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Estimating the Economic Impact of Mining Accidents: A Case Study from Peru

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ABSTRACT

The objective of this research was to evaluate the real costs of accidents and their impact on the management of a mining company, (Case: Fatal accident of a worker and the total loss of a backhoe), the causes that originated this study is that the vast majority of companies do not technically analyze all the costs involved as production loss due to the stoppage of the company's activities (costs of machinery and equipment rental, food and stay of workers, fines stipulated by law, compensation, loss of image, among others), whose consequence is the ignorance of the real amount of the loss generated by the accident. The previous studies were carried out with the Simonds Method or Average Costs, which improves Heinrich's study, and gives us an equation to calculate the costs: CT = CS + (CPi x Ai) + Ce, which was surpassed by Frank Bird's method, by means of his famous iceberg of accident costs, however these were carried out in factories in the United States, but the norms and laws of that country do not agree with those of Peru, which is why taking into account all this and adapting it to those of Peru, The present research work has been carried out, in which other variables have been considered, such as losses in the process, costs caused by work stoppages, collaborators' salaries, machinery stopped due to sanctions by the corresponding ministry (MEM), and miscellaneous costs; From the comparative result with the Frank Bird method, the sum of $980,000 USD has been calculated, while with the Frank Bird study the sum of $980,000 USD has been calculated. 000 USD, while with the study we have carried out we have calculated the sum of $3,856,710.30, being a considerable loss that the insurance does not cover and is assumed by the mining company or mining contractor, this study will be a valuable contribution for the top management of the companies. It is concluded that with the previous research methods it is not possible to know the real cost of the loss with which the company could make a favorable investment.

1. INTRODUCTION

Mining is an industry of high labor risk and of great importance in the economy of countries that have these resources. The labor market implications of the mining industry have increased the importance of sustainable human talent management at the strategic level of this industry [1]. Companies are not only focused on achieving objectives such as cost savings, increased efficiency and profitability, but are also adding other social and environmental objectives to their agenda, often including health, safety and environmental issues [2]. Exposure to any type of accident is detrimental to both individuals and organizations, they deprive individuals of their livelihoods, disrupt the way employees perform their work and impair individual well-being; for organizations, they compromise their functioning and profitability, often leading to their collapse. Hence the growing interest in studies relating accidents in the workplace [3].

The accidents that happen in the companies do not distinguish gender or age, neither the size of the company, day of the week or specific place within the work, all are factors that can influence to some extent in the days of leave for injuries that may occur at work affecting the costs of the company [4].

The work accidents that occur in mining companies in Peru, due to the fact that there is no real knowledge of the costs involved, and that harm the workers, the companies and society. Mining company officials assume that accident insurance covers the costs of the event, which are only the direct costs, but they are unaware of the indirect costs that these accidents entail, where the more serious they are, the greater the costs and the losses in the companies have a substantial impact on profitability, image and the failure to meet the goals that have been set with respect to productivity. [5].

The scientific literature does not yet provide a costing tool for occupational accidents that is sufficiently accurate and does not require additional data collection steps for decision makers in the area of Occupational Safety and Health [6].

Web applications have been developed that allow estimating the potential costs that could be generated by worker injuries in the company, in addition, it provides information on the distribution of the same, claims and compensation of workers by type of injury, in addition to considering the indirect costs associated with the accident [7].

Table 1. Fatal accidents in Peru from 2000 to 2019

Year/month	J	F	M	A	M	J	J	A	S	O	N	D	Total
2000	6	4	2	3	3	6	8	0	0	7	8	7	54
2001	2	9	5	5	8	3	8	8	4	5	4	5	66
2002	20	2	4	6	5	5	4	6	4	8	8	1	73
2003	4	8	5	7	5	3	4	5	3	3	4	3	54
2004	2	9	8	5	2	9	1	3	4	7	5	1	56
2005	3	8	6	6	6	3	5	3	7	5	8	9	69
2006	6	7	6	3	6	5	6	5	4	9	4	4	65
2007	5	6	7	3	7	6	4	6	5	6	5	2	62
2008	12	5	7	6	3	5	6	6	5	3	3	3	64
2009	4	14	6	2	3	8	6	4	2	1	4	2	56
2010	5	13	1	6	5	9	6	4	3	4	4	6	66
2011	4	8	2	5	6	5	4	5	4	5	1	3	52
2012	2	6	8	2	4	2	5	5	3	8	4	4	53
2013	4	6	5	6	1	4	4	4	5	2	4	2	47
2014	6	1	1	1	1	3	7	2	2	0	1	7	32
2015	5	2	7	2	0	2	1	2	2	3	3	0	29
2016	4	3	3	1	6	2	2	3	4	1	2	3	34
2017	5	5	3	2	6	1	3	4	2	8	0	2	41
2018	2	1	2	5	3	2	1	3	2	2	3	1	27
2019	4	2	1	4	4	3	3	3	3	1	6	6	40

The costs of work accidents occurring in mining companies in Peru, due to the fact that there is no real knowledge of them, are detrimental to workers, companies and society [8, 9]. Mining company officials assume that accident insurance covers the costs of the event that occurred, being these only the Direct Costs, however, they are unaware of the Indirect Costs that these accidents entail; where the more serious they are, the greater the losses in the companies and have a substantial impact on profitability, image and the failure to meet the goals that have been set with respect to productivity [10, 11].

The existing conditions in the work centers, as well as the machinery and equipment used in mining determine that they are high-risk activities that threaten the physical integrity and health of the workers, and indirectly of their families who are harmed in the event of undesired events [12]. The cost of the work accident with the method of their research was 15156500.60 US dollars and with the method they used previously in the company was only 3638201.03 US dollars, which is much lower than the design proposed by the study, since they only considered in the affected company the days lost due to the accident plus the social benefits and the replacement of the injured person [13]. Occupational accidents are disbursements that the company has to make and also affect the costs of the worker and society, which has to pay the administrative, judicial, medical and social costs resulting from the occurrence of the accident [14].

The costs of occupational accidents and occupational diseases always represent expenses for companies, in addition to the fact that these events are production losses, such as: temporary or permanent disability, time, equipment, monetary capital outlays, work stoppages, etc. Most companies do not quantify these costs because they do not keep records of undesirable events, which is why mining companies and others are unaware of the enormous losses they incur by not keeping records of the costs of occupational accidents and diseases [12, 14].

Table 1 shows that from 2000 to 2019, there have been fatal accidents in the different mining companies in Peru, where we can see that fatal accidents still cannot be controlled despite the fact that the companies have occupational health and safety management system, taken from ENERGIMINAS Magazine, April 13, 2021.

Figure 1 shows the grouping by type of accidents in 2020, with the two highest percentages being accidents by other forms or not classified with 42%, followed by collapse with 32%. Ministry of Energy and Mines-Peru.

Figure 2 shows the number of fatal accidents according to type of company in 2020, it is observed that there was a significant decrease with respect to 2019, where it is seen that there were 40 fatal accidents, for 2020 it decreased to 19, grouped in mining contractor (4), related company (6) and mining company.

In this study an approximate cost analysis was carried out in a mining contractor in the north of Peru, whose main objective is to determine the approximate real cost of a fatal accident with the following consequences: fatality of the operator of the backhoe, total loss of the machinery, work stoppage for 15 days while the investigation lasted, the investigation was done in a period of 10 days with an extension of 15 more days, in total 25 days lost for the same situation and 18 months of procedures with the insurance for the return of the backhoe for total loss of the machinery, after this period of time the company was able to provide this service to the client.

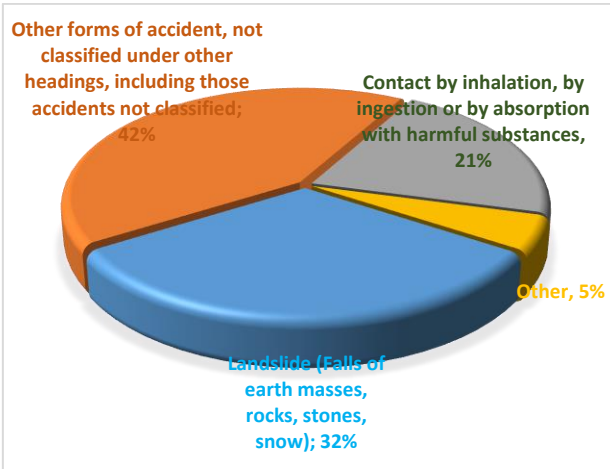

Figure 1. Percentage of fatal accidents by type of cause, 2020.MEM

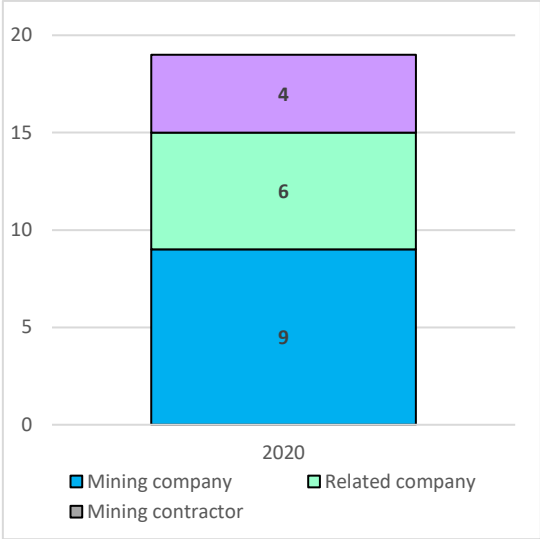

Figure 2. Number of fatal accidents by type of company, 2020. MEM

2. MATERIALS AND METHODS

2.1 Accident data collection

All data were obtained from the mining contractor in northern Peru, through participation in the investigation of the accident, according to the DS 024 and amendment 023 of the Ministry of Energy and Mines (MEM) of Peru. The company provides machinery and equipment rental services, in which there was a fatal accident with loss of human life and total loss of the backhoe, environmental damage due to contamination, damage to green areas to build a temporary access to rescue the equipment, rescue equipment for the injured person, and work stoppage: 10 days for accident investigation and talks to workers and operations supervisors; increase of 15 days for procedures with the insurance company (a safety and occupational health consulting engineer, company safety engineer dedicated exclusively to the accident investigation, an administrative employee to carry out procedures and conciliation with the family of the deceased, insurance procedures, rescue of the backhoe with machinery as required by the insurance company, etc. , which in reality are costs that are not taken into account in the costs for this concept, since the personnel are not dedicated full time to the work for which they have been hired.

2.2 Approaches to accident cost analysis

Safety Costs in the prevention of occupational hazards, gives us an acceptable method to apply in companies, to improve the method of Heinrich (scholar of occupational safety and occupational health; the method he proposed to take into account the Insured and Uninsured Costs, similar to the Direct and Indirect Costs. The equation is for calculating average costs [15].

The equation is as follows:

$$CT = CS + (CPi\ x\ Ai) + Ce \quad (1)$$

where,

CT: Total accident cost.

CS: Insured cost.

CPi: Average cost of accidents.

Ai: Number of accidents.

Ce: Includes catastrophic losses (explosions, fires, etc.), fatal accidents or those causing losses.

The same author points out four types of accidents, according to the classification of injuries and material damage, which are:

Class 1: Partial, temporary, permanent total disabling.

Class 2: Accidents with medical treatment requiring care outside the company.

Class 3: Accidents requiring only first aid medical attention in the company's first aid kit and causing less than $20 in property damage, or a loss of time of less than 8 hours.

Class 4: Non-injury accidents resulting in property damage of more than $20, or loss of time of 8 hours or more.

For the calculation of the average cost (C) of health care for accidents that required attention within the working day (e.g., class 3), Simonds gives the following formula:

$$Cp = (Tp * Sm + As)n + TC \quad (2)$$

where,

Tp: the average time lost in receiving assistance.

Sm: the average wage.

As: the average cost of health care.

n: the average number of cures per accident type.

TC: the average cost per average time spent by managers.

Once the average costs of the different types of accidents considered for the initial year of application are known, they can continue to be used in subsequent years, taking into account the variation they may experience. In this case, the following correction factor K is applied:

$$K = Sm/Smi \quad (3)$$

where,

S_m is the current average wage.

S_{mi} is the initial average wage calculated (year in which the first study was made). Therefore, CT = CS + k (CPi Ai) + C', where C' represents the insured costs for the year to be calculated.

It is advisable to recalculate average costs every three years. This method will be able to obtain more accurate results the more summands are included in the base formula, since the different average costs will offer less dispersion. The ideal would of course be to have a cost for each accident, but the exhaustive nature of this work is precisely what the method tries to avoid.

In practice, to determine a representative average cost, it is necessary to study a minimum of 20 cases for each type of accident, doing so for each accident that occurred. To obtain the necessary and timely data, the specialist who performs the calculation must have the collaboration of the managers and middle managers.

This method is applicable to companies with a high number of accidents, and not very applicable to companies with low accident rates.

This method has become obsolete because it works with average costs and is not done in a detailed way, where the real costs of the accident are diluted.

2.3 Frank Bird Jr. method

Company managers only see the tip of the Iceberg and are

unaware of the true hidden costs, which are in greater quantity; because here the Direct and Indirect Costs are clearly detailed. Indirect or hidden costs are those that increase the real value of accidents, and to calculate them it is necessary to have the support of the different work areas of the companies [16].

Thus, we have that the area of administration and human resources has to give us the payroll and salary of the collaborators according to the position they occupy; the area of safety and health at work will give us the time of inactivity until the injured person is discharged, which includes costs of rehabilitation and replacement of the worker; the area of logistics will give the costs of personal protective equipment, machinery repair; the area of operations will give the time lost due to the inactivity of machinery and equipment, as well as what is not produced and the delay in the planning of work execution, etc., in addition to the administrative costs associated with accidents [16].

Frank Bird is an occupational health and safety scholar who has conducted good research studies in North American factories and construction companies. In relation to mining, this method is trying to be adapted with respect to the costs of accidents, since mining operations have different work cycles according to the magnitude of production, as well as the number of collaborators working in the companies.

In the book Practical Leadership in Loss Control, he gives us better ways to calculate accident costs, but it has to be adapted to the laws and regulations of Peru, since this study was made for the United States of North America, in which he gives us guidelines such as [17]:

A. Direct Costs: $1, which are:

Injury and Sickness costs, which come to be the costs of:

- Medical costs
- Compensation costs (insured costs)

B. Indirect Costs: which are subdivided into:

B.1 Costs accounted for property damage (uninsured costs) $5 - $50.

- Damage to buildings
- Damage to equipment and tools
- Damage to product and material
- Interruption and delays in the production process.
- Legal expenses.
- Equipment expenses and emergency supplies
- Rental of replacement equipment.

B.2 Uninsured Miscellaneous Costs $1 to $3

- Research Time.
- Wages paid for lost time.
- Costs of preparing and/or hiring replacement person.
- Overtime.
- Extra supervision time.
- Administrative paperwork time.
- Decrease in production of the injured worker.
- Loss of prestige and business opportunities.

Although these costs are closer to reality, however, there are some that are not correctly typified, that is why we will make a systematic study of all the real costs that are met, in addition to the ranges of indirect costs that come to be the material damages that are typified from 5 to 50 times the direct cost and also the range of miscellaneous uninsured costs from one to three times greater than the direct cost of the accident [18].

These costs, in reality, reflect only a part if an exhaustive study is made of the costs caused by occupational accidents, as well as the type of company, activities and others.

For example: Frank Bird Jr. does not consider the loss of ore production due to the stoppage of mining activities, which represents a considerable sum when working with giant machinery, such as trucks, shovels and drills. In addition to lost production, there is the cost of rental of the giant machinery and auxiliary services, as well as salaries and general administrative expenses.

3. RESULTS AND DISCUSSION

3.1 Fatal and material accident due to backhoe falling off the cliff

The operator of a backhoe while clearing loose rock on an 8 m high slope, large rocks began to fall, to escape from the falling rocks the operator proceeds to leave the site with the backhoe, due to the haste of the maneuver the equipment leaves the 4 m wide road, causing the backhoe to fall into the ravine with the backhoe.

Backhoe operator dies, had 5 years of experience. He leaves a wife and 3 minor children. The equipment was destroyed with material damage under evaluation (Figure 3).

The Insurance returns to the owner a new equipment of USD ($) 90,000; 18 months after the accident.

Figure 3. Backhoe accident

The following tables show the results of the analysis of direct, indirect and miscellaneous costs to obtain the total cost of the accident. Table 2 shows the cost analysis of the machinery that stopped operating for 10 days during the accident investigations, resulting in a cost of 332,000 US dollars.

Table 2. Cost analysis of machinery that stopped working for 10 days

Description	Rental Hours USD ($)	Un.	Hours Worked S/day	Cost/day USD ($)	Cost x Unemployment (10 day)
Dump truck of 15 m3	45	30	16	21,600.00	216,000.00
Front Loader 966 CAT	95	3	16	4,560.00	45,600.00
Backhoe loader CAT 420	35	4	18	2,520.00	25,200.00
Motor Grader CAT 140K	95	2	14	2,660.00	26,600.00
10 Ton Smooth Roller	45	2	12	1,080.00	10,800.00
TOYOTA 4x4 pickup truck ($/day)	120	4	22	480	4,800.00
Passenger transport bus (30 seats)	150	2	22	300	3,000.00
Total Cost				USD ($)	332,000.00

Table 3. Salaries of mining contractor personnel

Description	N° of Employees	Days without Work	Salary/day USD ($)	Cost x Unemployment (USD) (10 days)
Construction Resident	1	20	142.86	2,857.20
Occupational Health and Safety Manager	1	20	142.86	2,857.20
Field supervisors	4	10	71.43	714.3
Administrative Manager	1	20	142.86	2,857.20
Head of Human Resources	1	10	80.95	809.5
Office Assistant	1	10	23.81	238.1
Secretary	1	10	23.81	238.1
Storekeeper	2	10	19.04	190.4
Warehouse Assistant	2	10	16.67	166.7
Service Personnel	6	10	16.67	166.7
Maintenance Foreman	2	10	40	400
Mine Foreman	2	10	43.81	438.1
Mechanics	6	10	20.95	209.5
Welders	2	10	20.95	209.5
Mechanic's and fitter's assistants	6	10	17,014.00	170,140.00
Mine operator	4	10	20.95	209.5
Mine officer	6	10	20	200
Laborers	35	10	19.04	190.4
Machinery operators	98	10	26.67	266.7
Equipment controllers	3	10	20	200
S. and S. O. Supervisors.	2	10	71.43	714.3
Fuel dispenser	2	10	20	200
Bus and van drivers	12	10	23.81	238.1
Total	200			184,711.50

Table 4. Food and lodging of personnel

Description	D/A/C Hours USD ($)	N° of Employees	Days without Work	Cost x Unemployment (USD) (10 days)
Feeding	40	200	10	8,000.00
Stay	30	200	10	6,000.00
Total		200	10	14,000.00

Table 5. Backhoe loader costs cease to charge for rental

Description	Hourly Rental USD ($)	Un	Hours Worked/day	Cost/day USD ($)	Cost Who Stopped Working (18 months) USD ($)
Backhoe loader CAT 420 F2	35	1	18	630	340,200.00

Table 6. Backhoe rescue access construction costs

Description	Cost $	Description	Quantity	Unit	Cost USD ($)
Cost x meter of access for equipment rescue	400	dollars/meter	450	meters	180,000
Crane of 30 Tm	200	dollars/hour	5	hours	1,000
Low bed	90	dollars/hour	6	hours	540
Civil Engineer	100	dollars/day	1	day	100
Topographer	40	dollars/day	1	day	40
Assistant	20	dollars/day	1	day	20
Total station rental	150	dollars/day	1	day	150
				USD ($)	181,850

Table 3 shows the salaries per day of the workers who stopped working during the 10 days of the investigation, talks and safety reinduction, giving a total of 184711.50 US dollars.

Table 4 shows the costs related to food and lodging for the Mining Contractor's personnel during 10 days of stoppage of activities, resulting in a cost of US$14,000.

Table 5 shows the costs related to the backhoe for the time that the company OPC SAC does not receive for rent, due to the fact that the process with the insurance of the equipment took 18 months to replace the backhoe, causing a cost of US$3,340,200.00.

Table 6 shows the costs related to the construction of accesses for the rescue of the backhoe, resulting in a cost of US$18,850.00.

Table 7 shows the costs related to the legal penalty for accidents resulting in death and non-compliance with occupational health and safety procedures, which is 30 Tributary Tax Units (UIT=3650.0 soles=1000.00 U.S. dollars).

With respect to compensation to the wife and education of the minor children:

Wife (compensation in accordance with international law (age=26 years).

Sons:

- 10 years, (cost of education per year) up to 21 years.
- 8 years, (cost of education per year) up to 21 years.
- 4 years (cost of education per year) up to 21 years.

The penalty to the legal representative of the company for fatal accident from 4 to 8 years and defense costs for the lawyer, amounts to approximately 15,000 US dollars.

Table 8 shows the results in detail for each type of cost, whether direct, indirect or miscellaneous.

Table 9 shows the summary of costs generated by the accident with fatality.

Table 7. Calculation of legal penalties for fatal accidents and non-compliance with OHS procedures

Rule/Law/DS	Title	Description/ Application	UIT	USD ($)
MINISTERIAL RESOLUTION N° 353-2000-EM-VMM	Scale of fines and penalties for noncompliance with provisions of the TUO of the general mining law and its regulations.	For the violations referred to in numeral 2.1. of this scale, and that have been determined during the investigation of the fatal accidents as causes of the same, the amount of the fine shall be 30 UIT for each violation up to a maximum of 100 UIT.	30	30000
SUPREME DECREE N° 019-2006-TR 29/10/2006	Regulation of the general labor inspection law [11].	Article 48.- Amount and application of penalties	Very Serious 11 to 20 UIT (10%)	11000
			Total ($)	41,000

The research carried out by different scholars of occupational safety and health, such as: Bird Jr. method, F. and Gemein: Iceberg of Accident Costs, G; Simonds Rollind, H.: Simonds Method or Average Costs; which are the main scholars who approached the real costs abroad, according to their laws and provisions, which shows that each country has its rules and regulations, and the above mentioned scholars have not taken into account these costs, instead in Peru if we analyze conscientiously the difference in accident costs are totally considerable [19].

The total cost of the incapacitating accident had a considerable impact on the company, which affected it because with what it had lost it could have acquired machinery and equipment to improve its services to the client according to the advance of technology; for example, it could have purchased: tractors, front loaders, excavators of greater capacity, rock drill drills, etc. And with all this, it would have increased its profitability and its image with the client [19].

About 90% of the mining contractors (in Peru) are unaware of these costs, they only know the direct costs: in this case, they only knew: $16,550.00, which is assumed by the company's insurance, however, the indirect and miscellaneous costs are not assumed by the insurance, because the company must assume them in their totality, which are as follows: Indirect Costs: $3,832,610.30 plus $7,550.00, which makes a total of $3,856,710.30, which must be assumed by the company and is considered a cost without return.

Table 8. Accident cost results

A. Direct Costs	Unit Cost USD ($)
Medical assistance	100
Ambulance (more choder)	150
Equipment insurance premium	12,800.00
Legal expenses (payment for removal of body)	500
Administrative costs	3,000.00
B. Indirect costs	**Unit Cost USD ($)**
Damage to equipment and tools	90,000.00
Damage to production	27,840.00
Disruption and loss in machinery/equipment rental	332,000.00
Staff salaries	184,711.50
Food and lodging for staff (10 days)	14,000.00
Cost of backhoe loader that stopped charging rent	340,200.00
Legal expenses	4,000.00
Expenses for emergency equipment and supplies	2,000.00
Rescue of the corpse	1,000.00
Rescue of the backhoe	10,000.00
Construction of access for rescue (450 mts)	181,850.00
Replacement equipment rental	340,200.00
Loss of company image	1,865,862.00
Training/training of replacement person	2,000.00
Limpieza de la contaminación ambiental	1,500.00
Wife's compensation and education of minor children	374,446.80
Breaches of law (penalties)	41,000.00
Payment for autopsy	2,000.00
Payment to attorneys for the defense of the legal representative	15,000.00
Burial costs	3,000.00
C. Miscellaneous Costs	**Unit Cost USD ($)**
Accident investigation time	3,750.00
Legal cost / administrative procedures	3,800.00

Table 9. Summary of accident costs

Description	USD ($)
A. Direct costs	16,550.00
B. Indirect costs	3,832,610.30
Miscellaneous Costs	7,550.00
Total accident cost	3,856,710.30

4. CONCLUSIONS

The analysis of the costs of work accidents that are carried out in a company, generally the top management is unaware of the real losses they suffer because they think that the insurance company assumes all the costs, but the hidden or indirect costs are much higher.

The elaboration of the costs of occupational accidents in the mines, vary according to the legal regulations of each country and the activities they perform, also influences the leadership of their managers and the real knowledge of the activities, as well as the importance of occupational health and safety. The methods used to obtain these costs in Peru are lower than the study method we have carried out based on the legal regulations of the country.

From the comparative result with Frank Bird's method, the sum of $980,000 USD has been calculated, while with the study we have carried out, the sum of $3,856,710.30 has been calculated, being a considerable loss that the insurance does not cover and is assumed by the mining company or mining contractor.

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NOMENCLATURE

$	U.S. dollars
CT	Total cost of accidents
CS	Insured cost
CPi	Average cost of type i accidents
Ai	Number of type i accidents
Ce	Catastrophic losses (explosions, etc)
T_P	Average time lost for assistance
S_m	Average salary
As	Average cost of health care
n	Average number of treatments per accident
TC	Average cost
S_{mi}	Average starting salary
K	Correlation factor (S_m/ S_{mi})
m^3	Cubic meter
Tm	Metric ton
DS	Supreme decree
Un.	Units
UIT	Taxable Tax Unit
mts	Meters