indirect), and imposed costs on workers, employers, and the community. The level of significance was  $P < 0.05$ .

4. Results

4.1. Practical Example of Calculating Costs in the Construction Industry

To clarify the calculation of the amount of costs in accordance with the described steps, a construction project in Tehran, Iran, was examined in 2013. In this project, which aimed to build 30 million units of residential buildings over 5 years with an investment of \$100 million, the number of accidents that occurred and the costs associated with the accidents were calculated. In this project, 220 accidents occurred, of which 10 were fatal accidents, 20 resulted in total disability, 30 resulted in partial disability, 40

**Table 2.** Summary of the Classification of Accidents in Terms of Group, Intensity of the Result, and Direct or Indirect Accident

Cost Group	Cases of Cost	Imposed on a Person or Accident	Direct or Indirect Costs	Intensity Result of the Accident
<b>PDC: production disturbance costs</b>				
PDC1	Overtime costs	Employer	Indirect	-
PDC2	Additional payments to employer	Employer	Indirect	-
PDC3	Cost of employee turnover	Employer	Direct costs	-
PDC4	Employee training and retraining costs	Employer	Indirect	S3, S4, S5
PDC5	Loss of current income	Worker	Indirect	-
PDC6	Indemnification	Society	Indirect	S3, S4, S5, S2
<b>HCC: human capital costs</b>				
HCC1	Loss of future earnings	Worker	Indirect	S3, S4, S5
HCC2	Loss of governmental revenue	Society	Indirect	S3, S4, S5, S2-
HCC3	Social welfare payments for lost earning capacity	Society	Direct costs	-
<b>MEDC: medical costs</b>				
MEDC1	Threshold of medical payments	Employer	Direct costs	-
MEDC2	Medical and rehabilitation costs	Worker	Indirect	-
MEDC3	Rehabilitation	Society	Direct costs	-
MEDC4	Health care costs	Society	Direct costs	-
<b>ADMINC: administrative costs</b>				
ADMINC1	Fines and legal sanctions	Employer	Direct costs	-
ADMINC2	Study costs	Employer	Indirect	-
ADMINC3	Travel costs	Worker	Indirect	-
ADMINC4	Legal costs	Worker	Indirect	S4, S5
ADMINC5	Cost of death (funeral)	Working	Direct costs	-
ADMINC6	Inspection and examination costs	Society	Direct costs	-
ADMINC7	All travel privileges for workers with total disabilities	Society	Direct costs	-
<b>TRANC: transfer costs</b>				
TRANC1	Welfare costs of welfare payments and tax losses	Society	Direct costs	-
<b>OTC: other costs</b>				
OTC1	Care costs	Worker	Indirect	S4
OTC2	Help and changes	Worker	Indirect	S4

resulted in long-term absence, and 120 resulted in short-term and minor injuries. The Kolmogorov-Smirnov test indicated the normality of the accident cost data ( $P = 0.604$ ).

The results in [Figure 1](#) show that the most expensive costs were PDC and HCC in the accidents resulting in death,

total disability, partial disability, and long-term and short-term absences. Meanwhile, the lowest costs were MEDC, ADMINC, TRANC, and OTC.

[Figure 2](#) shows that most of the costs of accidents resulting in death were imposed on society (\$860,000) and

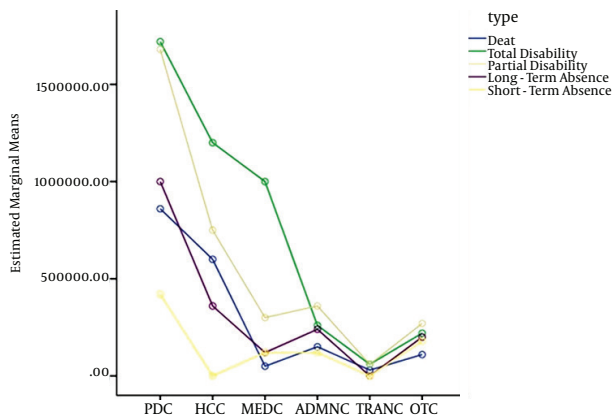


Figure 1. The Cost of Accidents Based on Type and Outcome

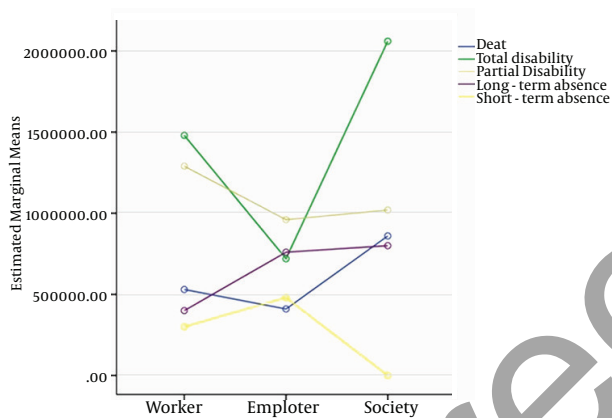


Figure 2. The Costs of Accidents in Terms of the Costs Imposed on Workers, Employers, and the Community Based on the Type of Accident

workers (\$530,000) rather than employers (\$410,000). In the accidents resulting in total disability, most of the costs were imposed on community (\$2,060,000), followed by workers (\$1,480,000) and employers (\$960,000). Most of the costs of accidents resulting in partial inability were imposed on workers (\$1,290,000), while less were imposed on society (\$1,020,000) and employers (\$960,000). However, in the accidents resulting in long-term absences, most of the costs were imposed on the community (\$80,000) and employers (\$760,000), while less was imposed on workers (\$400,000). In the accidents resulting in short-term absences, most of the costs were imposed on employers (\$480,000), while there were no costs to society.

In this study, the maximum calculated costs were related to PDC (\$5,680,000, min: 2,340,000 and max: 8,430,000) and HCC (\$2,910,000, min: 1,340,000 and max: 4,670,000), while the lowest costs were related to MEDC

(\$1,390,000, min: 867,000 and max: 1,687,540), ADMINC (\$980,000, min: 643,000 and max: 1,340,000), TRANC (\$150,000, min: 75,000 and max: 234,000), and OTC (\$980,000, min: 543,000 and max: 1,450,000). The differences were statistically significant ( $P = 0.0001$ ). Statistical analysis for the expression of the difference between the imposed cost of accidents on society, employers, and employees did not show statistical significance ( $P = 0.511$ ); that is, the highest accident costs are imposed on society, but statistically, no significant differences were detected. A significant difference was observed between the cost of accidents resulting in death, total disability, partial disability, and long-term and short-term absences ( $P = 0.005$ ), which indicates that the highest costs were related to accidents resulting in total disability (\$4,260,000) and partial disability (\$3,270,000), and the lowest costs were related to fatal accidents (\$1,800,000), long-term absences (\$1,960,000), and short-term absences (\$840,000). Statistical analysis of the direct and indirect costs of accidents indicated a significant difference ( $P = 0.019$ ). In other words, the direct and indirect costs of fatal injuries (\$290,000 and \$1,510,000, respectively), total disability (\$820,000 and \$3,440,000, respectively), partial disability (\$540,000 and \$2,730,000, respectively), long-term absence (\$480,000 and \$1,480,000, respectively), and short-term absence (\$180,000 and \$660,000) exhibited several significant differences.

## 5. Discussion

The present research considered a construction project that took place in Tehran in 2013. The purpose of this project was to construct a residential building of 30,000 units over 5 years with an investment of \$100 million. The numbers of accidents occurring and incidents costs were calculated. In this project, 220 accidents occurred, 10 of which they were fatal accidents, 20 resulted in total disability, 30 resulted in partial disability, 40 resulted in long-term absence, and 120 resulted in short-term absences and minor injuries. Most of the cost of accidents in construction projects relate to PDC and HCC, while the lowest costs relate to MEDC, ADMINC, TRANC, and OTC; this indicates that, generally, the costs arising from accidents involve loss of work, reduced income, and additional payments, including overtime costs, employee training and retraining costs, loss of current income, indemnification for loss of future earnings, and other costs. Most of the costs arising from accidents resulting in death, total disability, and long-term absences are imposed on society, while the lowest costs are imposed on the employer. However, the maximum cost of the accidents leading to

**Table 3.** Analysis of the Calculated Costs of Accidents in the Construction Industry (in Dollars)<sup>a</sup>

Cost Group	Death (N = 10)	Total Disability (N = 20)	Partial Disability (N = 30)	Long-Term Absence (N = 40)	Short-Term Absence (N = 120)	Sum of Code's Costs	Overall Code's Costs	P Value
<b>PDC: production disturbance costs</b>							5680000	0.0001
PDC1	180000	260000	390000	360000	120000	1310000		
PDC2	20000	40000	60000	80000	120000	320000		
PDC3	10000	20000	30000	40000	60000	160000		
PDC4	100000	200000	300000	120000	0	720000		
PDC5	50000	200000	600000	400000	120000	1370000		
PDC6	500000	1000000	300000	0	0	1800000		
<b>HCC: human capital costs</b>							2910000	0.0001
HCC1	300000	600000	300000	80000	0	1280000		
HCC2	200000	400000	300000	200000	0	1100000		
HCC3	100000	200000	150000	80000	0	530000		
<b>MEDC: medical costs</b>							1390000	0.0001
MEDC1	100000	60000		40000	120000	370000		
MEDC2	400000	90000		0	0	490000		
MEDC3	100000	0		40000	0	140000		
MEDC4	200000	150000		40000	0	390000		
<b>ADMINC: administrative costs</b>							980000	0.0001
ADMINC1	20000	40000	30000	120000	0	210000		
ADMINC2	30000	60000	90000	0	120000	300000		
ADMINC3	0	20000	0	40000	0	60000		
ADMINC4	20000	40000	30000	0	0	90000		
ADMINC5	50000	0	0	80000	0	130000		
ADMINC6	30000	60000	60000	0	0	150000		
ADMINC7	0	40000	0	0	0	40000		
<b>TRANC: transfer costs</b>								0.0001
TRANC1	30000	60000	60000	0	0	150000	150000	
<b>OTC: other costs</b>							980000	
OTC1	10000	20000	30000	40000	0	100000		
OTC2	100000	200000	240000	160000	180000	880000		
<b>Cost imposed on</b>								0.511
Employee	530000	1480000	1290000	400000	300000	4000000	4000000	
Employer	410000	720000	960000	760000	480000	3330000	3330000	
Community	860000	2060000	1020000	800000	0	4740000	4740000	
<b>Type of cost</b>								0.019
Direct	290000	820000	540000	480000	180000	2310000	2310000	
Indirect	1510000	3440000	2730000	1480000	660000	9820000	9820000	
Total	1800000	4260000	3270000	1960000	840000	12130000	12130000	

<sup>a</sup> Comparison of accident result P Value is 0.005.

partial disability are imposed on the worker and the lowest is incurred by the employer. Furthermore, in accidents leading to short-term absence, most of the cost is imposed on employers and there is no cost to the community. In other words, accidents with serious consequences such as death and total and partial disability impose a huge cost burden on society, while the employer's burden is relatively low. This is due to payments for health, treatment, and the welfare system on the part of the community for the treatment and rehabilitation of injured employ-

ees and their family. Only in low-impact accidents with milder results, such as short-term absence, are more costs imposed on the employer as additional wage and health payments must be made to the injured worker; in long-term absences, in contrast, a high cost is shouldered by the worker because of the reduced salary. High-cost accidents are those resulting in total inability (\$4,260,000) and partial inability (\$3,270,000), while the accidents with the lowest cost are those resulting in death (\$1,800,000), long-term absences (\$1,960,000), and short-term absences

(\$840,000). This indicates that the adverse effects and the high cost of accidents can cause total and partial disability in the construction industry. The direct and indirect costs of in fatal injuries were \$290,000 and \$1,510,000; those of total disability were \$820,000 and \$3,440,000; those of partial disability were \$540,000 and \$2,730,000; those of long-term absence were \$480,000 and \$1,480,000; and those of short-term absence were \$180,000 and \$660,000, respectively. This shows that the indirect costs of accidents are much greater than the direct costs; moreover, indirect costs mostly influence society and the injured person, and they have irreversible effects on society.

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. In addition, the high costs of PDC and HCC in the construction industry are due to indemnifications, the cost of training new workers, loss of efficiency and current profits, as so on. In addition to the high incidence of accidents leading to total and partial disability and death in the construction industry, the greatest financial and mental burden is primarily imposed on the community, followed by the family and the injured worker, as this causes increasing financial pressure. It is suggested that new studies should be conducted to provide a control strategy to reduce the number of incidents occurring in the construction industry, as well as to reduce the indirect costs and costs imposed on the community and workers with the aim of increasing welfare and public health.

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### Footnotes

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