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DEMONSTRATING THE FINANCIAL IMPACT OF MINING INJURIES WITH THE SAFETY PAYS IN MINING WEB APPLICATION

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ABSTRACT

The *Safety Pays in Mining* web application, developed by the National Institute for Occupational Safety and Health (NIOSH) Mining Program, helps mines determine the potential costs associated with mining injuries. This web app groups injuries by type, either by the cause of the injury or by the nature of the injury. When the user selects one of over 30 common types of mining injuries, the app provides information on the distribution of costs of workers' compensation claims for that type of injury. Based on other user inputs, *Safety Pays in Mining* will estimate the total costs of the selected injuries, including an estimate of additional indirect costs, the estimated impact of total injury costs on mining company profits, and provide some examples of other items (services, equipment) on which companies could spend the savings that result from the prevention of injuries. This paper reviews the *Safety Pays in Mining* web application by discussing the development of the app, how it is used to show the true costs of mining injuries, and how mines can benefit from using this app.

INTRODUCTION

Injuries on the job cause pain and suffering. They can also profoundly affect profits and daily operations. In addition to paying direct costs or increased premiums for workers' compensation insurance, a company might need to pay overtime for other workers to fill an injured worker's job role, cover training costs for a replacement worker, or divert administrative resources in the wake of an injury. *Safety Pays in Mining* is a web app that estimates the distribution of these injury costs and assesses the impact that occupational injuries have on a company's profits.

The costs of specific types of occupational injuries in mining are not readily available as mining and insurance companies don't usually share this information. As a consequence, companies only have cost information based on previous experience with their own employees. Therefore, if a mine never experienced a finger amputation for one of its miners, it would not be aware of the possible costs associated with this type of injury. In addition, injury costs are unique in that the cost distribution is so wide — with half of the injuries in our dataset having mean costs higher than 90^{th} percentile costs — just using the average cost of a specific injury type does not provide adequate information. Some injuries involve immensely high costs, and even though the risk of these high-cost injuries occurring is low, mines need to be aware of their potential impact on their company's financial health.

Safety Pays in Mining was designed to enable users to enter their own cost, sales, and profit margin values, or to use the default values based on the mining industry to show impact to profits. The app brings awareness to what specific injuries, such as burns, fractures, dislocations, and sprains, might cost a mine—from $820 for an ankle sprain, $22,500 for a fractured hand, to more than $45,000 for a sprained shoulder. The *Safety Pays in Mining* web application can be found on the NIOSH Mining Website at: https://www.cdc.gov/niosh/mining/content/economics/safetypays.html.

METHODS OF APP DEVELOPMENT

There are four sections in the *Safety Pays in Mining* application, including:

- Most Common Injuries and Work Activities for 2015
- What is the Cost of Occupational Injury?
- What is the Impact of the Cost of Occupational Injury on Your Company
- How Could Your Company Spend the Savings from Preventing Injury?

The methods for developing each of these sections are described next.

Most Common Injuries and Work Activities for 2015

The Mine Safety and Health Administration's (MSHA) accident/injury/illness file for 2015 (NIOSH, 2017a) was used to calculate the most common injury types and to identify the activities miners were performing when injured. This dataset includes all of the injuries reported to MSHA in 2015. The injury data was sorted by commodity and then by: (1) the most frequent *Mine worker activities* during which a miner was injured and (2) common injuries, which is *Part of body* cross-tabulated with *Nature of injury* to identify specific types of injuries.

What is the Cost of Occupational Injury?

Direct cost in *Safety Pays in Mining* is the cost of workers' compensation claims (medical expenses and indemnity payments for wage loss, both paid and reserved) for a specific injury type represented as a mean cost and various percentile costs.

Injury costs are presented by one of two injury classifications, "injury by nature" and "injury by cause." One injury type is "injury by nature," which is based on the Ohio Bureau of Workers' Compensation's (OHBWC) 57 injury diagnosis category descriptions. About a third of the claims included multiple diagnosis categories. In these cases, the category used for the claim was the diagnosis most likely to keep the injured worker off work for the longest period. Claims with multiple diagnoses tend to have higher costs than claims with single diagnoses. Additional injuries were identified from the aforementioned 2015 MSHA injury data and were classified in the OHBWC data by using the Barell Injury Diagnosis Matrix (Barell et al., 2002). Only injury types with more than ten claims were included in the analysis to calculate direct costs.

The other injury type is "injury by cause," which indicates the manner in which the injury was inflicted. NIOSH used the Occupational Injury and Illness Classification System (OIICS) to code the occupational injury incident descriptions included in the claims data, which were provided by the OHBWC. The OIICS v2.01 event and exposure codes were used, and more information can be found on the NIOSH OIICS Code Trees page (NIOSH, 2017b).

The injury cost data is based on the cost of workers' compensation insurance claims in the mining industry (excluding oil and gas) in the OHBWC system for the years 2001 through 2011. Only nonzero cost injury types with more than 10 claims were included in the cost analysis. A total of 4,041 mining claims were included in the analysis. For all injuries, the mean, 25th percentile, 50th percentile (median), and 75th percentile direct costs were calculated. If there were more than 50 cases of a specific injury, the 90th percentile costs were calculated. If there were more than 100 cases, the 95th percentile costs were calculated, and if there were more than 500 cases, the 99th percentile costs were calculated.

All costs are adjusted to 2015 dollars. The most recent total cost evaluations (medical expenses and indemnity payments for wage loss, both paid and reserved) for each claim were used. A time-trend analysis on claims filed from 2001 to 2011 showed that total claim costs are rising at about 5.8% a year. Using this percentage, injury costs were calculated in 2015 dollars. For example, a claim in 2005 that had a total cost evaluation of $1,000 is estimated as having a total cost evaluation of $1,757.34 ($\$1{,}000 * (1.058)^{10}$) if it had occurred in 2015.

Indirect costs usually account for the majority of the true costs of an injury, and these costs may be uninsured and unrecoverable. The indirect costs used in *Safety Pays in Mining* are the costs to the employer beyond those covered by workers' compensation. Indirect cost estimates can include:

- Any benefits paid to injured workers for absences not covered by workers' compensation
- The wage costs related to time lost through work stoppage associated with the worker injury
- The overtime costs of other workers necessitated by the injury
- Administrative time spent by supervisors, safety personnel, and clerical workers after an injury
- Training costs for a replacement worker
- Lost productivity related to work rescheduling, new employee learning curves, and accommodation of injured employees
- Clean-up, repair, and replacement costs of damaged material, machinery, and property
- Increased workers' compensation insurance premiums (Jallon et al., 2011; Sun et al., 2006).

To estimate the indirect costs of injuries, *Safety Pays in Mining* uses an indirect cost multiplier of 2.12 (Huang et al., 2007). The indirect cost is calculated by multiplying the direct cost of an injury and the indirect cost multiplier:

$$\text{Indirect cost} = \text{Direct cost} \times 2.12.$$

Total cost of an injury is the sum of the direct and indirect costs.

What is the Impact of Occupational Injury?

The financial impact of occupational injuries can be calculated by using the total injury cost, profit margin, and annual sales of a company. Profit margin measures how much of a company's sales it keeps as earnings, and in the web app it is calculated as after-tax profit divided by revenue. The profit margin used in *Safety Pays in Mining* can be either a company's actual profit margin (if the user chooses to enter it) or a pre-calculated default value. The default value of 5.5% represents the average of after-tax profits per dollar of sales for all mining commodities for the years 2010 through the second quarter of 2015. The average was calculated using data from the U.S. Census Bureau's Quarterly Financial Reports for Manufacturing, Mining, Trade, and Selected Service Industries (2016a). The default value gives the best estimate for corporations with North American Industry Classification System (NAICS) mining codes and assets of $50 million or more.

Annual sales were averaged using U.S. Census Bureau Enterprise Statistics data for 2011 (2016b) and are shown in Table 1. This is the average yearly sales estimate for the selected commodity for companies with at least 250 employees and at least two establishments.

Table 1. Mining commodities and their associated default annual average sales values.

Commodity	Default Annual Sales
All Mining (except oil and gas)	$32,820,000
Coal	$41,560,000
Metal	$182,750,000
Nonmetal	$12,360,000
Stone, Sand & Gravel	$12,360,000

To calculate the total cost of the injury as a percentage of annual sales, total cost was divided by annual sales. To calculate the additional sales needed for a company to cover the total cost of the injury, total cost was divided by profit margin.

How Could a Company Spend the Savings from Preventing Injury?

Although a mining company might choose any number of ways to spend or reinvest savings from injury prevention, mines could decide to add to their workforce or better outfit their existing workers. Safety Pays in Mining calculates the number of employees a mine could hire for one year, the number of employees a mine could enroll in a hearing loss prevention program for one year, pairs of MSHA-suitable safety boots, and number of MSHA-suitable hard hats a company could purchase if an injury was prevented.

To estimate the number of employees a mine could hire for one year if the injury was prevented, total cost of the injury was divided by total employee compensation and multiplied by the average hours worked per year. Hourly wage data was retrieved from the Bureau of Labor Statistics (BLS) Occupational Employment Statistics, National Industry Specific Occupational Employment and Wage Estimates, which is calculated each May (BLS, 2017a). The default hourly wages were calculated from the five-year (2011 to 2015) average hourly wages for mining (based on NAICS coding) and are shown in Table 2.

Employee compensation includes both the wage amount and any additional benefits a company provides to their workers. Employee benefits might include Social Security, insurance, retirement benefits, paid leave, and overtime pay. The average benefit amount for mining industries (calculated using 2011 to 2015 data) was one-third of the total compensation figure. Therefore, total compensation is equal to hourly wage plus another 50 percent of the wage value in employer-paid benefits. This data was retrieved from the BLS National Compensation Survey (BLS, 2016).

Table 2. Average hourly wages from 2011-2015 for each mining commodity.

Commodity	Default Hourly Wage
All Mining (except oil and gas)	$25
Coal	$26
Metal	$28
Nonmetal	$22
Stone, Sand & Gravel	$22

Data on the average weekly hours worked was retrieved from the BLS Current Employment Statistics program (BLS, 2017b). The average hours worked per week for the mining industry (for the years 2011 to 2015, excluding oil and gas) was 44.5 hours per week. By calculating 50 working weeks per year, the average employee worked 2,225 hours per year.

To calculate how many employees a company could enter in a hearing loss prevention program for one year, total injury cost is divided by the yearly cost of a hearing loss prevention program. The default $375-per-person annual estimate for a hearing loss prevention program is based on averaging estimates, based on a presentation by D. P. Driscoll, The Economics of Noise Control Engineering versus the Hearing Conservation Program, from the 2010 Professional Conference on Industrial Hygiene (PCIH), American Board of Industrial Hygiene, as cited in the OSHA Technical Manual (OSHA, 2017).

To calculate how many employees could be provided with MSHA suitable safety boots, the total cost of the injury is divided by the cost of a pair of MSHA-suitable safety boots. The default price of $175 for MSHA-suitable safety boots was averaged by NIOSH, using 2016 prices from numerous occupational safety and health equipment suppliers and NIOSH purchases from 2015 to 2016.

To calculate how many employees could be provided with MSHA-suitable hard hats, the total cost of the injury is divided by the cost of an MSHA-suitable hard hat. The default price of $60 for MSHA-suitable hard hats was averaged by NIOSH, using 2016 prices from numerous occupational safety and health equipment suppliers and NIOSH purchases from 2015 to 2016.

RESULTS

The results section focuses on the most common injuries for all mining commodities.

Common Injuries and Work Activities for 2015

In 2015, for all mining commodities, handling supplies or materials was the most common activity when an injury occurred, with 1,408 cases, making up 19% of mine worker activities performed when an injury occurred. Table 3 shows that machine maintenance and repair was the second most common activity, occurring in 15% of all injury cases, followed by powered and nonpowered hand tools (13%), walking/running (11%), and getting on/off equipment (6%). These common mine worker activities had the same patterns in metal, nonmetal, and stone, sand & gravel commodities. Coal included the aforementioned activities plus roof bolting, which was the mine worker activity in 9% of all coal injuries (268 injuries) and also included the activity of moving power cable, which occurred in 3% of all coal injuries (91 injuries) in 2015.

The common injuries also had similar patterns for each commodity, and are shown in Table 4. For all mining, hand/finger lacerations were the most common injury, making up 11% of all injuries in 2015, followed by back sprains/strains (10%), hand/finger fractures (6%), shoulder sprains/strains (5%), and knee sprains/strains (5%). In addition to the injuries shown in Table 4, coal also had black lung as a top illness, with 204 cases (7% of all reported coal injuries/illnesses). The metal, nonmetal, stone, sand& gravel commodities also had eye injuries show up in the top injuries, making up about 7% of all injuries in those respective commodities.

Table 3. The most common mine worker activities performed when injuries occurred in 2015, for all mining commodities.

Mine Worker Activity	Percentage of All Injuries	Count
Handling supplies or materials	19%	1,408
Machine maintenance and repair	15%	1,067
Hand tools (powered and nonpowered)	13%	945
Walking/running	11%	774
Getting on/off equipment	6%	444

Table 4. The most common injuries in 2015 for all mining commodities.

Common Injuries	Percentage of All Injuries	Count
Hand/finger lacerations	11%	818
Back sprains/strains	10%	729
Hand/finger fractures	6%	421
Shoulder sprains/strains	5%	387
Knee sprains/strains	5%	385

What is the Cost of Occupational Injury?

The direct costs in *Safety Pays in Mining* are shown in percentiles. Table 5 shows the common injuries for all mining in 2015 and their direct cost percentiles. Looking at the difference between the 25th and 95th percentiles helps illustrate the wide distribution of the injury costs. Percentile is the percentage of injuries with equal or lower cost. For a given injury, a direct cost in the 75th percentile would mean that injury costs as much or lower than 75% of the same type of injury cases, and therefore 25% of that injury type's costs would be higher. Using hand and finger fractures as an example, the direct cost in the 75th percentile is $9,000. This means that for all mining hand and finger fractures, the direct cost is likely to be $9,000 or less 75% of the time.

Within this OHBWC mining injury cost dataset, the mean was always higher than the 75th percentile, and for about half of the injuries, the mean was higher than the 90th percentile. The mean would generally overestimate injury costs, as the mean alone does not fully represent a distribution of costs. Variability and skewness must also be taken into account. Showing percentiles of the direct costs helps show the distribution of this injury cost data.

There are two main reasons why a mine might want to use different percentiles rather than the 50th percentile, or median, which is usually the most familiar. The median provides a good estimate for a single "typical" claim, because half of the claims have higher costs and half of them have lower costs. One reason to select a cost higher than the median is related to the total number of claims that are expected. If you are expecting more than one claim, the chance of having a very expensive claim increases. As a result, if expecting two to ten claims, using the 75th percentile for each claim will lead to a better estimate for total costs. When the number of claims exceeds fifteen, the 90th percentile for each claim provides a better estimate.

Another reason to select a cost higher than the median is concern about the risk of having a high-cost claim that costs much more than the typical claim. There is substantial risk that claims will cost much more than the "typical" claim, as illustrated by the cost of claims at the 90th percentile and above. Even if you have a single claim, there is a 10% chance that your claim will exceed the 90th percentile cost. Table 5 helps explain why different percentiles are used. For shoulder sprains/strains, the median (50th percentile) cost is $2,300 but the mean is $20,600, which is much too high an estimate for a typical injury.

Table 5. Percentiles of direct costs for the most common mining injuries in 2015.

Common Injuries	25th	50th Median	75th	90th	95th	Mean
Hand/finger lacerations	$600	$910	$1,300	$2,400	$3,400	$2,300
Back sprains/ strains	$540	$1,400	$5,200	$16,300	$31,800	$8,700
Hand/finger fractures	$990	$1,900	$9,000	$22,500	$42,700	$10,400
Shoulder sprains/ strains	$600	$2,300	$15,400	$45,200	$78,400	$20,600
Knee sprains/ strains	$620	$1,100	$3,400	$14,100	$32,900	$6,400

When the indirect cost is taken into account, the total cost of injury can be quite surprising. Table 6 shows the common mining injuries, their 75th percentile direct cost, the calculated indirect cost, and the total cost, which is the sum of direct and indirect costs. The total cost gives a good estimate of what the true cost of the specific injury can be to a company. A hand or finger fracture with a direct cost of $9,000 is actually going to cost a company about $28,000.

Table 6. Most common mining injuries and their associated 75th percentile direct costs, indirect costs, and total costs.

Common Injuries	75th Percentile Direct Cost	Indirect Cost	Total Cost
Hand/finger lacerations	$1,300	$2,756	$4,056
Back sprains/strains	$5,200	$11,024	$16,224
Hand/finger fractures	$9,000	$19,080	$28,080
Shoulder sprains/strains	$15,400	$32,648	$48,048
Knee sprains/strains	$3,400	$7,208	$10,608
Total	**$34,300**	**$72,716**	**$107,016**

What is the Impact of Occupational Injury?

Using the total costs of the selected injuries from Table 6, the impact to a company's profits can be calculated. Table 7 displays the common mining injuries along with their total cost, total cost as a percentage of annual sales, and most importantly, the additional sales needed to pay for the total cost of that specific injury. The example in Table 7 is for a mine with $10 million in annual sales and a 5.5% profit margin. To cover the cost of a hand and finger fracture with a direct cost in the 75th percentile, a company would need to have additional sales of $510,545. One of each of the top five common injuries could cost a company over $100,000 and take nearly $2 million in additional sales to recoup those injury costs.

How Can a Company Spend Savings from Preventing Injury?

To put these costs in different terms, one could think of ways a company could spend money if an injury is prevented. Table 8 displays the common mining injuries and uses the total costs shown in Table 7 to give examples of what a company could spend money on if an injury was prevented. If a hand or finger fracture was prevented, instead of paying the costs associated with that injury, a company could enroll 75 employees in a hearing loss prevention program for one year, or purchase 160 pairs of safety boots, or purchase 468 hard hats. If a company prevented all five injuries, they could hire an additional employee for one year.

Table 7. Most common mining injuries from 2015, their estimated total costs, the total cost as a percentage of $10 million in annual sales, and the additional sales needed to pay for the injury cost with a 5.5% profit margin.

Common Injuries	Total Cost	Total Cost as Percentage of Annual Sales	Additional Sales Needed to Pay for Injury Cost
Hand/finger lacerations	$4,056	0.041%	$73,745
Back sprains/ strains	$16,224	0.162%	$294,982
Hand/finger fractures	$28,080	0.281%	$510,545
Shoulder sprains/ strains	$48,048	0.480%	$873,600
Knee sprains/ strains	$10,608	0.106%	$192,873
Total	**$107,016**	**1.070%**	**$1,945,745**

Table 8. Most common mining injuries and examples of how savings from preventing injuries could be spent by a company.

Common Injuries	Additional employees company could employ for one year	Employees that could enroll in hearing loss prevention program	Pairs of MSHA suitable safety boots	Number of MSHA suitable hard hats
Hand/finger lacerations	0	10	23	67
Back sprains/ strains	0	43	92	270
Hand/finger fractures	0	74	160	468
Shoulder sprains/ strains	0	128	274	800
Knee sprains/ strains	0	28	60	176
All Injuries	**1**	**285**	**611**	**1,783**

DISCUSSION

Listing the most common injuries and the worker activities performed during injuries by commodity can help mines identify which possible hazardous activities and injuries are occurring in similar mining commodities. A metal mine might not have had an eye injury in the past, but it is helpful to be aware that eye injuries are the third most common injury in that industry. If they are occurring at other metal mines, they could occur at any metal mine.

The direct costs data really shows how the costs of specific injuries are widely distributed. With the mean higher than the 75th percentile for every injury and higher than the 90th percentile for half of the injuries, this shows that every injury has a few cases of extremely high costs. Generally, costs will be between the first and third quartiles, but it is important to be aware that there are those high-cost cases.

Allowing the web app user to choose direct cost percentile based on number of injuries or their own risk profile allows users to explore the various costs per injury and how these costs can impact the financial success of a company.

Safety Pays in Mining is intended for mine managers, safety managers, consultants, researchers, government agencies, and students—or anyone who is interested in the costs of specific injuries in the mining industry. Mines can benefit the most from *Safety Pays in Mining*, as it can help mines prioritize safety and health interventions and focus on areas for improvement. Mines may want to focus on eliminating the higher-cost injuries first. By showing the additional sales needed to cover the injury cost and providing examples of how money could be spent instead of paying for an injury, the web app presents the same information in different terms, which can be useful for safety managers who do not have experience dealing with financial aspects of the industry. They can also use the web application to assist with cost-benefit analysis for safety budget allocations to help justify purchasing personal protective equipment (PPE), enrolling in safety programs, or obtaining engineering controls to reduce exposure to injury.

LIMITATIONS

The main limitation of this web app is that workers' compensation claims data is from only one state, Ohio. Even with ten years of workers' compensation cost data with over 4,000 mining claims, the costs from Ohio may be different than costs from other states.

To mitigate this limitation, NIOSH is working to acquire workers' compensation claims data from additional states. The National Council on Compensation Insurance (NCCI) is a rating bureau that collects data, analyzes trends, and provides insurance rate recommendations for thirty-five states. NIOSH is working with NCCI to obtain mining-related workers' compensation claims data, which can improve the accuracy and generalizability of *Safety Pays in Mining*.

Another limitation is the estimate of indirect costs, by using the indirect cost ratio. There is not a universally accepted method for estimating indirect cost ratios (Manuele, 2011). The survey study by Huang, et al., (2007) focused on large manufacturing, healthcare, and finance/insurance industries, which are markedly different than mining; the mining industry tends to have fewer available skilled workers and employ fewer workers per location, with many mines employing five or fewer miners. The indirect cost ratio of 2.12 may underestimate indirect costs in the mining industry.

Also, direct costs are paid by those companies who self-insure. Companies who purchase workers' compensation insurance would have these direct costs paid by the insurance company. However, the cost impact for mines with workers' compensation insurance would largely be through increased premiums and even eligibility to participate in group policies.

Finally, it should not be assumed that all injuries result in workers' compensation claims. Many injuries are unreported. These injuries can result in costs for employers as well, although there is some evidence that the unreported injuries tend to be less severe. Unreported injuries can still result in reduced productivity, absenteeism, sick days, and group medical costs (Leigh, et al., 2004; Ruser, 2008; Boden and Ozonoff, 2008).

CONCLUSION

The *Safety Pays in Mining* web application can be used to estimate the total costs of common mining injuries to a mine. This web app can raise awareness of these costs and the distribution of direct costs for each injury. The app can also educate users on the wide range of occupational injury costs. For specific injuries, mine management will find it useful to see the distribution of workers' compensation costs as well as the indirect costs, which are often overlooked. The web app demonstrates that even a common injury has the potential to be extremely expensive. *Safety Pays in Mining* can be used to help mines prioritize health and safety interventions.

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DISCLAIMER

The findings and conclusions are those of the authors and do not necessarily represent the views of the National Institute for

Occupational Safety and Health (NIOSH). Any mention of company name, product, or software does not constitute endorsement by NIOSH.

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