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Learning from Workers' Near-miss Reports to Improve Organizational Management

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Abstract

Near misses recorded and reported by workers can provide awareness to the potential causes of injury and prompt safety management initiatives. Although most companies require near-miss reporting, it is unclear what the value of these reports are, if any, and how they influence subsequent actions or controls to reduce on-the-job risks. Researchers at the National Institute for Occupational Safety and Health (NIOSH) conducted a case study with an aggregates company in which near-miss reports were analyzed at each of their locations over an entire quarter during the summer of 2018. Within that quarter, workers recorded 249 near misses. Of those, 167 were valid near misses that occurred at work. Researchers coded the reports using a qualitative 5 × 5 risk matrix. Of the 167 near misses, 19% were deemed low risk, 25% moderate risk, 30% high risk, and 26% critical risk. Several patterns in the near-miss incidents were documented, including classification of incidents and common corrective actions referenced (i.e., elimination/substitution, engineering control or redesign, work process/procedures, and personal protective equipment). The analysis provides insight into ways that risk communication and management programs can be improved to reengage workers and their situational awareness on the job.

Keywords

Health and safety management system; Hierarchy of controls; Near-miss incident; Qualitative risk matrix; Risk assessment

1 Introduction

Identifying job hazards and managing risks is a multilevel concern for organizations [1]. To help identify and mitigate such risks, most companies possess some type of health and safety management system (HSMS) that promotes regular safety audits, documentation of near-miss incidents, and analyses of work procedures and processes [2, 3]. Specifically, near-miss

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incidents, regardless of their minor or major consequences, have been touted as a critical metric of an HSMS as well as “free lessons for safety management” and knowledge production [4, p., 1]. Although many companies have and promote this reporting, the collective analysis of near misses and how these reports have informed corrective actions and prevented future incidents has not been studied in-depth in the mining industry. To that end, this study collected and analyzed 167 near-miss reports of an aggregates mine company using a common 5 × 5 risk assessment (RA) matrix. The analysis identified relationships between the risk type and corrective action for each near miss, prompting critical, usable feedback in improving risk communication and engagement through enhanced health and safety (H&S) management practices. This paper starts with a review of near-miss incidents, risk assessments, and how the two efforts can overlap with each other to build knowledge around hazard recognition and risk mitigation. Then, details of the study are provided followed by the results and implications for improving near-miss management in the mining industry.

2 Literature Review on Near-miss Incidents as a Leading Indicator

The mining industry, regardless of sector, is considered a high-hazard work environment that presents ongoing, changing risks. To help prevent and manage ongoing risks, most companies adhere to some type of safety management system and have near-miss management programs [5]. Within the US mining industry, regulatory oversight from the Mine Safety and Health Administration (MSHA) requires near-miss reporting on a quarterly basis. These include, for example, poor housekeeping that may result in slip, trip, and fall hazards; unexpected explosions; inadequate personal protective equipment (PPE); and failures of hoisting equipment. Another industry report [6] also provides examples of damaged equipment, spills and other housekeeping, and any unusual work conditions. If there are near misses reported from which the entire industry can learn, MSHA may publish a near-miss alert along with best practices to prevent the event from turning into a recordable incident.

Due to the changing nature of mining environments, it is likely that numerous near misses occur each workday, even if they are not always recorded. According to the National Safety Council [7], a *near miss* is an “unplanned event that did not result in injury, illness, or damage – but had the potential to do so.” Similarly, OSHA indicates that a near miss is an incident that could have caused a serious negative outcome but did not. If debriefed effectively, learning from near misses can improve safety within the organization and enhance organizational productivity—all without experiencing an actual incident [8, 9]. For example, recognizing the fundamental cause of a near miss, learning what went wrong, and responding to a near miss are critical tasks of both workers and the organization [10, 11].

However, corporate management must demonstrate a commitment to safety through its risk management process, which includes support to notice and identify a near miss followed by swift corrective actions to avoid future risks [12]. Research has long argued that small-scale near misses have the potential to cause more serious events in the future [13] while recent research continues to show a statistical case that near misses often precede loss-producing incidents [14]. Other work has argued that for every injury reported there are between 10 and

100 near-miss incidents associated with it [6]. Thus, near-miss reporting represents a critical metric and learning component to any safety management system. In this sense, near misses can be considered and treated as a critical learning metric and leading indicator in a safety management system [15, 16].

2.1 Assessing the Risks of Near-miss Incidents and Responding Appropriately

Although safety literature supports the need to analyze near misses to improve safety, another layer of any analysis is the consideration of workers' individual factors when assessing the likelihood of such occurrences. For example, research has demonstrated that if near misses are not adequately assessed or discussed, it can lead to riskier behavior due to lower perceived risk or believing that the original perceived risk was over-estimated [17]. In response, organizations must tailor their safety management system to provide workers with resources to understand personal risks and empower them with the decision-making autonomy necessary to carry out protective actions on the job. Advanced methodologies to technically investigate the content of near-miss reports in high-hazard industries are currently underdeveloped [18]. However, research has called for near-miss incidents to be risk ranked to their consequences and probability of occurrence to gather knowledge and assess information around specific H&S hazards [19, 20]. Based on the probability of a negative event occurring, such assessments can help determine whether the level of risk is acceptable to the organization [21, 22]. If initiated and completed consistently, RAs allow root causes of accidents and even patterns to emerge that can guide proactive decision-making [23]. See Fig. 1 for an example of a risk matrix.

If RAs are completed in tandem with near misses, this may help reveal to organizations areas that should be further investigated [19]. However, one gap in RAs being used more frequently and consistently is that, while other parts of the world such as Europe, Australia, New Zealand, Canada, and the UK mandate or require risk assessments, they are not mandated in the USA—with the exception of OSHA's process safety system standard (29 CFR 1910.119) [27]. Many of these workplace provisions call for a review and revision of RA standards if there are accidents, near misses, or dangerous occurrences; however, the detail of these reviews is usually unknown to others within an organization [28]. It should be noted that, despite not being required, many US mining companies use RAs as a part of their daily safety practices [e.g., 29], but again, the details of these processes are not always clear and consistent across worksites and workers.

Although general risk management strategies are deemed an important element of overarching mine H&S management [30], previous research has found that organizations do not adequately perform RAs [31]. More often, employees assess risks using a series of checklists or general observations during jobsite walkthroughs rather than learning from and responding to near misses [32, 33]. Specifically, such tools often do not offer as much proactive information to help prevent future incidents [34]. To that end, NIOSH researchers felt that it was important to take two prevalent activities (near-miss reporting and risk assessments) that are more often completed as separate entities on mine sites and assess what additional knowledge they could offer when viewed together to better inform HSMS practices and processes around near-miss management.

2.2 Incorporating Risk Assessment into Near-miss Reporting

The use of near-miss data is an important indicator in preventing incidents [35] and can be beneficial to the mining industry. Although near-miss management is widely used as an effective mechanism in H&S, research has argued that this documentation is not well integrated into overall features of a safety management system and the use of near misses to improve system implementation is extremely limited [4, 36]. As previously indicated, analyses of mining establishments have shown that low-severity near misses often precede injury and loss-producing incidents [14]. Consequently, near misses can be considered a leading indicator of potential incidents by providing opportunities that can improve safety and enhance productivity without experiencing an actual incident [8, 9, 16, 37]. Alternatively, a lack of such learning suggests that subsequent near misses are more likely to result in injury and cost-producing incidents [38]. Despite organizations and their workers being familiar with near misses in the mining industry, documentation on near misses has not been collected and analyzed in the most holistic way. Additionally, research has argued that near misses are an untapped area of social science research that have yet to be fully explored in an effort to improve worker knowledge and risk-based actions to best align with organizational H&S practices [39]. To that end, specific research objectives to help merge these two areas of proactive safety (i.e., near-miss reporting and risk assessment) to understand and inform the strengths and weaknesses in organizations' near-miss management approaches were addressed.

2.3 Research Objectives

NIOSH researchers initiated the research with several objectives in mind. Specifically, NIOSH researchers hoped to understand the frequency of low, moderate, high, or critical risks identified and documented in near-miss reports and the ways in which workers and organizational management responds to near misses that are reported via corrective actions. More specifically, researchers were interested in the following questions:

- What is the relationship between the risk type (i.e., low, moderate, high, and critical) and the corrective action implemented by the organization and/or its employees?
- What kind of feedback can near-miss incidents provide for HSMSs?

3 Methods

To better understand what near-miss information can provide in the context of H&S management, two NIOSH researchers traveled to visit three aggregate mine locations in the Midwest during summer 2018. The three specific locations that were visited in person had excellent safety records with no recordable incidents for the last several years. The objective of these visits was to gather and document the sites' near misses within the last quarter. The near-miss incidents collected were *behavioral incident near misses* [39]. Behavioral incident near misses occur when a worker observes or experiences an event and records their observation or experience as soon as possible [39]. This method is how most companies document their near-miss incidents, although this information is rarely transparent to the

research community, and rather, researchers usually rely on workers' self-reporting of near-miss experiences months later.

3.1 Near-miss Information Collection

The purpose of visiting site locations first was not only to gather near-miss reports observed or experienced by workers but also to understand the process that workers go through to report a near miss, how they are recorded into the company's database, and finally, how leadership assesses and documents their corrective actions as a part of the company's overall HSMS. Upon arrival at the three aggregate mine locations, the NIOSH researchers viewed and recopied all near misses that were reported and recorded during the previous three months. After understanding the company's processes for near-miss reporting, NIOSH was provided with near-miss reports for the entire company during the same three-month quarter in summer 2018. The near-miss reports contained the following information: product group, classification, date occurred, date entered, description of event, corrective action, and company-specific information, which was deleted to maintain site anonymity. The quarterly report of near misses, including those from the three aggregate sites that NIOSH visited, contained 249 near-miss incidents.

3.2 Information About Participating Company

The participating aggregates company specializes in production of sand and gravel across the USA, although other types of production do occur in some locations. The company organized their near-miss reports from 33 site locations into several product groups: aggregates, asphalt, construction sand and gravel, equipment, distribution, ready-mix concrete, trucking, and administration. The bulk of the near-miss reports stemmed from the aggregates group and the construction sand and gravel group and represented divisions across the USA. To respect the confidentiality of these mine operations, specific details about site safety records are not disclosed. However, the company, based on recent experiences and attention from MSHA, had been focused on powered haulage issues across their locations.

For example, in 2019, the company worked with employees to develop a plan to eliminate and manage powered haulage accidents, injuries, and fatalities [40]. The plan focused on three major causes of incidents or negative consequences of incidents: (1) Larger vehicles striking smaller vehicles, plants, or other structures; (2) mobile equipment moving on the site/seat belt usage; and (3) using conveyors to move materials. Corrective actions they took this year to mitigate some of these hazards included designating staging/loading areas for pickup trucks, pickup trucks with trailers, and other smaller vehicles in an effort to keep smaller vehicles away from operation areas, stockpile areas, and roads used by frontend loaders, heavy haul trucks, or other large equipment; blind spots were noted between stockpiles and fixed; the development and use of checklists around powered haulage were implemented; and all employees were provided with hand signal cards to increase hand signal awareness and consistency throughout the work crews. Along these lines, the use of seatbelts and overall communication have been safety issues addressed by the company within their annual refresher trainings in recent years.

3.3 Data Cleaning and Reclassification

Company employees used approximately 30 classifications to label the hazard type of their near-miss reports. Upon running frequencies of these classifications, researchers found that several classifications were only used one, two, or three times. Additionally, it was clear that some of these classifications were inaccurately labeled as a location rather than the hazard or incident type. For example, there was one near miss that was classified as *shop* even though it more accurately fell into a *slip/trip hazard* classification. This was also the case for blasting operations for which near misses were often classified under *third-party driving hazards* but, upon closer examination, were more often *plant hazards*.

In a few cases, the worker-assigned classification was too specific and could be placed into a more general classification category. As an example, in one near-miss report, an activity around the conveyor area was classified as *lifting operations*, but the hazard was related to a broken part and could more accurately be reassigned to the *equipment failure* classification. Researchers read and recoded the following low-populated classifications into more populated classifications: *conveyance and storage of materials under pressure*, *office hazard*, *edge protection for slopes and benches*, *improper tools/equipment*, *lifting operations*, *lock out/tag out*, *shop*, *working at heights*, *security*, and *training issue*.

In a similar situation but with more populated classifications, there were 26 near misses that were classified as *other* and 7 that were classified as a *subcontractor violation*. Researchers went through these 33 near misses and were able to reassign all but 9 of them into specific hazard classifications. The 9 that researchers were not able to assign were deleted from the dataset because these were near misses that were documented as occurring at home with no corrective action taken. As an example of reassigning a classification, one incident classified as *other* was: “Customer truck was sitting near break room when it quit running and the driver had to check for a problem. An electrical issue was found.” Researchers moved this from *other* to *equipment failure*. Regarding *subcontractor safety violation* incidents, one near miss recorded was “Subcontractor was working on top of a bridge without properly being tied off.” Researchers reclassified this incident as *use of PPE*.

There were 58 *third-party/public driving* near-miss classifications recorded. These near misses were incidents that happened off the job (e.g., other car ran a red light, did not use a turn signal). Thirty-six incidents were near misses that occurred on public roads outside of work hours. The remaining 22 were near misses that also happened off the job, usually at home. Although these reports can enhance situational awareness and help in recognizing certain hazards on the job, specific hazards were often not identified, and therefore, corrective action could not be taken by the worker. As a result, these reports contribute little to organizational learning and were deleted from the dataset.

Finally, there were 15 near misses that, upon examination, were not reported in enough detail to provide guidance on finding or mitigating a hazard. In most cases, these were actually positive-behavior-based or bystander-intervention reports that made mention of a safe decision or process on site. Although a positive occurrence, these were deleted from the database as well because no hazard or corrective action was identified. After cleaning and categorizing the data, 167 near misses remained and fell into 12 hazard classifications (see

Table 1). These 167 near misses were then analyzed by the researchers to answer the research objectives.

3.4 Analysis

Researchers applied a 5 × 5 matrix to guide a qualitative risk assessment (RA) analysis of each near miss. A qualitative RA approach is useful for potential or recently identified risks to decide where more detailed assessments may be needed and can help prioritize corrective actions [41–43]. In general, qualitative risk models are based on more subjective descriptions of events—such as the behavioral incident near-miss reports that researchers collected—and also require less precise information to assess [21]. Because the researchers were not present when these near misses occurred nor discussed the near misses with employees, this approach to analyzing the archival information was deemed to be most effective.

3.4.1 5 × 5 Risk Assessment Matrix—Several risk matrices are available that use anywhere from three to five scoring levels on both probability of occurrence and severity of harm. The researchers chose ANSI's Z590.3 prevention through design (PtD) risk reduction standard, which uses a 5 × 5 system and contains four risk levels based on the matrix calculation (i.e., low risk, moderate risk, high risk, critical risk) [24–26]. Released in 2011, this standard represents a more prominent emphasis on the role of risk assessment in safety [31]. Other standards also recommend the numeric 5 × 5 risk matrix [e.g., 28], and it has been used by mining companies who are proficient in RA [e.g., 29, 44].

Another reason that this standard was chosen is because ANSI's Z590.3 standard discusses risk reduction within a hierarchy of controls framework (Fig. 2), indicating the most preferred (i.e., risk avoidance and elimination) to least preferred (i.e., PPE) control methods. Organizations often use the hierarchy of controls when responding to near-miss incidents and by focusing not only on their risk level but also on the processes and decision-making surrounding the near miss [45]. This process provides a greater opportunity to learn about safety management processes as well as determine how well the organization achieved acceptable risk levels [39, 45].

All matrices include similar, systematic steps to identify hazards as well as discretized scales to help estimate workers' risk levels to prompt a risk ranking [22, 31, 41, 47]. Using the 5 × 5 matrix to assess the risks of the 167 near misses allowed NIOSH researchers to determine and anticipate the risk of a hazard, action, or situation from very low to very high. Three researchers met on several occasions during a six-week period to discuss and code the near misses. As Taylor and colleagues [48] indicate, coding near-miss narratives is not as simple as coding an actual injury narrative. Specifically, to code a near miss you must "look for the most likely outcome that could have occurred, recognizing that one decision must be made when multiple outcomes are possible" (p. 126). In response, meeting and discussing the near misses as an interdisciplinary group was imperative to ensure that all outcomes were considered when assigning scores. It took researchers approximately 12 h to complete the coding as a group.

After the near misses were coded, researchers consulted an H&S subject matter expert (SME) in the aggregates mining industry to validate the coding decisions. Ten percent of the near misses were shared with the SME along with researcher thoughts on the probability of occurrence, consequence of occurrence, and corrective action. The near misses chosen were those that applied to a specific range of hazard classifications and scenarios, allowing researchers to double-check previous codes upon receiving feedback from the SME. In all but one instance, feedback from the SME did not change the risk type of the near miss. As an example, there was a near miss that discussed a light fixture that shorted out and started smoking during which workers were present to notice the situation and immediately intervene. NIOSH researchers coded this as a 3 × 3 = 9. Our SME indicated that electric shock was a very real possibility, which caused us to move our probability rating from a 3 to a 4, moving our risk score to a 12. However, in both cases, the risk type fell into the “high” category.

4 Results

4.1 Risk Assessment Ratings

The frequencies of near-miss occurrences demonstrated a fairly even distribution of the RAs across categories. This distribution is shown in more detail in Fig. 5. Figure 4 shows the percentage of low, moderate, high, and critical risks assigned for each specific near-miss classification. The percentages in Fig. 3 total all 100% of the near-miss reports coded by researchers. For example, 1.2% of the near-miss reports coded were made up of electrical hazards that were “critical risks.”

The results for the maximum reasonable consequences, probability of occurring, and overall risk score for the cumulative assessment are shown in Fig. 4. As the figure shows, regarding probability of occurring, n = 6 (3.6%) were deemed rare; n = 46 (27.5%) unlikely to happen; n = 56 (33.5%) moderate/possible; n = 46 (27.5%) likely to happen at some point; and n = 13 (7.8%) almost certain to happen. Regarding the maximum reasonable consequence if an incident did occur, n = 19 (11.4%) were rated as causing first-aid injury or minor damage; n = 28 (16.8%) as causing minor injuries that were recordable; n = 44 (26.3%) as causing moderate damage that results in lost time; n = 63 (37.7%) as causing permanent disability or fatality; and n = 13 (7.8%) as being able to cause multiple fatalities. Of the 167 near misses, n = 31 (18.6%) were deemed low risk; n = 42 (25.1%) were moderate risk; n = 50 (29.9%) were high risk; and n = 44 (26.3%) were critical risk. Figure 4 shows how these cumulative numbers for each of the four risk ratios originated. For example, the green sections of Fig. 4 show those near-miss incidents that were deemed to be “low risk” based on multiplying the probability and consequence ratings of the incident. In this case, there was 1 incident that was rated 1 × 1, 1 rated 1 × 2, 4 rated 1 × 4, 12 rated 2 × 1, 8 rated 2 × 2, 1 rated 3 × 1, and 4 rated 4 × 1, which comes to a total of 31. The individual results within each outcome are effective in showing areas in need of additional intervention. Specifically, that there were 24 near-miss incidents that were rated as likely to happen and, if they did happen, would result in a disability or fatality. These would be issues that should be addressed immediately on site and could be better mitigated if such risk assessments were completed regularly and in near real time for near-miss incidents recorded.

4.2 Corrective Actions

Corrective actions were coded to each near miss based on whatever activity had been completed and documented in the report. A specific corrective action could only be assigned if it was noted as being completed and not in process [37]. Consequently, for near-miss reports that referenced an action as in process or going to be done, the corrective action was coded as "not yet fixed." Table 2 shows the total frequency of each corrective action that was coded as well as an example of the related action.

4.3 Relationship Between Corrective Action and Risk Type

Researchers were interested in the relationship between risk type and corrective action to address specific feedback for organizational HSMS. Figure 5 shows the frequency of corrective actions associated with the four risk types within the matrix.

To determine if there was a relationship between the risk type and the corrective action implemented by the organization or its employees, a nonparametric median test was performed using PROC NPAR1WAY in SAS 9.4. The median test compared the proportion of scores within each category of corrective action that fell above the median risk type across all categories; risk types were ranked from 1 (low risk) to 4 (critical risk). The results of the median test were significant (chi-square = 13.64, df = 4, $p < .005$), indicating that the relative frequency of levels of risk varied across types of corrective actions. For example, the action "Implements safe procedures" was associated with a higher level of risk than the action "Not fixed" (Table 3).

5 Discussion

Analyses of near misses often occur on an informal level, but they are rarely used to formally contribute to accident prevention within an HSMS [49], especially specific to mining. However, because near-miss incidents often do not occur by chance and preventative measures fail or do not exist, it is important for an HSMS to retain both positive and negative feedback for continual improvement [36, 50, 51]. Specifically, positive feedback in the current study included the prevention of a reportable incident because of strategies in place and, as a result, these practices should be more widely disseminated. Additionally, in many cases, workers were able to regain control over their work tasks, processes, or equipment, demonstrating high adaptability on the job.

Negative feedback included failures in safety management and decision-making, such as not wearing PPE, and requires organizational follow-up and attention. Specifically, the results indicated that the frequency of needing to improve the implementation of safe work procedures increases as the risk severity increases. In other words, the corrective action of implementing safe work procedures is associated with significantly higher levels of risk rather than elimination of an energy source or improving engineering controls. Implementing safe work procedures in response to a near miss was suggested in many of the near-miss reports because safe work procedures were not followed in the first place.

To that end, these results provide specific, usable feedback for not only the case study company but also an organization's HSMS to better communicate about safe work

procedures as well as understand some of the underlying reasons why some work procedures are not always implemented as intended. We start by addressing individual differences in workers' risk tolerance that may contribute to these results, followed by potential weaknesses in the organizational HSMS that can be improved to encourage and support worker participation in near-miss reporting and execution of mitigation strategies on behalf of their worksite. This discussion draws from recommendation in the literature as well as actions taken on behalf of the specific company or respective sites that participated in this study.

5.1 Workers' Risk Tolerance

Previous research among industry and academic professionals has identified factors related to risk tolerance [e.g., 52–58]. Some of the factors outlined by these researchers include overestimating or relying on experience too much, familiarity with a task, underestimating the probability and/or severity of an outcome, being in control if something happens, overconfidence on the job, and observing others perform a task in a way that accepts or rewards risk. Specifically, research has continually shown that near-miss events can result in workers believing that they were overestimating the initial risks that caused or were associated with an incident [59]. As an example, several near-miss reports in the current sample reported workers' driving around site or leaving site with their truck bed raised. Although this can result in significant damage and injury if the truck bed encounters another energy source, it is likely that some workers underestimate this contact can happen and result in electrical shock.

It is possible that workers' risk tolerance has something to do with these specific results in that if workers are more tolerant of risks, they may be more likely to make judgments that are acceptable to them and unconsciously work around certain procedures to complete a job task [60]. Research has shown that individual workers with higher tolerance toward risks are more prone to suffer occupational injuries [61]. This research has recently been applied specifically to the mining industry whereas mineworkers' risk avoidance increased (on one-unit scales); their likelihood for experiencing a near-miss incident decreased by 30% [62]. Not surprisingly, risk tolerance has also emerged as a significant predictor of mineworkers' performance, particularly among workers' compliance to worksite rules [63]. Pertaining to this company, participation in previous research illustrated that, among 214 company employees surveyed, anywhere between 10 and 21% reported taking risks regularly while at work. Additionally, 44% of the workforce who participated felt that health and safety rules were sometimes ignored while 45% felt that they sometimes have impossible production pressures [64]. These results do not necessarily mean that workers want to take risks; rather, as other research has shown, many workers may accept risks in order to get the job done [66]. To that end, communicating about the probability and severity of risks is imperative. Judgments about risk tolerance are made, in part, based on the processes through which safety is managed and communicated, as well as if those messages are deemed reliable and trustworthy [65].

The few Midwest locations that participated in this previous survey effort in 2016 and 2017 developed specific efforts to improve worker initiatives and perceptions in the area of risk

tolerance. For example, the sites embraced the idea of risk assessment cards for employees (i.e., I Choose to Reduce Risk) to identify hazards related to their job tasks and assess or rate the risk involved in doing the task [64]. Employees consistently used these cards as a platform for consistent communication among employees and their supervisors. Additionally, when employees take the time to not just think about risk, but to process and write down the hazards and assess specific risks, it provides the opportunity to overcome complacency on the job, which can happen easily after completing similar tasks throughout the day [66]. In follow-up surveys with these same sites a year later, the percentage of workers who admitted to engaging in risks regularly was significantly lower. It is possible that some of these risk reduction methods have not yet been implemented across the entire company. Therefore, it is important for this specific company to better disseminate new approaches that seem to be effective in lowering workers' tolerance for risks.

5.2 Improvements to HSMS Programs and Practices

Some organizations may respond to such results by implementing more H&S training; however, research suggests looking beyond safety training alone to prevent risk-related outcomes at work [60]. Because risk is an emergent trait that can be influenced [67], others have argued that organizations need to understand what contributes to workers' high levels of risk tolerance to build or improve an effective management program [68]. However, a formal near-miss reporting and management protocol as a part of company practices has been ignored in many studies related to high-risk industries [69].

5.2.1 Improving and Learning from Near-miss Reporting—Results of the current study show the importance of organizations developing and promoting formal near-miss reporting systems within the implementation and monitoring of their organizational HSMS. The presence of such programs can also be a sign of a positive safety culture that is conducive to changes in work practices [50, 51]. Although an important first step, these reporting systems must be sure to establish guidelines for a quality near-miss report. For example, in the current study, researchers started with 249 near misses and ended with 167. Approximately 30% of the near misses turned in by employees who are part of a company that does have a formal reporting mechanism were deemed ineffective. What implications might this have for companies who do not have formal near-miss programs? These results show that additional factors need to be considered to successfully foster a near-miss program within an overall HSMS.

A guide published by the American Industrial Hygiene Association [6] discussed basic steps for promoting a near-miss management program. The first step is defining what entails a near miss for the company. Additionally, examples of quality near misses should be provided as a reference point. Next, it is important to engage with workers and management to support the reporting of near misses, which includes a structured incident reporting process to make sure that near misses are expected and enforced [36]. However, near-miss programs should also allow for the investigation of incidents. Organizations should routinely check these near misses and act on an organizational level to fix hazards via feedback and interventions that correct the hazards [70]. Accurate, timely feedback to workers using

charts, onsite messaging, and safety meetings has been deemed critical in preventing subsequent occurrences [71].

Although it may sound daunting to do an initial scan of near-miss reports for trends that can be potential problem areas, there are a few simple patterns that may be easily identified among mine-level management. For example, at the three site locations NIOSH initially visited to better understand the company's near-miss reporting mechanisms, researchers also examined other modes of communication used to discuss daily hazards. One of these methods included the 5-min pre-shift safety meetings. In general, it was noticed that a near miss for the day tended to align with topics discussed during the pre-shift safety meeting. For example, in one pre-shift safety meeting, the topic discussed was slip, trip, and fall awareness. A near miss recorded that day read, "I was climbing the ladder to check the metal detector and as I stepped onto the ladder my boot was muddy and I slipped off as I put pressure on it to climb the ladder." This means that the pre-shift meetings may prompt awareness and attention to workers for specific health and safety issues. In response, managers can use this to their advantage to further prevent specific incidents that are more common or those that are a result of non-routine tasks. This finding is not surprising as management plays a key role in encouraging workers to identify and act upon unsafe situations by reporting hazards and near misses, and if possible, implementing corrective solutions and stopping work if necessary [6].

5.2.2 Worker Participation in Programs—Workplace safety programs, including worker involvement and feedback, performance feedback, and management commitment to safety, are all important parts of an effective HSMS [72]. However, organizations must do more than just establish another program to encourage near-miss reporting efforts. Workers must be able to participate in "check" and "act" activities by conducting RAs on site-specific near misses, like the current research effort, to inform a comprehensive plan around identifying, ranking, and mitigating risks. Specifically, rather than leaving the ranking efforts up to management, workers should have practice in assigning probability and consequences to hazards identified on site as well as the option to make suggestions to improve the deficiencies in company plans and processes [73]. It is also possible that efforts can force workers to truly assess the reasonable probability and consequences of hazards and motivate them to think critically about their daily surroundings. Additionally, this involvement and support, trickled down, helps situate near-miss events as a critical component of a successful management system [74]. Having an active near-miss system has been shown to strengthen safety culture, particularly when workers are involved in not only identifying but analyzing the near-miss events [8, 75, 76].

In addition, it is apparent that workers feel a sense of accountability to mitigate risks that they identify, so giving them the autonomy and support to be more proactive may be a worthwhile effort. As a reference point, at the three site locations NIOSH initially visited to better understand the company's near-miss reporting mechanisms, in about half of those near misses' employees referenced a personal corrective action in response to what they recorded. Examples include:

- Stopped work until they were locked out. See something say something.

- Clean up area where loading pit trucks.
- I marked where the chain was bad, tagged it out.
- Told operator when bleeding air from grease gun, make sure it is not in an area where foot traffic will be.
- Looked at chain, replaced with bigger chain, locked out broken chain.
- I got a water bottle and cleaned the window.
- Decided to take corners as wide as possible rather than coming close to pile and then turning.

Some workers gave generic actions in their near-miss responses that indicated little action was taken on their part. Examples included things like “honked my horn to get their attention,” “try to prepare for the unexpected,” “stay alert when driving,” and “slowed down and continued watching.” There is not necessarily anything wrong with these responses; however, they are not actionable or measurable in terms of reducing or mitigating the chances of an incident happening in the future. It is possible that managers can encourage the workforce to take as much action as possible to mitigate a hazard or prevent a risk from becoming even greater on site.

5.3 A Safety Square of Near Misses

Lastly, a variety of recent research both within the mining industry [14] and in other occupational sectors [77] has shown that the concept of the safety triangle is not as straightforward as researchers once thought. More specifically, studies have found little evidence between the occurrence of minor incidents and subsequent severe outcomes. Other studies have even found that an increase in near-miss reports results in fewer high-severity incidents—again, supporting the use of valid near-miss management programs [78, 79].

In some ways, the current research supports these results in that there was a fairly even ratio of low, moderate, high, and critical risks identified among workers’ near-miss reports. In other words, no risk triangle was identified when examining consequences of risks and overall risks. These results, when examined with previous research about the safety triangle, indicate that perhaps focusing on gaps in corrective actions to mitigate risks (i.e., proactive approaches to H&S management) is just as important as or even more important than assessing the actual near misses and their relationships to outcomes. Therefore, upon completion of an RA, organizations can come up with a list of hazards that are evaluated and prioritized for future interventions [21], which may result in changes to a policy or protocol [41]. Regardless of the changes implemented, however, workers should be involved in the decisions and informed of new practices and procedures to execute.

6 Limitations and Conclusions

These study results, although useful to consider for mining practitioners, must be considered within their limitations. First, this study represents a small case study with one mining aggregates company. The scope of near misses is much broader than what was reported and able to be assessed by NIOSH. Additionally, within the case study sample, it is assumed that

not all near misses that occurred within the company were reported. There are likely several reasons that near misses are not reported, including some of the barriers referenced in the discussion. For example, research has found that the acceptance of risk, regarding certain events as inevitable, contributes to a lack of near misses being reported and responded to on site [35]. Regardless of the unknown reasons, NIOSH was unable to analyze 100% of the near misses, which limits the decisiveness of the results.

Also, no demographic data for individuals are associated with the near-miss reports. Previous research has found that greater risk tolerance is associated with longer tenures of workers in hazardous industries, such as mining [80]. Additionally, those who have more time in the mining industry have been shown to have a higher tolerance for risks [81]. Being able to associate individual factors with the severity and actions of near-miss reports may have further informed individual-level interventions that companies can use within their management systems.

6.1 Future Directions

Despite the limitations, this study, like others, shows that near misses can serve as learning tools [82, 83]. However, to date the combined use of formal risk assessments and near misses has not been taken advantage of as much as it could be [39, 84, 85]. Moving forward, it is important that organizations better assess their own H&S management and communication processes around near misses and residual feelings of perceived risk. To do this, new ways of collecting and assessing near-miss data may be necessary for companies to make quick and decisive decisions. Specifically, it is known that the time, effort, and resources to collect such information are already extensive prior to even trying to understand the data. In this case, researchers spent the time qualitatively analyzing the near-miss data for quantitative trends. In future scenarios, it is possible that more predictive analytics can be used to ensure that the most value is extracted from the data and practitioners are able to identify areas that need attention [86]. High-risk industries are already experimenting with such ideas to save time, resources, and further protect the workforce. However, this study also showed the importance of an interdisciplinary team in analyzing the information. Therefore, even as the use of big data and predictive analytics continue to replace traditional matrix assessments, interpretations of findings by social scientists, engineers, and H&S practitioners will continue to be imperative to best apply the outcomes.

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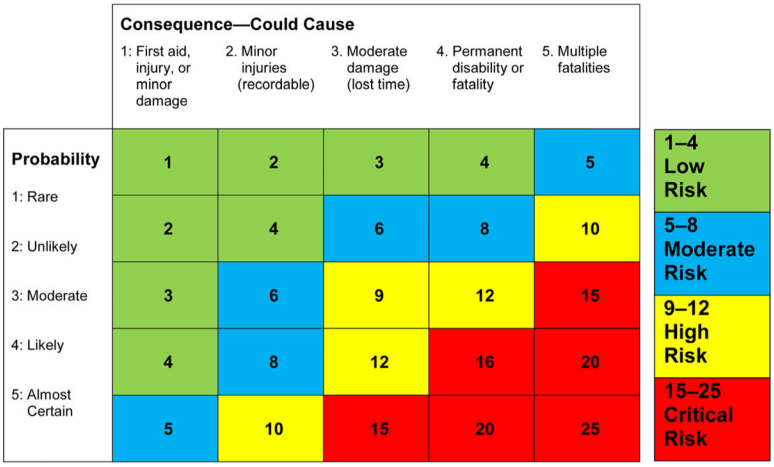

Fig. 1.
Example risk matrix and evaluation key used by ANSI/ASSE [24–26]

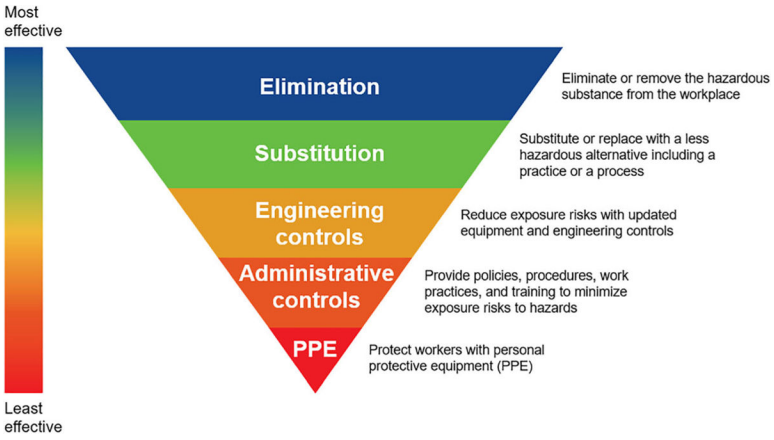

Fig. 2.
Hierarchy of controls [46]

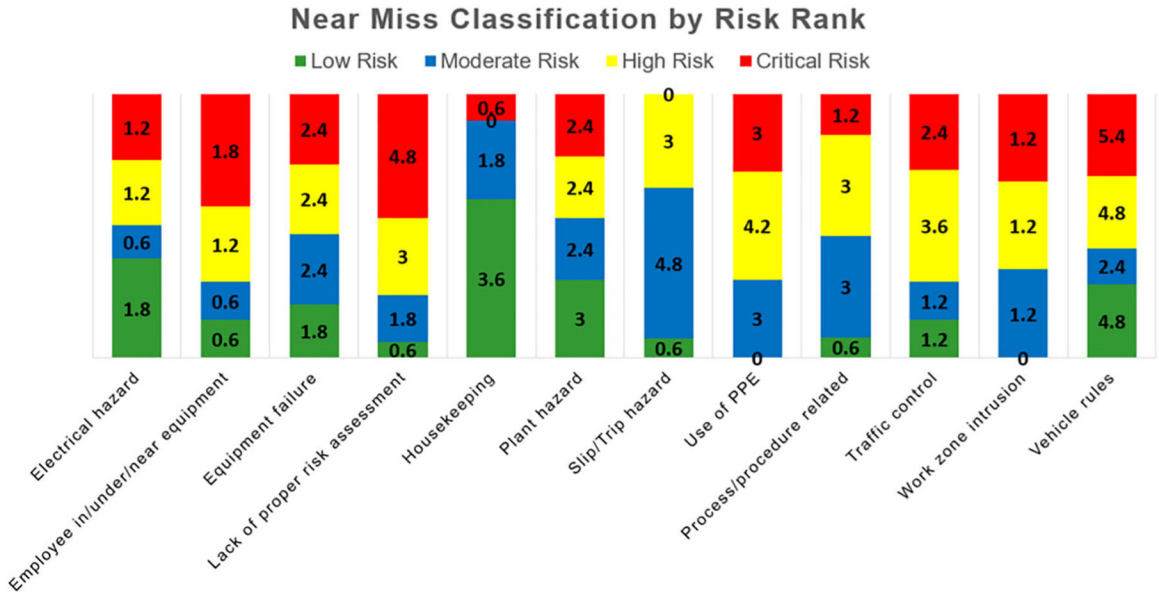

Fig. 3.
Near-miss classification by risk rank (percentage of total)

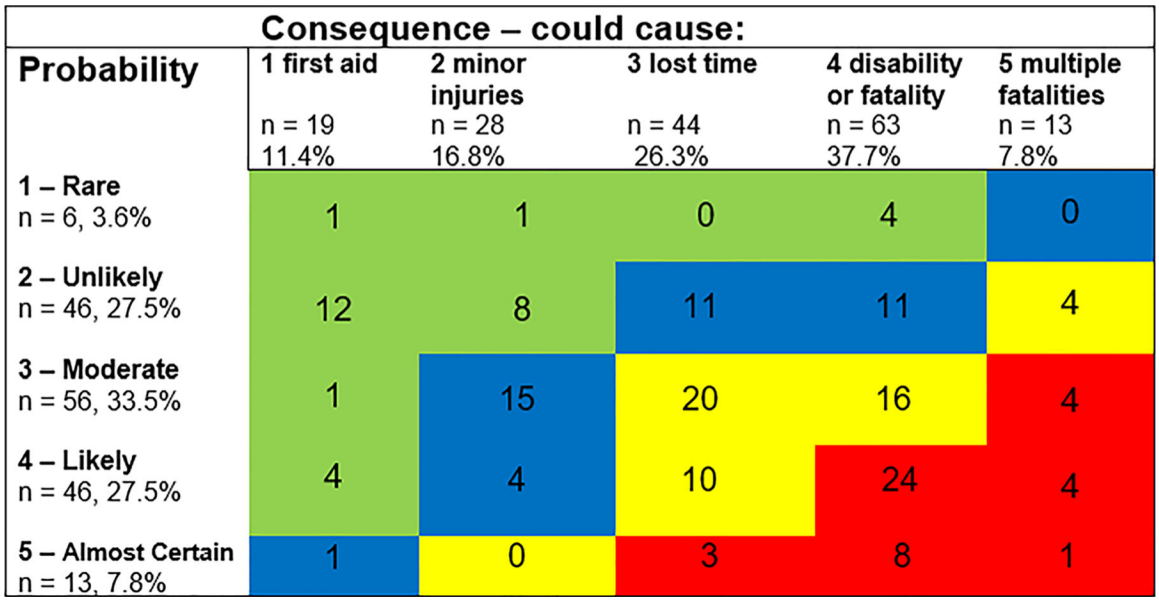

Fig. 4.
Cumulative RA results for 167 near-miss incidents

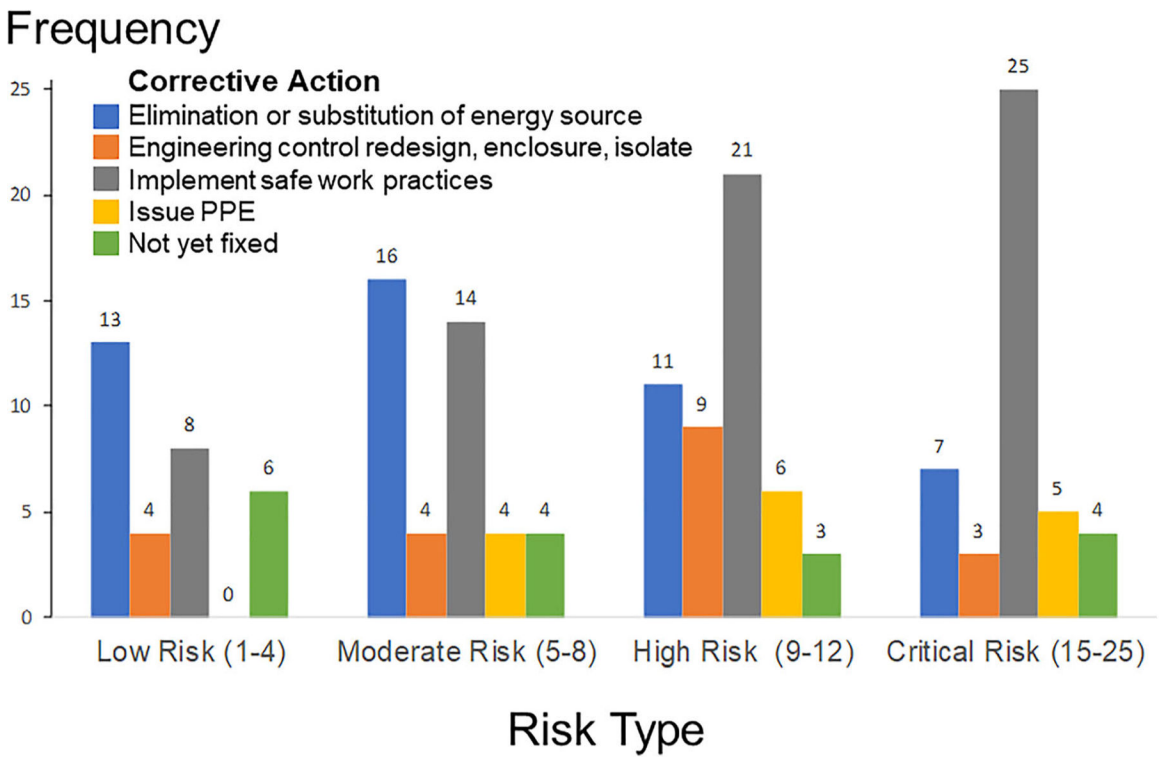

Fig. 5.
Corrective actions implemented by risk type

Table 1

Frequency of near-miss classifications

Company classification	Frequency	Percent
Electrical hazard	8	4.8
Employee in/under/near equipment	7	4.2
Equipment failure	15	9.0
Lack of proper RA	17	10.2
Housekeeping	10	6.0
Plant hazard	17	10.2
Slip/trip hazard	14	8.4
Use of PPE	17	10.2
Process/procedure related	13	7.8
Traffic control	14	8.4
Work zone intrusion	6	3.6
Vehicle rules (e.g., pedestrian segregation, alarm/reversing, load securement)	29	17.4
Total	167	100

Table 2

Frequency of corrective actions

Corrective actions	Frequency	Percent	Example
Elimination or substitution of energy source	47	28.1	“Tagged out tool and replaced.”
Engineering control redesign, enclosure, isolate	20	12.0	“Built up berms around area.”
Implement safe work procedures	68	40.7	“Good use of mirrors but we need to stay aware of our surroundings because they easily could have been in a blind spot We tightened up our cones there and talked about keeping your head on a swivel.”
Issue PPE	15	9.0	“Plant manager told employee he needed to get safety glasses on which he did immediately.”
Not yet fixed	17	10.2	No action listed or futuristic statement such as “make sure people are aware.”

Table 3

NPAR1WAY median results

Corrective action	*N*	Sum of scores	SD under H0
Engineering control	20	10.020	1.875531
Elimination or substitution energy source	47	15.580	2.597707
Implement safe procedures	68	41.380	2.838067
Not fixed	17	6.340	1.746710
Issue PPE	15	9.680	1.651650

Average scores were used for ties