Out of the Box Approach to Mine Safety

Focus on construction, maintenance & repair activities

By Kathleen M. Kowalski and Lynn L. Rethi

AFOR YEARS, SH&E PROFESSIONALS have been devising ways to identify and mitigate hazards, and evaluate the success of those interventions. Within his/her specific industry, each has worked to reduce injuries. SH&E professionals have studied the environment, job protocols, scheduling, specific injuries and incentives; they have recommended engineering controls, PPE, administrative controls, various safety programs and employee safety training. As the old saying goes, could we be barking up the wrong tree? In retrospect, it might appear that some safety programs have mirrored the "flavor of the month" or the "management style of the year." However, the focus has always been on improving the safety performance of the individual, the organization and the industry.

What if we are looking at the trees and missing the forest? Perhaps the circumstances surrounding injuries can be evaluated in another way—one that can guide recommendations and development of interventions. What if SH&E professionals can take this analysis "out of the box"? Using the mining industry as an example, safety efforts have traditionally focused on extraction and production activities. Viewing historical injury data from the 1990s within a broader paradigm, this article focuses not on specific injuries linked to extraction and production of minerals, but rather on mining injuries occurring within the context of worker construction, maintenance and repair activities. Broad implications for safety are also considered.

Brief History of Danger in Mining

Mining is one of the world's most dangerous occupations. From the early days of mining, the removal of materials from the earth has resulted in significant human losses. From 1880 to 1910, mine explosions and other accidents claimed thousands of lives. The deadliest year in U.S. coal mining history was 1907, when 3,242 deaths occurred. Public concern over the deaths, injuries and destruction caused by mine accidents led Congress to form the Bureau of Mines in 1910 (MSHA "Mining Disasters").

At the beginning of the 20th century, the average number of deaths per year was near 1,500. This total decreased throughout the century, arriving at an average of less than 100 during the 1990s. There were 85 mining fatalities in 2000 (MSHA). Presently, the U.S. mining community employs approximately 380,000 people. The commodities included are coal, metal/nonmetal, stone, and sand and gravel. Mining, along with agriculture, construction and transportation, continues to rank among the most dangerous of industries in which to work (Figure 1) (MSHA "Mining Disasters"). After the initial establishment of the Bureau of Mines, injuries and fatalities dramatically declined as researchers learned about fires and explosions, developed new technologies, created innovative protective equipment and implemented new methods of ground control (Figure 2). More recently, rates have leveled and SH&E professionals are devising interventions to further reduce injury.

Mining Safety Regulations Focus on Production

The U.S. mining industry is highly regulated by Title 30 CFR. Safety training and inspections are also mandated and enforced by MSHA. In addition, NIOSH has a research division devoted to the safety and health of the nation's miners (the former Bureau of Mines).

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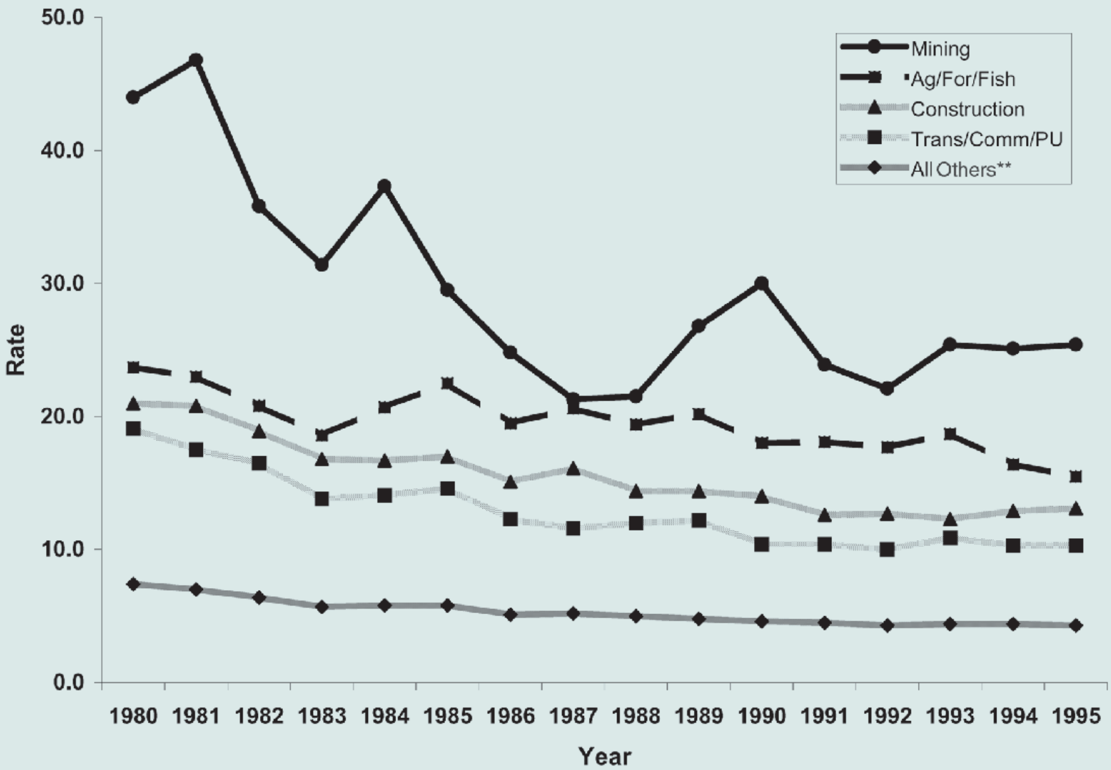
Figure 1

Occupational Injury Death Rates* by Industry Division & Year: U.S., 1980-1995



**Per 100,000 workers.*

***Includes public administration, manufacturing, wholesale trade, retail trade, services and finance/insurance/real estate.*

Source: CDC.

These federal agencies are dedicated to reducing and eliminating fatalities and injuries in the mining industry. In recent years, a principal focus has been on developing safety programs in the area of production—the extraction of the mineral—and in further developing and enhancing equipment engineering controls, PPE and, more recently, safety training. Yet, the industry's injury and fatality rates have "flatlined" for the past several years, which has increased concern and the need for new approaches.

Increased Focus on Miner Activity

Of late, informal attention has turned to observing *the activity the miner was engaged in* at the time of the accident. In many ways, this is a departure from the traditional manner in which data were analyzed. Many SH&E professionals evaluate injury data using the typical categories such as the classifications of job title, type of injury, level of experience, training and similar comparisons. This approach can be helpful in identifying specific facts on which to base interventions. However, by looking at the historical injury data within a broader paradigm, it may be possible to develop more-focused intervention strategies.

With the cooperation of a major U.S. stone company, whose safety director drew attention to the issue (Seago), NIOSH conducted a study to evaluate and catagorize specific activities the miner was engaged in at the time of injury; this was achieved using the narratives of MSHA data on the cooperating company. The goal was to identify, evaluate and compare the frequency of injuries that occurred during production activities to those that occurred during other activities, such as construction, maintenance and repair (CMR).

This in-house study utilized 605 narratives from the firm's accidents over a three-year period (1994 to 1996). Narratives were categorized as 1) "CMR activities" or 2) "other"—not CMR activities. Results indicated that 64 percent of injuries occurred during construction, maintenance or repair activities, while 36 percent occurred during extraction or production activities. A follow-up inter-rater reliability analysis among the four raters showed 94-percent agreement.

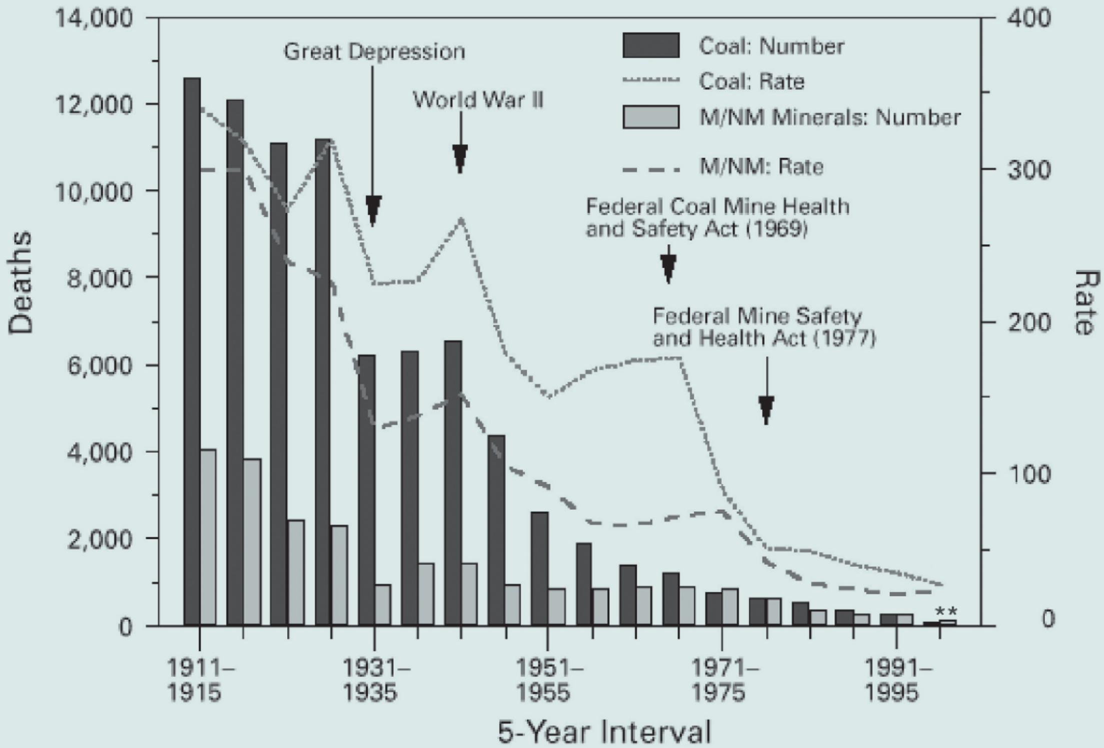
These results prompted many questions. During the 1990s, the industry focused its engineering interventions and safety training on activities related to production, which, according to the data, represented only 36 percent of the activities being conducted at the time of injury. In addition, questions were raised about whether these results were relevant only to this specific company and only to the stone industry. What about other mining commodities and locations? What about independent contractor activities? Answers to these questions will be addressed in the following sections.

Formal Study—Mining Commodities

Stone is one of five classifications of mining commodities, the others being coal, metal, nonmetal, and sand and gravel. Under a service contract with a national research organization, a second study was

Figure 2

Number of Deaths & Fatality Rates* in Mining Coal & Metal/Nonmetallic (M/NM) Minerals, by Five-Year Interval: U.S., 1911-1997



**Per 100,000 workers.*
***Data are for 1996 and 1997.*

Source: CDC.

designed to evaluate these mining commodities and to include a separate evaluation of contractor injuries (Lehman and Layne). In addition, location—underground, surface or mill/prep plant—was included in the data.

Modeled on the original NIOSH study, this study had three activity evaluation categories. Each of the incident reports was assessed and placed in one of the following evaluation categories:

1) CMR;
2) not CMR;
3) to be reviewed.

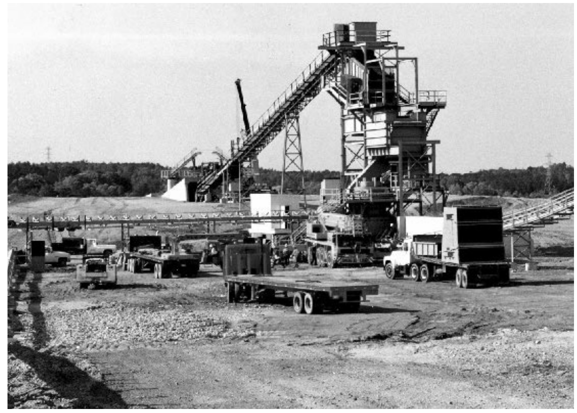
In the case of category 3 events, the activity being performed at the time of the accident was judged to be too unclear to be placed in category 1 or 2. A total of 166 cases were coded as category 3. Mining safety professionals reviewed the narratives in this category. Only one of these cases was subsequently coded by these expert reviewers as category 1 (a positive CMR case).

Study Objectives & Methods

MSHA compiles a database known as the Mine, Accident, Injury and Illness Database (n = 104,108). The primary objective of this study was to review narrative descriptions from a sample of nonfatal injury incidents (n = 21,024) contained in the MSHA data file to determine whether the injury incident could be characterized as one that involved a CMR activity during the period 1993 through 1997. (See Figure 3 on pg. 25 for examples of narratives.) Specifically, the goal was to evaluate the injury reports by classifying an event as attributable to CMR or to an "other activity."

A secondary objective was to determine the basic weighted frequency distributions of CMR-related cases, comparing mine operator employees and contractor employees by primary commodity mined, and by locations within each commodity. Independent contractor employees continue to supplement the permanent workforce and their injury rates tend to be higher, which influences the industry incident rate (NIOSH "Worker Health" 164).

Most previous mining injury evaluations have primarily related to job classification, body part, lost time, location at the mine and other specific categories. Work activity was one of these categories, but it was defined within such a narrow context and in such detail that the overall picture was lost. For example, included among the most frequent activities at the time of injury were "hand tools (not powered)," "materials handling," "walking/running," "maintenance and repair (electrical)," "move power cable" and "getting on and off equipment." These categories specify a task, but do not necessarily paint an overall picture of what the victim was actually doing at the time of injury. For example, "hand tool—electrical" does not specify what the victim was doing at the time of injury, nor how the tool was being used. Thinking out of the box demanded the full picture, which appeared to be the broad category of CMR activities. At this point, it became necessary to clearly define what was meant by these activities.



Construction, Maintenance & Repair

Construction work activities involve the building, rebuilding, alteration or demolition of any facility or addition to existing facility at a surface mine, surface area of an underground mine or underground mine.

These activities would include tasks such as painting, decoration or restoration associated with those facilities or with the land connected to those facilities at the mines.

It excludes any tasks involved in shaft and slope sinking or work performed on the surface incidental to shaft or slope sinking. Examples of construction activities would include the building of stoppings that control the airflow in the mines or the building or destruction of offices or shops at the surface of a mine.

Maintenance and repair work activities are tasks associated with the construction, installation, setting up, adjusting, inspecting, modifying, or maintaining any servicing machines or equipment. These activities may include: lubricating, cleaning or unjamming of machines or equipment, making adjustments or tool changes to any equipment or machines used in the mining process.

The researchers adopted a definition of CMR activities that had been written for the previous in-house study by SH&E professionals representing industry and several government agencies. By this definition, construction work activities involve the building, rebuilding, alteration or demolition of any facility or addition to existing facility at a surface mine, surface area of an underground mine or underground mine. These activities include tasks such as painting, decoration or restoration associated with those facilities, or with the land connected to those facilities. However, the definition excludes any tasks involved in shaft and slope sinking, or work performed on the surface incidental to shaft or slope sinking. Examples of construction activities include the building of stoppings that control the airflow in the mines or the building or destruction of offices or shops at the surface of a mine (Photos 1 and 2, above, top).

Maintenance and repair work activities include tasks associated with the construction, installation, setup, adjustment, inspection, modification or service of machines or equipment. These activities may include: lubricating, cleaning or unjamming machines or equipment, and making adjustments or tool changes to any equipment or machines used in the mining process (Photo 3; left, bottom).

Other key words that assisted the researchers in classifying an event as CMR included welding, grinding, cutting, leveling, examining, splicing, booting, greasing, resetting, sewing, replacing, working on, digging and checking. Certain types of equipment and materials were also typically considered to be indicators of a CMR event. These included track, drive or take-up rollers, tail piece, head, stopping, gunnite, overcast and undercast. Any activity that employed mobile or fixed cranes (also called overhead hoist or chain hoist), or involved getting in and out of those cranes was considered a CMR activity.

Results

A total of 21,024 narratives were classified in the three activity categories: CMR; not CMR; and to be reviewed. Table 1 shows the frequency distribution tables for the observed number of injuries related to CMR activities for mine operator employees and contractor employees by major commodity group in the sample dataset. It is interesting to note that the CMR-related activities for operators and contractors were virtually the same. Thirty-nine percent of all injuries were attributed to CMR activities for both operators and contractors. Minor differences between the two groups were found relating to the commodity in which the injury occurred. The number of operator employee CMR injuries was highest in the coal, and sand and gravel commodities. Contractor employee CMR injuries were highest in coal and metal, while lowest in sand and gravel.

Based on the sample of injuries studied, estimates were extrapolated for the entire population of 104,108 injuries to provide estimates of CMR-related injuries over the five-year period. These estimates show that among all operators, 36,772 injury incidents involved CMR activities. Coal operator employee incidents were estimated at 14,019 and sand and gravel at 4,240. Among all contractors, an estimated 2,872 injury incidents involved CMR activities. Coal contractor employee injuries were estimated at 1,253 and metal was 877 (Table 2). Thus, a substantial number of injuries—39,644—were attributed to CMR activities, which demonstrates the need for further attention to this issue.

CMR activity injuries were most frequent at surface locations for both operator and contractor employees, followed by mill/prep plant. Forty-three percent of operator employee CMR activity injuries and 35.6 percent of contractor employee CMR activity injuries were related to work located on the surface. The degree of injury with respect to the CMR-related activities shows that the average number of days lost per injury is 26 for operators and 25 for contractors (Table 3). The average number of days lost to all other activities, for both operators and contractors, is 29.5 (Table 3).

Significance & Implications

Clearly, this study documents the significance of CMR-related activities to mining industry injuries. The data indicate that the CMR-related activities account for 39 percent of injuries for both operators and contractors, and such activities play a major role in lost days. Injuries due to CMR-related activities are found in all commodities and locations in the mining industry.

What could this mean for safety intervention, hazard recognition training, inspections, contractors and overall safety planning for the workplace? In an industry that has focused its safety programs and interventions on engineering controls, ground control and production activities, these findings have significant implications. By analyzing these same data from a new perspective, new directions in intervention and safety training become possible. Although miners must be trained in accordance with MSHA Part 48 and Part 46 requirements (subparts of 30 CFR that detail training requirements for underground and surface coal and noncoal employees), they are unlikely to receive additional instruction on safe work practices used in the general construction industry and applicable to mining construction. In addition, evaluating the present data from an enforcement perspective could bring a new focus to improved safety. In fact, MSHA has recently become proactive in this area. Education and training that details safe work practices and parallels specific training developed for the general construction industry would benefit the mining industry.

Training Application to Out of the Box Data

Once the SH&E practitioner has an accurate evaluation of the factors that contribute to an incident, s/he is better equipped to address the problem. Using an out-of-the-box approach to analyze the data in any industry can reveal new ways to document trends occurring within the injury history. In this mining application, once researchers determined that a high percentage of injuries occurred during CMR-related activities, a training intervention was developed to specifically target at-risk employees in the mining industry.

Table 1

Frequency Distribution: Sample Dataset

Frequency distribution table for a mine accident, injury and illness database sample dataset (n = 21,024). Observed number of injuries related to construction, maintenance and repair activities for mine operators and contractors by major commodity group in sample dataset (n = 21,024).

Operators & Contractors by Major Commodity	CMR-Related Activities		All Other Activities	
	Number	*Percent*	*Number*	*Percent*
Operators	**5,336**	**39.0**	**8,338**	**61.0**
Coal	1,778	37.1	3,015	62.9
Metal	985	37.4	1,652	62.6
Nonmetal	714	36.6	1,238	63.4
Stone	849	39.6	1,297	60.4
Sand & Gravel	1,010	47.0	1,136	53.0
Contractors	**2,872**	**39.1**	**4,478**	**60.9**
Coal	1,253	37.6	2,080	62.4
Metal	877	40.2	1,304	59.8
Nonmetal	192	37.2	324	62.8
Stone	501	41.2	714	58.8
Sand & Gravel	49	46.7	56	53.3

Figure 3

Sample "CMR" Narratives

- Injured was welding on the shear drum at face of the 16e mn longwall section; a piece of roof coal fell from top, striking injured on right shoulder, neck and right hand.
- The EE was using a pry bar to unwedge a board from the D.A. Ram. He cut his right palm. He went to the emergency room after his shift. The cut required four stitches.
- Moving a track rail with a bar. Rail slipped causing bar to fly out of his hands and the bar struck him on the right cheek. Laceration and fracture to right cheek.
- Injured stated he was helping coworker make a belt splice in #3 entry on the belt line. His knife slipped and hit the inside of his left leg above the knee, causing a laceration to his left leg.
- EE was jacking the track jeep back onto the track when the bar for the jack slipped from the jack causing the EE to fall catching his fingers between the bar and the track rail, thus fracturing his left middle finger and ring finger. Actual cause of the injury was probably due to being in a hurry; no rules or regulations broken.
- Shoveling on belt line bottom; belt caught shovel carrying back through tailpiece between bottom and bottom belt. Shovel blade was sticking out from under tailpiece guard. Started to reach for shovel; splice came through and knocked shovel blade into right cheek.
- Employee was working around #2 belt head drive repairing broken belt. Belt head drive was energized thus pulling employee into power rollers resulting in employee's fatal injuries.

Table 2

Frequency Distribution: Estimated Injuries

Extrapolated estimates for all injuries 1993 to 1997 (n = 104,108). Tables for the Mine Accident, Injury and Illness Database extrapolated number of injuries related to construction, maintenance and repair activities for mine operators and contractors by major commodity group (n = 104,108).

Operators & Contractors by Major Commodity	CMR-Related Activities Number	CMR-Related Activities Percent	All Other Activities Number	All Other Activities Percent
Operators	**36,772**	**38.0**	**59,986**	**62.0**
Coal	14,019	31.1	31,034	68.9
Metal	5,197	40.0	7,787	60.0
Nonmetal	2,467	37.9	4,040	62.1
Stone	10,849	46.0	12,737	54.0
Sand & Gravel	4,240	49.1	4,389	50.9
Contractors	**2,872**	**39.1**	**4,478**	**60.9**
Coal	1,253	37.6	2,080	62.4
Metal	877	40.2	1,304	59.8
Nonmetal	192	37.2	324	62.8
Stone	501	41.2	714	58.8
Sand & Gravel	49	46.7	56	53.3

Note: This table contains the estimated number of injuries related to construction, maintenance and repair activities for mine operators and contractors by major commodity and the type of operation. Percent of injuries for each type of operation is given as a function of the major commodities. Percent of injuries in each major commodity is given as a function of either all operator or contractor injuries.

The *Hazard Recognition Training Program for Construction, Maintenance and Repair Activities* (Rethi, et al) consists of an 80-pg. teaching document and a set of three 3D slide reels. The 20 slides on these reels depict various CMR activities at noncoal surface mining operations. They provide visual references for the class and stimulate discussions as trainees focus on the hazards of the CMR activity depicted.

Use of 3D & Degraded Images

The concept of degraded images is incorporated into the 3D slides. Originally observed by the military and used for target detection training, degraded images are scenes where hazards are partially hidden from view; observed from an eccentric angle; viewed through haze or dust; inadequately illuminated; or otherwise obstructed so as to camouflage the target. Bureau of Mines research has shown that miners who were trained with less-than-ideal (or degraded) visuals were more successful in subsequent identification of hazards than those trained using ideal (or highlighted) pictures of hazards (Kowalski, et al).

In earlier studies, both instructional aids—3D slides and degraded images—have been shown to train miners to recognize and respond to hazards effectively (Barrett, et al). The former Bureau of Mines reported that 3D slides were effective for teaching miners to recognize various geologic and mining-induced irregularities that may cause ground failures. Such slides serve as an excellent proxy for training miners to recognize cues that distinguish various types of hazards.

The CMR Training Program

The instructor's manual for the training program includes comprehensive information for the instructor plus instructional overheads and handout masters, pre- and post-test (with answer key) and a student handout that summarizes safe work practices. The training program was field tested in order to determine its effectiveness using a 20-question true/false pre- and post-test. In a pretest, the mean score among all subjects (n = 340) was 14.49 correct answers; standard deviation was 2.57. In the post-test, the mean score among all subjects was 16.01 correct answers; standard deviation was 2.28. Seventy-one percent of the subjects (241 of 340) showed improvement in their post-test scores following the training intervention. Among these students, the mean post-test score was 16.47 correct answers; standard deviation was 2.13.

The training program, based on the out-of-the-box injury data analysis, was completed in December 1999. Since then, NIOSH has distributed more than 4,500 copies throughout the U.S. and in 18 foreign countries.

New Safety Directions—A Different Box?

For any firm or industry wanting to improve its safety performance, looking at the data in a different way and regrouping the information can lead to discoveries that may point the way to a reduction in injury statistics. By exploring existing data associated with injuries and lost-time incidents from a different perspective, SH&E practitioners may open new intervention avenues. This approach does not preclude the use of traditional evaluation techniques, but encourages SH&E professionals to step back and examine the data from different views. Even organizations with better-than-average incident rates can improve their performance by examining their injury data differently, then employing interventions specific to the trends identified. New engineering and administrative controls may be identified as well.

Conclusion

Traditionally, mining injury data are categorized into specific subgroups such as job classification,

Table 3

Frequency Distribution: Degree of Injury

Extrapolated number of nonfatal injuries related to construction, maintenance and repair for mine operators and contractors by degree of injury (n = 95,958).

Degree of Injury by Operators & Contractors	CMR-Related Activities Number of Injuries	CMR-Related Activities Average Days Lost	All Other Activities Number of Injuries	All Other Activities Average Days Lost
Operators	**34,408**	**26**	**54,828**	**31**
(2) Permanent disability	511	24	574	39
(3) Days away from work only	12,626	27	28,697	34
(4) Days away and restricted activity	1,753	26	3,481	28
(5) Days of restricted activity only	3,675	-	6,144	-
(6) Injuries without disability, days away or restricted activity	15,843	-	15,932	-
Contractors	**2,681**	**25**	**4,041**	**28**
(2) Permanent disability	51	21	68	26
(3) Days away from work only	1,064	26	2,014	29
(4) Days away and restricted activity	134	18	288	18
(5) Days of restricted activity only	230	-	412	-
(6) Injuries without disability, days away or restricted activity	1,202	-	1,259	-

For any firm or industry wanting to improve its safety performance, looking at the data in a different way and regrouping the information can lead to discoveries that may point the way to a reduction in injury statistics.

injury classification, body part, location at mine site and work activity. In the studies using the mining industry as an example, regrouping tightly defined activities into the more general category of construction, maintenance and repair has provided an opportunity for innovative avenues to be explored to further enhance the goal of injury reduction. Thinking out of the box or creating a new box using the same materials helped to energize and focus new programs and, thus, improved safety. This broader data analysis perspective and resulting training intervention is applicable to other industries as well. ■

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