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Case Study

The Relationship between the Economic Consequences of Accidents and Safety Measures: A Case Study

Ahmad Soltanzadeh [1], Fatemeh Ghaderi [2], Samira Ghiyasi [3*], Milad Moohammadi [4]

[1] Department of Occupational Health & Safety Engineering, Research Center for Environmental Pollutants, Faculty of Health, Qom University of Medical Sciences, Qom, Iran● [2] Department of Health, Safety, and Environment, Faculty of Engineering, Islamic Azad University, Central Tehran Branch, Tehran, Iran● [3] Department of Environmental Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran● [4] Safety Engineering and Technical Inspection, Safety and Fire Department, Iranian Gas Engineering and Development *Corresponding Author: Samira Ghiyasi, Email: s.ghiasi@iauctb.ac.ir

ABSTRACT

Background: Accidents impose harmful economic consequences for workers, employers, and society. The present study aimed to evaluate the economic consequences of occupational accidents. **Methods:** This descriptive-analytical study was conducted in the Iranian Gas Engineering and Development Company in 2020. Data collection tools were a checklist and a researcher-made questionnaire. The reliability of this questionnaire was calculated through Cronbach's alpha coefficient. Data analysis was conducted using SPSS statistical software and the significance level was considered 0.05. **Results:** The reliability of this questionnaire was estimated at $\alpha = 0.87$. The average lost work day caused by occupational accidents was 36.67 days and the average cost imposed for each accident was 23.97 million Tomans. The total safety index in the studied environment was calculated at 3.59± 1.01. The results of linear multivariate regression analysis indicated that the cost imposed for each accident has a significant relationship with accident type and accident consequence, level of education, number of workers, training hours, work experience, salary, and total safety index ($p < 0.05$). **Conclusion:** The findings of this study showed that the economic performance of a company can be affected by individual, occupational, and most importantly safety factors of the company. In addition, such factors are considered as strong predictors for economic safety performance.

Keywords: Occupational accident; Economic consequence; Accidents cost; Safety index

Introduction

The development of industry and technology have been accompanied by adverse effects along with its positive effects. The complications such as occupational accidents and work-related illnesses are among the adverse consequences threatening the lives of people, especially employees, with the development of modern industries and technologies. Occupational accidents are raised as the third leading cause of death in the world, the second leading cause of death in Iran after car accidents and one of the most significant health, social, and economic risk factors in industrial and developing societies. [1-3] Accidents are regarded as the most obvious cause of huge costs in the oil and gas industry, as well as mega-projects. The oil, gas and petrochemical industries are the scene of accidents due to the nature of materials, equipment and processes. Such accidents can lead to temporary or permanent

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injuries to employees and can also result in death, damages to equipment, or both. In today's society, the occurrence of industrial accidents causes high economic costs to the person involved in the accident, society, and industry including medical and emergency costs, lost wages, accident investigation costs, stopped production and the loss of quality of life. In addition, such accidents cause psychological traumas like grief, sorrow, and anxiety to the injured person and his family. Occupational accidents are among the most significant problems in countries and have critical psychological, health, social, economic and organizational consequences. The costs imposed by accidents and the damages on employers and the country's economy are considerable. The costs by accidents and work-related illnesses are of the same type as well. [2, 4]

In the classification of accidents costs and work-related illnesses, they are divided into direct costs, indirect costs, and intangible costs. Direct costs include the costs related to the treatment and insurance of the injured person, wages, compensation, repair and replacement of equipment, as well as facilities, etc. Indirect costs are the cost of training new staff, changing the job of the trained person, lost working hours, reduced productivity, psychological trauma to the person and his family, etc. Some researchers have estimated indirect costs several times more than direct costs. Indirect costs are normally 4-12 times more than direct costs. The consequences of occupational accidents include permanent disability, death, the loss of working days, and economic loss. However, the failure of a system or the occurrence of accidents can result in disruption at different levels and can be even considered as a threat to society. The occurrence of accidents mainly leads to different damages. In estimating the cost of an accident, the accurate determination of practical damages may be impractical while a general estimate can show the economic damages by accidents. [5, 6] Some of these costs may include the cost of investigating the accident, legal issues, using a reformative method to prevent the recurrence, damaged property other than what the insurance company pays, as well as the cost of increasing premiums, defense against complaints, and public trust due to reduced revenue. In addition, this study aimed to evaluate the economic consequences of different accidents in Iranian Gas Engineering and Development Company.

Methods

This study was a retrospective research of descriptive-analytical type which was conducted in 2020. The research unit of this study was Iranian Gas Engineering and Development Company.

The main studied variable was the economic consequences of occupational accidents which occurred in this company. The statistical population and sample of the study included all of the occupational accidents which had occurred during 2017-2020. In this study, sampling included census method and the selection of all samples available in the studied population. The initial sample size in this study included 176 accidents which had to be reviewed for the eligibility of all the criteria in the study. The only accidents which remained in the study were all of the factors and variables studied in the report or the research team could obtain the data related to it through performing the collection steps. It should be noted that out of 176 collected work-related accidents, 147 accidents were eligible as the final sample. The selection of 83.5% of accidents due to insufficiency and appropriate completion of accident checklist, registration, and the lack of complete report of such accidents for the objectives of this study included the lack of access to information on economic consequences caused by different occupational accidents. In this study, all of the occupations with occupational accidents were evaluated. Some of the most significant studied occupations included the staff in the electrical installations sector, riggers (riggers in lifting operation is a person who moves equipment with the necessary

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coordination with the crane driver), scaffolder, welder, workshop supervisor, as well as the people working in the workshop and the Health and Safety and Environment (HSE) units.

The data of this study were collected through referring to the database of occupational accident registration in the studied industry. Data collection tools were a checklist and a researcher-made questionnaire. The steps of implementing this study were collecting preliminary data, designing checklists and questionnaires, distributing and collecting checklists and questionnaires, as well as conducting the statistical analysis of the results. In the preliminary data collection stage, the study was designed based on the objective and methodology of the study. Then, a checklist and a questionnaire were designed based on the parameters affecting the economic consequences of accidents. After that, the questionnaire was developed during a study according to the opinions of 15 experts in the field of HSE and economics. In addition, the reliability of the questionnaire used in this study was specified by Cronbach's alpha coefficient. The results of evaluating the reliability of the studied tool in this study, which was calculated through Cronbach's alpha coefficient, indicated that the reliability of the questionnaire used in this study was estimated at $\alpha = 0.87$. Cronbach's alpha or reliability test is a statistical test which results in a coefficient called Cronbach's alpha. It is used for testing the reliability of a tool or a questionnaire designed as a Likert scale and its answers are multiple choice. Cronbach's alpha is used for measuring the one-dimensionality of attitudes, judgments, and other categories which are not easy to measure. [7] Ultimately, the data were collected based on this model. After that, the data related to the economic consequences of different accidents during the four years were collected. At this step, the most significant accidents were screened and identified based on the inclusion and exclusion criteria of the study. Then, the selected accidents were analyzed based on the studied criteria and factors and the required information was elicited. In this study, the average cost per accident including the average total costs calculated for each accident was estimated based on the instructions provided in the studied environment. It should be that in this study, different types of accidents such as fire, gas poisoning, human (the accidents in which working people were injured by a mechanical or physical agent), as well as health accidents (the accidents caused by a harmful chemical or biological agent) were evaluated.

Data analysis

The data analysis was conducted using SPSS statistical software version 23 based on regression analysis approach. The statistical tests used in this study were two-way and the significance level was regarded less than 0.05. In this study, the effect of independent variables such as the type and consequence of accident, age, background and level of education, average hours of training and salary, as well as the overall safety index on the economic consequences and costs of accidents were investigated.

Results

The mean age and work experience of the subjects were 38.34 and 7.03 years, respectively. The highest frequency of accidents was for workers, radiographers, and guards (39.5%, 22.4% and 14.3%) and the lowest frequency was related to the jobs such as electrical installations, rigger and execution expert (0.7%), manager, scaffolder, welder and workshop supervisor (0.2%) and HSE supervisor (4.1%). Approximately two-thirds of married individuals (65.3%) and one-third of single individuals (34.7%) had an accident. The highest frequency was related to the individuals with a diploma degree and less (0.85%) while the lowest frequency was related to the individuals with postgraduate degree and higher (1.4%). The average training hours for the studied individuals was 25.48 and the average salary received by the injured individuals was 5.27 ± 2.67 million Tomans. The trend of accidents during the four years

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under investigation was downward. Thus, the highest frequency was related to 2017 (44.9%) while the lowest frequency was related to 2020 (12.2%). The findings of the study based on the accident time indicated that 15 accidents (10.2%), 88 accidents (59.9%) and 44 accidents (29.9%) occurred during the first three, second, and third decades of the month, respectively. Furthermore, 102 accidents (69.4%), 11 accidents (7.5%) and 34 accidents (23.1%) occurred in three shifts in the morning (7:00-15:00), evening (15:00- 23:00) and night shift (23:00-7:00).

The highest frequency was related to 12:00, 00:00 and 8:00 (21.8%, 12.2% and 11.6%) while the lowest frequency was related to 6:00 and 20:00 (1.4%), 2:00 and 3:00 (0.2%), and 15:00 and 22:00 (2.7%).

The findings of the study based on the type and consequence of accidents indicated that the highest frequency was related to human accidents (63.9%) while the lowest frequency was related to health accidents (6.1%). In addition, the highest frequency of accident consequences was related to injuries (46.9%) while the lowest frequency was related to muscle dislocation consequences (1.4%).

Economic costs and consequences of the studied accidents

The average working day lost due to the studied accidents was estimated at 36.67 days. The average cost imposed per accident was estimated at 23.97 million Tomans based on the calculation of 12 variables related to the economic effects of the studied accidents.

Accident-related variables

The descriptive results related to 20 accident variables indicated that the maximum and minimum scores related to the items of using personal protective equipment by employees (4.34) and the use of hazardous substances (2.30) were estimated. The total safety index in the studied environment was estimated at 3.59± 1.01.

The relationship between economic costs and consequences and the variables assessed in the studied accidents

Linear multivariate regression analysis in this study indicated that the average cost imposed per accident has a significant relationship with accident type, accident consequence, level of education of the injured, the hours of training, work experience, salary, and total safety index ($p < 0.05$). The highest relationship between the average cost per accident with training hours, total safety index and accident consequence with a correlation coefficient (B) was 4.1, 3.15 and 3.12, respectively. In addition, the lowest relationship of the average cost imposed per accident was with level of education, work experience and type of accident with a correlation coefficient (B) of 1.9, 2.12 and 2.34, respectively.

Table 1. Descriptive results of the study based on the year of accident

Year	Frequency	Percentage
2017	66	44.90
2018	32	21.80
2019	31	21.10
2021	18	12.20
Total	147	100.00

Table 2. Descriptive results of the study based on the type and consequence of accident

Variable		Frequency	Percentage
Type of accident	Fire	18	12.20
	Gas poisoning	26	17.70
	Human	94	63.90
	Health	9	6.10
Consequence of accident	Death	13	8.80
	Injury	69	46.90
	Injury	3	2.00
	Fracture	31	21.10
	Amputation	5	3.40
	Fatigue	15	10.20
	Dislocation	2	1.40
	Respiratory	9	6.10

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Table 3. Descriptive results of economic costs and consequences of the studied accidents

Variable (Million tomans)	Mean	Standard deviation	Minimum	Maximum
Medical costs	1.25	1.52	0.00	10.00
Compensation / insurance costs	1.29	2.19	0.00	9.00
Costs caused by death / burial, etc.	1.22	5.22	0.00	30.00
Salary and benefits at the time of absence	1.88	1.68	0.00	6.00
Costs due to damage to equipment / facilities	0.54	3.26	0.00	20.00
Costs due to stopped work / project	2.62	8.13	0.00	50.00
Costs of analysis / investigation and handling of the accident	0.83	4.08	0.00	25.00
Costs of conducted remedial actions	3.16	13.11	0.00	80.00
Costs of paid fines	4.00	11.88	0.00	50.00
Costs of hiring and introducing temporary / permanent staff	1.45	2.93	0.00	10.00
Costs of work loss in accordance with lost working days	3.05	4.33	0.00	25.00
Costs imposed by damage to the company's credit	2.53	5.99	0.00	28.00
Average cost imposed per accident	23.97	45.14	1.00	280.0

Table 4. Descriptive results of accident-related variables in the studied accidents

Variable	Mean	Standard deviation	Minimum	Maximum
Was a safety agenda used?	3.82	0.95	2.0	5.0
Did safe conditions change into unsafe conditions over time?	2.53	0.84	1.0	4.0
Were the right tools available?	3.71	0.749	2.0	5.0
Were the tools appropriate for the activity used?	3.63	1.03	2.0	5.0
Were there technical defects in equipment and devices?	2.93	1.21	1.0	5.0
Was the necessary care applied in the design of machinery?	3.70	1.23	1.0	5.0
Were harmful and dangerous materials used?	2.30	1.35	1.0	5.0
Was the hazardous nature of the materials known?	3.29	1.44	1.0	5.0
Was personal protective equipment used by staff?	4.34	1.10	1.0	5.0
Was the accident caused by inappropriate conditions at the workplace?	2.87	1.29	1.0	5.0
Has the safety instruction been communicated to the staff?	4.11	1.19	2.0	5.0
Was the work instruction available in a codified way?	3.60	1.19	2.0	5.0
Was there any proper supervision on the execution?	3.96	0.87	2.0	5.0
Did the staff receive the necessary training?	4.18	0.83	3.0	5.0
Was a plan created to solve the problems?	4.04	0.82	3.0	5.0
Was the risk assessment edited according to the accident?	3.34	0.99	1.0	5.0
Was the work environment safe and reactivated?	4.22	0.89	1.0	5.0
Were maintenance services performed periodically and regularly?	3.46	0.72	2.0	5.0
Were there regular periodic inspections?	4.00	0.79	2.0	5.0
Were TBM meetings held for staff before beginning the work?	3.78	0.72	2.0	5.0
Total safety index	3.59	1.01	1.0	5.0

Table 5. Analytical results of evaluating the relationship between economic consequences and costs and the assessed variables

Independent variable	B	Standard error	95% confidence interval	P-value
Accident type	2.34	0.66	(1.05, 3.63)	0.01
Accident consequence	3.12	1.01	(1.14, 5.1)	0.00
Level of education	-1.9	0.08	(-2.06, -1.74)	0.00
Hours of training	-4.1	1.02	(-6.1, -2.1)	0.00
Work experience	-2.12	0.12	(-2.36, -1.88)	0.00
Salary	-2.8	0.45	(-3.68, -1.92)	0.00
Total safety index	-3.15	1.01	(-5.13, -1.17)	0.00

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Discussion

The results of this study, which was conducted to evaluate the economic consequences of different accidents in Iranian Gas Engineering and Development Company, indicated that the frequency of incidents is a relatively high frequency. Thus, evaluating the trend of accidents during the four years indicated that the incidence of such accidents was downward. Although this number of accidents is relatively appropriate and acceptable considering the size and scope of the personnel, processes, and activities which are performed in this company, according to the engineering and management approaches in this company and taking advantage of human, scientific and research resources, as well as the state of technical resources and equipment to decrease a variety of accidents leading to financial losses and the economic effects and costs of this frequency of accidents can be considered as unacceptable. The results of evaluating the incidence of such accidents based on time including month, day, and hour of accident per day revealed that these accidents occurred more in winter (approximately one third of accidents = 30.6%). Furthermore, the findings indicated that the most of the accidents occurred during one month in the second decade (59.9%), third decade (29.9%) and the first decade (10.2%). Further, evaluating the accidents based on the time of accidents during the day indicated the incidence of such accidents in three shifts in the morning (7:00- 1:00), evening (15:00-23:00) and night (23:00-7:00), was 102 accidents, (69.4%), 11 accidents (7.5%) and 34 accidents, respectively (23.1%). The results of this study revealed that the mean and standard deviation of the lost working day due to the studied accidents was 36.67 days. Lost working days are one of the parameters which can be evaluated based on the safety status, and also accident conditions in an industry or organization. [8, 9] A study by Heydari et al., entitled "The role of hidden variables in lost working days based on the structural equation model in the oil exploration industry" indicated that the average index of lost working days in this part of the industry was 57.49 days. [9] In this study, the economic costs and consequences resulting from the occurrence of the studied accidents were evaluated with 12 parameters such as the amount of lost working day due to the studied accidents, medical costs, compensation/ insurance costs, costs due to death / burial, etc., costs of salaries and benefits during the absence, costs due to damages to equipment / facilities, costs due to stopped work / project, costs of analysis / inspection and accident handling, costs of remedial actions, costs of paid fines, costs of hiring and introducing temporary/permanent staff, costs of wasting work in accordance with lost working days, and the costs of damaging the company's credit. The results of this evaluation indicated that the average of these parameters was 1.25, 1.29, 1.22, 1.88, 0.54, 2.62, 0.83, 3.16, 4.00, 1.45, 3.05 and 2.53 million Tomans, respectively. In addition, the highest and lowest average economic costs and consequences resulting from the occurrence of the studied accidents belong to the paid fines was estimated to be (4.11± 0.88) million Tomans and the costs of damages to equipment/facilities (0.3±54.26). Furthermore, the average cost imposed per accident was estimated at 23.97± 45.14 million Tomans. The results of regression analysis based on linear multivariate regression analysis in this study revealed that the average cost imposed per accident was related to accident type, accident consequence, level of education of the injured, hours of training, work experience, salary, as well as the total safety index in the studied environment. These findings indicated that the highest correlation of the average cost imposed per accident with hours of training, total safety index, and accident consequence with a correlation coefficient (B) of 4.1, 3.15 and 3.12, respectively. In addition, the lowest correlation of the average cost imposed per accident was related to level

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of education, work experience, and accident type with a correlation coefficient (B) of 1.9, 2.12, and 2.34, respectively. In line with the comparison of the findings of this study and other studies, Tang et al. (1997) studied the performance of the relationship between safety investment and the safety performance of building projects in Hong Kong and discovered a weak correlation coefficient (0.25) between safety investment and safety performance. Thus, there may be some other factors affecting the relationship between safety investment and safety performance. Some studies revealed that the low correlation coefficient (0.25) between safety investment and safety performance might be due to differences in the safety culture of different companies. However, there is still a need to understand the theory elated to the issues which affect safety performance. [10, 11]

Physical input refers to investments in safety or costs for accident prevention activities. Its objective is to protect the health and physical integrity of employees. In addition, safety investments are considered as costs for safety. Heinz et al. (2003) mentioned that safety costs are among the costs which are imposed due to the emphasis on safety of supply, whether in the form of training or drug testing, safety incentives, staff recruitment in the field of safety, personal protective equipment, safety facilities, safety programs, etc. It is believed that safety investments have always a positive effect on the safety performance of building projects. However, this effect is largely a matter of probability since there may be no harm even if no safety investment is made. If the safety investment is high, the probability of imposing the cost of high damages is relatively slight. On the other hand, if the investment in safety is low, the probability of costly damages can be relatively high. [12-14]

In addition, some studies have emphasized that a good safety culture is not accidental but is the result of a coordinated effort and needs investment in training, equipment, and safe work procedures. Thus, evaluating the relationship between safety investment, safety culture, and safety performance is based on three basic hypotheses such as "safety culture is positively related to safety investment", "safety performance is positively related to safety investment" "and" the effect of safety investment on safety performance is related to safety culture ", in addition to "safety investment has direct and indirect effects on safety performance". In line with this significant issue, the findings of this study indicated that the safety performance evaluated in this study with the total safety index, as well as also other parameters such as individual and occupational variables are significantly related to safety economic performance by calculating and estimating the average cost per accident. The results of regression analysis based on linear multivariate regression analysis revealed that the average cost imposed per accident has a significant and inverse relationship with level of education of the injured, hours of training, work experience, salary, and total safety index in the studied environment. [15-17]

In other words, the average cost imposed per accident can significantly reduce by increasing the level of each of these variables and parameters. In addition, these results showed that the average cost imposed per accident has a significant and direct relationship with accident type and accident consequence. [17, 18] Based on this finding, the average cost imposed per accident could increase significantly by increasing the level of these two factors. Thus, it should be noted that safety can be achieved only by cost or investment. Accident prevention costs refer to the costs of resources spent by contractors in implementing safety and health measures to observe their safety and health obligations. Such costs which may include first aid, personal protection equipment, safety training, safety promotion, supply of safety personnel and types of equipment required for safety will have acceptable functions for increasing the level

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of safety and reducing costs due to the occurrence of a variety of accidents in the workplace.

Conclusion

In general, this study concluded that the performance of a company or industry depends on the set of its activities in the field of safety since the occurrence of accidents and injuries can cause the occurrence of human and social damages and can have negative, harmful and sometimes catastrophic effects on the economic productivity of an organization or company. Such economic effects are due to the imposition of costs on organizations due to the occurrence of different accidents and events in a way that sometimes threaten the survival of an organization or causes considerable delays in competition with other industries and companies.

Based on the findings of this study, it was concluded that the economic performance related to the safety of a company, which is evaluated and analyzed with the average cost per accident can be affected by personal, occupational, and most importantly the safety performance of the company and such factors should be regarded as strong predictors for the economic performance of safety. In this regard, the results indicated that the average cost imposed per accident was related to accident type, accident consequence, level of education of the injured, hours of training, work experience, salary and total safety index in the studied environment.

Conflict of interest

The authors have declared that there is no conflict of interest.

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Authors contribution

All authors contributed to the final version of the manuscript, equally.

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