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Exploring the Differences in Safety Climate Among Mining Sectors

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Abstract

Currently, the US mining industry is encouraged, but not required to adopt a formal health and safety management system. Previous research has shown that the adoption of such systems has been more difficult in some subsectors of the mining industry than others. Given the interdependencies between management systems and safety climate in addition to their predictive utility of incidents, it is important to assess differences in the perceptions of safety climate among mining subsectors in the USA. If significant differences exist, then mining subsectors may not necessarily be able to adopt a one-size approach to system implementation. To that end, the National Institute for Occupational Safety and Health assessed mineworkers' perceptions of several individual and organizational safety climate constructs. Participants consisted of 2945 mineworkers at coal, industrial mineral, and stone/sand/gravel mine sites throughout 18 states. Linear regressions were used to answer the research question. The results suggest that coal miners, in comparison to those miners in industrial mineral and stone/sand/gravel sectors, had significantly less favorable perceptions on each of the organizational climate constructs measured (i.e., organizational support, supervisor support and communication, coworker communication, engagement/involvement, and training) ($p < 0.001$ in all cases). Importantly, these results parse out organizational indicators to show that perceptions are not only lower in one area of organizational or supervisor support. Rather, engagement, training, and communication practices were all significantly lower among coal miners, prompting considerations for these significant differences and actions that can be taken to improve system practices.

Keywords

Health and safety management system (HSMS); Linear regression; Mining; Safety climate

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1 Introduction

Although major advancements in mine health and safety have contributed to a decreasing number of fatalities each year, mining is still a high-risk industry that experiences disproportionate rates of injury and disease [1]. Based on various analyses, underground coal mining is consistently labeled as one of the riskiest operations in the world [2–6]. For example, the Bureau of Labor Statistics [7] found that workers in underground coal mines are more likely to experience fatal or nonfatal injuries and illnesses than workers in private industry. With special equipment needed to work in deep seams underground, often while in water or mud, and while maintaining a proper ventilation system, the work conditions in underground coal mining have been described as substantively different from those in surface mining [8]. As examples, the possibilities of gas release, subsequent combustions, or outbursts are hazards that coal miners must consider. Other research has even discussed underground coal mining as a more complicated operation than other mining sectors, with more risk factors in its environment [9].

Due to the increased complexity of underground coal mining, there are numerous rules and regulations that are in place in the United States of America (USA), including those within the Federal Coal Mine Safety Act of 1952, the Coal Mine Safety and Health Act of 1969, and the Federal Mine Safety and Health Act of 1977 [10]. Most recently, Congress passed the Mine Improvement and New Emergency Response Act in 2006 [11], which included updates to new miner training and annual retraining of underground mineworkers (Part 48 training, CFR 30). Such regulations serve as important health and safety roles in the US mining industry. Although other mining commodities face regulations and retraining standards, underground coal mining faces more stringent requirements. Specifically, the most recent version of the Federal Coal Mine Safety Act requires four annual inspections at all underground mines and only two annual inspections at surface mines. Additional inspections and rules may be necessary given the underground environment requires attention to roof and rib control, methane and other gasses being monitored for potential fires and explosions, exposure to respirable coal mine dust in addition to other respirable dust contaminants, and the requirements needed to self-escape quickly from an underground mine environment including labeling primary and secondary escapeways [11]. It is not implausible to think that additional standards may impact the decisions made around how work is done on the job.

To that end, this study assessed safety climate perceptions among three US mining subsectors with a specific focus on how the perceptions of workers within the coal subsector differ from the other two subsectors that participated (i.e., stone, sand, and gravel and industrial minerals). Researchers felt it was important to assess differences in safety climate perceptions among industry commodities in order to glean ways to improve the diffusion of safety management practices. Specifically, if there is a significant difference in safety climate among mining subsectors, there may be valuable insights into how organizations can go from not only having a documented management system, but also understanding the specific, necessary tools and information to effectively execute their system on a daily basis.

1.1 Health and Safety Management Systems

According to Vinodkumar and Bhasi [12], one root cause of many industrial disasters can be traced back to the absence of an effective HSMS. Health and safety management systems relate to the tangible roles, processes, and practices associated with staying safe on the job [13]. According to the ISO 45001:2018 [14] standards, the purpose of an HSMS is to "provide a framework for managing health and safety risks and opportunities" (p. vi). These standards discuss the implementation of an HSMS as a "strategic and operational decision for an organization" (p. vi). There are several HSMS frameworks available for companies to adapt and use. Regardless of the HSMS framework chosen, these systems are designed and based on a continuous improvement process to control hazards and risks to an acceptable level and improve worker health and safety [15]. Additionally, they all utilize and advocate some form of the Plan-Do-Check-Act process including the National Mining Association's CORESafety program [16], Occupational Health and Safety Assessment Series (OHSAS) 18001 [17], ANSI Z10 [18], and the Occupational Safety and Health Administration's Voluntary Protection Program [19] (see Table 1). The authors of this article also added another safety management system designed for use in the coal mining industry. As shown, the Anglo American Plc [20] also created a systems maturity model for coal mining in the UK. Anglo's system contains 12 standards that are like the 20 elements in CORESafety. For example, in the CORESafety framework, there are two elements labeled "leadership development" and "responsibility and accountability," whereas the UK's framework just lists one element, "leadership and accountability." Similarly, NMA's framework offers "risk management" and "change management" as two separate elements, whereas the UK's framework offers these as one element, "risk and change management." These examples are provided to show the overlap in areas of focus, but with varying emphasis on the semantics. The main point to make about these systems is that common elements and principles are included, just organized and detailed to different degrees.

In response to both the unique risks and potential for at-risk responses by the workforce, the mining industry has been encouraged—but not required—to go beyond mandated regulations and adopt a comprehensive HSMS [9]. However, it has been argued that risk-based management inherent within a health and safety management framework has diffused more slowly in US coal mining [21]. Specifically, analyses of occupational HSMS in the coal mining industry have shown several limitations to implementation. For example, follow-up assessments with organizations have shown that daily work activities often do not follow an established, systematic approach [9]. One barrier is the ability of organizations and their employees to circulate and process large, varying amounts of risk-based information and respond proactively [22]. Depending on whether responses to procedures, policies, and practices being targeted within the HSMS are proactive or reactive, the organization's safety climate may be affected. Not surprisingly, an HSMS, and its supplemental practices, has been observed as an indicator of an organization's safety climate or culture [12], making their interdependencies an important distinction to consider in research. However, considering that most HSMSs have supplemental practices upwards of 100 (CORESafety boasts approximately 135 within their 20 elements) [16], it can be difficult to pinpoint strengths and weaknesses within your overall system. However, by examining the practices that often overlap between safety climate and health and safety management (i.e., leadership, communication, and accountability), it may be easier to identify unknown predictors of risk at operations.

1.1.1 Assessing Safety Climate Within a Risk Management Strategy—

An organization's safety climate encompasses perceptions regarding the priority of safety and behavior that originates from interpretations of organizational health and safety policies, procedures, and practices [23, 24]. A large body of knowledge on safety climate/culture has been collected over the past century showing that both organizational (e.g., priority toward safety, training adequacy, leadership) and personal factors (e.g., risk tolerance, thoroughness) influence worker performance, which has further advanced what we know about safety climate [25–30]. However, even with all of the research done on occupational safety climate, the various influences that these factors have on influencing worker performance make the overall construct difficult to measure. To that end, this research examined a new way to tease out and examine aspects of safety climate relative to the overall HSMS.

Routine safety climate assessments are conducted as a part of an organization's HSMS to help identify necessary policies, procedures, and practices that may need improvement [31–34]. Specifically, safety climate surveys represent a commonly employed strategy for continuous improvement of HSMS development and implementation within mining [35]. The interdependence of safety climate and HSMS is critical, as Gordon and colleagues [36] argue, if a strategic HSMS exists without safety commitment or culture, then successful implementation of the HSMS strategy is highly unlikely given most decisions will not prioritize safety. Similarly, if there is a strong safety culture, but lack of a developed HSMS, then the way that safety is organized may be inconsistent [36]. To that end, it is possible that risk management issues experienced at mine sites are due to a culture/systems mismatch [37]. Therefore, determining safety climate perceptions is an important indicator of potential ways to improve the effective execution of an HSMS.

Although some studies have compared safety climate across occupational sectors, mining has not been included in many comparative assessments. For example, in a systematic review of safety outcomes and performance in high-risk industries, underground mining was not included because the industry was said to represent highly specific risks [38]. Other studies have collected safety climate data from a variety of subsectors, including a 500-worker survey at Australian mines [39]; however, a breakdown of mining sector differences was not reported. Consequently, there is a need for not only information specific to the mining industry, but also mining subsectors in order to provide a more tailored, information-driven approach to generate specific benchmarks, predict risks, and develop interventions to improve safety outcomes [40].

1.2 Research Question

Previous research has shown varying rates of HSMS diffusion among the coal mining industry; however, there have not been studies to examine the potential impacts of these slower diffusion rates. This study sought to understand differences in safety climate perceptions among mining subsectors:

Research question 1: How do perceptions of organizational safety climate differ between coal mining and other commodity sectors?

Knowing this information can help improve the development and implementation of health and safety management processes, policies, and practices where needed across the industry.

2 Materials and Methods

The National Institute for Occupational Safety and Health (NIOSH) created a safety climate survey that was used to assess mineworkers' perceptions of several personal and organizational constructs. The survey was originally developed to support a research objective to determine the most important organizational and personal characteristics needed to support worker performance in the mining industry. A report of these initial results is described in another document [41].

2.1 Survey Development

First, researchers reviewed constructs that had been used within universal safety climate scales that could perhaps provide contextualized assessments as well as be used to aggregate data across and beyond mining applications in the future [40]. Research has argued that using universal safety climate measures could allow for comparison and aggregation of industry results [30]. There was concern for the content validity of the survey to ensure that the items selected would accurately represent the scope of the construct being measured [42]; therefore, the use of prominent causal and theoretical models of workplace safety to identify relevant constructs (e.g., [25], [43–47]) was reviewed.

Several key constructs from the model depicted in Christian and colleagues' [25] meta-analysis were incorporated as well as outcomes described by Griffin and Neal [43]. This research promoted the use of both organization- and person-related factors as predictors to workers' behaviors on the job. NIOSH researchers identified constructs that were presumed to be important in fostering knowledge, motivation, behaviors, and outcomes. These organizational-related factors included supervisor support and reinforcement of safety, organizational support and reinforcement of safety, adequacy of safety training, employee involvement or engagement, and coworker communication. Important person-related factors included adaptability, locus of control, job thoroughness, and risk propensity.

It is important to note the broadness of terms used in the current study. Recent meta-analyses show trends in grouping several safety climate scales that are labeled differently but still measuring a similar concept into one category to avoid being double-counted or excluded from outcome analyses [48]. An additional point of consideration was that different sectors of mining have subtle differences in industry requirements, staffing, and equipment, which is one of the reasons this topic needed exploration (i.e., is there a difference in safety climate perceptions among different mining sectors?). To engage in accurate comparisons, more universal scales were needed to avoid the inclusion of different terminology for those who mine on the surface or underground as well as mining different minerals. These generic scale names went over positively with mining industry personnel. Publicly available, universal measures that were consulted are described in more detail in a recent report of investigations [41].

The survey used a 6-point Likert scale, with responses ranging from strongly disagree to strongly agree. A score of 6 represented a high perception of the safety climate construct, while a score closer to 1 represented a poor perception of the construct. Although odd-numbered Likert response options are more conventional, methodological research has revealed several reasons why an even-numbered scale should be used. Specifically, even-numbered scales are more desirable to encourage respondents to avoid answering what they see as being socially acceptable or unpopular [49]. Particularly, Johns research [49] found that, when a neutral response is offered, approximately 25% of respondents take advantage of it—usually when they tend to disagree with an item. In the case of assessing organizational safety climate on behalf of companies, it was critical to have a disagree/agree dichotomy to provide accurate and relevant direction to mine management. Additionally, participants tend to have different interpretations of a midpoint, even if it is labeled (as was the case in our current survey) and can cause measurement error [50]. Consequently, due to our sample and purpose of the survey, an even-numbered scale was used. Each item related to one of a series of organizational constructs identified above and responses were used to calculate a mean score for each construct.

2.2 Recruitment and Data Collection

NIOSH received approval from the Institutional Review Board (14-OMSHR-08XM) as well as from the Office of Management and Budget (0920-15BM) prior to this data collection. Subsequently, recruitment and data collection occurred from February 2016 through February 2019. Individual mines were initially recruited through research contacts. NIOSH researchers either coordinated data collection with mine health and safety annual refresher training or worked with mines to distribute surveys at pre-shift meetings. The purpose of the survey was explained to all employees. They were also told that their responses would remain confidential. Participation was always voluntary and the principal investigator’s contact information was available to everyone. The survey took approximately 15 min to complete.

2.3 Participants

Participants consisted of 2945 mineworkers at 40 mine sites throughout 18 states. The mines represented nine major companies and three mining sectors (i.e., coal; stone, sand, and gravel; and industrial minerals). To our knowledge, everyone who was present during data collection completed the survey. The breakdown of participation by subsector is shown in Table 2, experience by subsector in Table 3, and demographic characteristics of the overall sample in Table 4.

3 Analysis and Results

Because NIOSH was interested in comparing the differences in perceptions across participating mining subsectors to improve HSMS interventions and practices across the industry, focusing on the differences in organizational, rather than personal, constructs was deemed most appropriate.

3.1 Exploratory Factor Analysis

An exploratory factor analysis (EFA) was performed on the 22 organizational items contained in the survey. There were 18 positive and 4 negatively worded items. A sample of over 300 is recommended for EFA [51]; therefore, the current sample size sufficed. According to Fabrigar and colleagues [52], items in a survey are assumed to share a linear relationship with a common factor, which reflects the underlying domain that the item represents. Researchers used a maximum likelihood extraction method with direct oblimin rotation on a correlation matrix (which shows the correlation coefficients between sets of variables) in order to reduce the number of items into meaningful factors and to demonstrate that the theoretical constructs were statistically supported.

3.1.1 Exploratory Factor Analysis Results for Organizational Constructs—

After reverse coding the negatively worded items, the EFA showed that the factors loaded into their original construct scales with loadings ranging from .524 to .876. There were no cross-loading items. Research suggests that the presence of at least three items sharing factor loadings of at least .40 is desirable, along with theoretical justification [53, 54]. Table 5 shows the factor pattern matrix of the organizational safety climate constructs.

Following the EFA, internal consistency was assessed for each of the survey construct factors. The Cronbach's alpha [55] ranged from .6 to .9. Specifically, organization support = .607; coworker communication support = .854; supervisor communication support = .936; worker engagement = .800; and training = .745. The resulting correlations between each of the constructs are shown in Table 6. The correlations ranged from .27 between organizational support and coworker support to .67 between worker engagement and supervisor support.

3.2 Statistical Analysis

Analyses were performed in the Statistical Package for the Social Sciences (SPSS), a software package used for complex statistical analysis of large datasets [56]. Mining sector (i.e., the independent variable) was used to predict each of the perceptual constructs (i.e., the dependent variable) in a unique regression equation. This means that five different regression equations were used, one for each of the perceptual constructs. Mining subsector was entered in the regression as a categorical independent variable with three levels (coal, industrial mineral, and SSG) where the coal subsector was set as the reference category.

These models provide a direct answer to the research question in that they estimate if the perceptions of miners working in the industrial mineral and SSG mining subsectors were significantly different from the subset of miners working in coal mines. Given that the data were slightly negatively skewed, a maximum likelihood robust estimation technique was used and numerous robustness checks were completed.

The data were also analyzed using an ordinary least squares regression, analysis of variance (ANOVA), through a generalized linear model assuming a gamma distribution, and by using an adjusted Wilcoxon rank sum test. Each of the alternative methods used to examine the robustness of results found the same pattern of significance. A significance level of < 0.05 was used to identify differences that were statistically significant.

3.2.1 Regression Results—

The means for each of the scales and the results of each of the regressions are reported in Table 7. The results suggest that the group of miners working in coal mines had significantly less favorable perceptions on each of the organizational climate constructs measured:

- Coal miners had a significantly lower mean perception of organizational support ($M = 3.86$) when compared to both industrial mineral ($M = 4.53$) and SSG ($M = 4.33$) ($p < 0.001$ in both cases).
- Coal miners also had a significantly less favorable perception of coworker communication support ($M = 4.79$) when compared to industrial mineral miners ($M = 5.05$) and SSG miners ($M = 5.09$) ($p < 0.001$ in both cases).
- Coal miners showed less favorable perceptions of supervisor communication support ($M = 4.58$) when compared to miners working in industrial minerals ($M = 4.88$).
- Coal miners reported significantly lower perceptions ($M = 4.14$) than miners in industrial minerals ($M = 4.64$) and those working in SSG ($M = 4.55$) ($p < 0.001$ in both cases).
- Coal miners had less favorable perceptions of training ($M = 4.78$) when compared to industrial minerals ($M = 5.32$) and SSG ($M = 5.09$) miners ($p < 0.001$ in both cases).

Within the regression results, *B*, the regression coefficient reflects the magnitude of the mean difference between coal miners' perceptions and those of the other two sectors. Given that these results were estimated using the variables untransformed, the difference shown represents the actual difference on the 6-point Likert scale used to measure each of the constructs. The mean differences between coal miners' perceptions and those of the other two subsectors ranged from 1/4 of a point (mean difference = 0.25 when comparing perceptions of supervisor communication support between coal miners and stone, sand and gravel miners) to 2/3 of a point (mean difference = 0.67 when comparing perceptions of organizational support between coal miners and industrial mineral miners).

4 Discussion

The results showed that miners who work in the coal subsector have significantly less favorable perceptions of their organization's safety climate, which assessed organizational support for safety and supervisor support for safety, as well as overall coworker support, worker engagement, and training adequacy. First, it is important to note when interpreting these results that, in general, the averages for each scale among each subsector were relatively high. That is, even though the coal subsector experienced lower averages, the averages tended to still be in the "somewhat agree" to "agree" range. Even so, with this trend in the results, it is important to consider that small differences on a perception scale can equate to meaningful differences in individual outcomes. For example, in another analysis using the same Likert-based scale, a one-point increase in a miner's risk avoidance resulted in a 34% decrease in near-miss probability [57]. This finding illustrates that just a one-point difference can have large, significant effects on worker outcomes. Therefore, even if coal miners' perceptions are only between one-quarter and two-thirds of a point lower than workers in other mining subsectors, these less favorable perceptions could have substantial implications on workers' decision-making on the job and should be further explored to identify ways to improve the effectiveness of HSMS practices to indirectly influence safety climate perceptions.

Additionally, because it has been argued that the development and diffusion of HSMS processes, specifically, risk-based processes, have been slow to take hold in the coal mining industry [21], the current results have important implications. The core components of commitment, participation, and communication between workers and supervisors have been argued to be critical aspects of implementation not just within a regulatory system [23–25], but also within proactive systems and intervention research (e.g., [58–60]) and should be further integrated in the US mining industry and its respective subsectors. In response, practical explanations for the significant differences between coal and the other two sectors are offered.

4.1 Size of Mining Worksites

One factor to consider and further study is the size of the mining companies and their respective work sites that participated. As shown earlier in Table 1, the average size of the coal mines that participated was much larger ($n = 207$) than the other two subsectors ($n = 101$ in industrial minerals and $n = 51$ for SSG). This lends questions to the topic of company size and whether size may impact the ability of companies to disseminate HSMS practices, policies, and processes effectively. Previous research has shown that safety management and organizational environments of smaller companies are often informal, and even ambiguous [61]. More specifically, Brooks [61] went on to argue that the HSMS in small companies do not compare to the complexity and coverage of those in larger organizations.

Additionally, larger mines often have more resources and can develop and implement complex, albeit bulky, management systems and other auditing approaches [62]. Even though they have more resources, larger mines often must resort to more routine regimes, limiting ranges of tasks and discretionary action taken by workers [63]. At these large mines with lower task diversity, accident rates have been lower [64]. However, even if accident rates are lower, the perceived safety climate may be lower too due to the lack of task autonomy and communication present on site. It is possible that the samples of large coal mines that participated are experiencing similar barriers described here. To that end, the "lack of complexity does not necessarily equate to lack of systematic safety management" ([61] p. 74). Following rules and processes so closely without the autonomy to deviate if necessary may hinder workers' enhanced involvement in H&S actions as well as letting certain risks go unnoticed or attended to onsite. In response, the coal industry may need to take a more conscious approach to being proactive on a daily basis by encouraging workers' participation in risk-based processes such as job task analyses, risk assessments, and workplace exams [21].

On the other side, many have postulated that smaller organizations should be able to communicate more effectively or develop proactive approaches from simple solutions disseminated through personal contact [65]. For example, in a safety culture mining assessment completed in Australia, smaller mines consistently showed more positive responses in all their employee groups, although the differences were less discernable in the supervisor group [63]. This led authors of the study to believe that the closer contact between worker groups can outweigh benefits of resources. Consequently, additional research that includes smaller coal mines may be necessary to further understand the results of the current study.

4.2 Prescriptive Versus Proactive Risk Management

Research has argued that prescriptive environments create a mentality toward compliance and can minimize the level of thinking that workers do on the job [21]. Particularly, prescriptive programs and standards do not emphasize aspects of worker performance (i.e., the human element) when determining safety processes [66]. Some level of safety management is always necessary, but for those workplaces in earlier stages of assessing and improving their safety climate, different techniques and approaches may be required as their HSMS matures [37]. Although the US coal mining industry has progressed toward a more risk-based systems approach, particularly using NMA's CORESafety framework [16], rules and regulations in the USA are still more prescriptive than other countries and should be considered regarding the current results.

Specifically, a comprehensive report of occupational health and safety systems in the UK determined that highly prescriptive regulations were limiting improvements in performance outcomes [67]. This report paved the way for more flexible HSMS internationally [68]. For example, in the UK, a safety maturity model was developed and has been used in collaboration with a standards-based safety management system in coal mining operations, where the focus is on continual improvement and effectiveness of the standards, rather than on pure compliance [37]. This model has been shown as a way of assurance to their HSMS standards. These efforts also had an immediate impact in Australia, and since the 1980s, their HSMS have become much more performance based to emphasize risk management [21, 68]. Therefore, it is important to consider whether differences in international HSMS standards should be considered and what we can glean for adoption in the USA.

Without going too in-depth on the differences between approaches that are proactive and risk-based versus those that are more prescriptive, the main takeaway is that approaches to health and safety management within mines are likely to vary based on a myriad of uncontrollable, organizational factors including size, current management, and even the economy. Future research should consider the maturity of a site's HSMS when doing safety climate research and vice versa. Safety climate/culture maturity models are common in the literature (e.g., [37, 69]) with research showing that, mine sites with fewer best practices require different strategies than those more advanced in their HSMS. Consequently, researchers designed a Risk Management Maturity (MIRM) chart that showed safety culture and HSMS must progress together to be most effective [70]. Additionally, OSHA [71] describes an HSMS as an evolving resource that varies based on the organization's size, complexity, hazard types, and even capital equipment, staff, and training. Because the coal mining industry is different in terms of complexity and hazard types, different controls and guidelines may be necessary, perhaps influencing the development and maturity of programs in place. Therefore, knowing the maturity of an HSMS or respective safety culture can inform progress in the other area. Also, discussing the current results and possible reasons for a significant difference among perceptions is not alone helpful for improving perceptions and processes. Rather, it is important to consider what and how coal mines can improve miners' experiences at work.

4.3 Improve Risk Management Processes

As previously discussed, the core component of cooperation, participation, and communication between workers and supervisors is a critical aspect of all regulatory HSMS as well as effective interventions and should be further integrated in the US coal mining industry. Specifically, personal commitment and responsibility to be safe should outweigh the emphasis on organizational demands of following written rules [72]. To that end, we highlight possible processes around organizational and supervisor support as well as improved mechanisms for worker engagement and communication. These are potential areas and ways to overcome barriers in which the coal subsector may be experiencing.

4.3.1 Prioritize Safety over Production—Production expectations from miners stemmed from one of the questions within the survey and is something that should be considered when gleaning the significant differences among mining commodities. The question asked workers to respond to the question "I often have impossible production pressures." All three sectors reported high levels of perceived production pressures with 61.8% responding in a "somewhat agree" to "strongly agree" format. Specifically, 18% of the sample somewhat agreed that they have impossible production pressures; 23.3% agreed, and 20.5% strongly agreed. Because production pressures are often set by a corporate level and filtered down to varying levels of leadership and eventually to the site-level workforce, it is expected that workers may contribute feelings of production priority over safety priority.

However, within coal mining and particularly after the series of mine disasters in 2006, miners discussed the challenges and priorities of meeting production quotas and that, meeting quotas was tied to making not only their supervisors happy but also their coworkers [73]. Such perceptions can lead to feelings of increased anxiety and risk-taking. For example, Brown and colleagues [74] found that during times of increased production, workers feel an intense need to meet quotas and as a result, neglect safety rules. A similar consensus has been supported in other studies. For example, one report indicated that a large percentage of continuous mining machine operators in underground coal mining believed that it was necessary to break the rules to get the job done [75]. Miners also reported feelings that their bonuses and jobs may be in danger if they followed safety rules due to a slowdown in production. However, another study within the US coal mining industry showed that an increase in enforcement following a workplace fatality led to a decline in severe accidents in the subsequent 2 years (without affecting production) [76].

Considering these findings, there are ways to proactively implement elements of an HSMS, in cooperation with rules and procedures, without sacrificing productivity or safety.

It is possible that perceived or actual pressures to produce may have been present when the current survey was distributed and could have contributed to varying perceptions of the safety climate. However, there have been successful changes in HSMS processes that have helped mitigate such pressures. Examples include limiting task diversity [64] and improving autonomy and communication [63]. Specifically, Yang [21] argued that worker participation in risk-based processes such as risk assessments and workplace exams can reveal some of these self-inflicted pressures in the workplace. Due to the varying but steadily decreasing demands for coal [77], organizational leadership must remain cognizant that when larger orders come in, continuing to emphasize safety over production is important.

4.3.2 Seek Out Employee Engagement Efforts—The possible influence of employee engagement in executing HSMS practices is an ongoing, active process. The level of engagement and responsibility that is effective among organizational systems will vary based on leadership structure and size. Haight and colleagues [78] indicated that, although most systems have an employee engagement or participation element within their HSMS, leaders often choose to engage employees differently. However, employees who are given an active role in developing and improving safe work practices have been more likely to identify safe practices on the job and encourage coworkers to follow safer practices [65]. This is particularly important because supervisors are not always present and corrective feedback from coworkers can significantly reduce the likelihood of accidents on the job [79].

Examples of effective interventions used by companies include the opportunities for experienced employees to mentor newer, more inexperienced employees; improving management commitment to safety by emphasizing one-on-one employee feedback; allowing employees to vote when making a new decision or procedure such as the use of new workplace gloves or hiring a new employee; and supervisors allowing the opportunity for employees to observe them and their work practices [41, 79, 80]. Obviously, some of these examples are more advanced. Importantly, showing an active, engaging approach to health and safety management has been associated with positive safety climate perceptions and outcomes among the workforce [81].

Regarding the current study, perhaps because coal mining tasks and environments are much more specific than those of other mining environments, finding opportunities for workers to engage in identifying and mitigating risks may be more difficult. Most mining-specific risks are generalized to that of the entire industry and as a result, there are limited types of training modules and assessments available for commodity-specific hazards. However, research in coal mining has shown that behavioral interventions have been more successful; if specific, key behaviors are identified and corrected in interventions [82]. As a result, the coal mining industry may benefit from focusing on and involving workers in key risks specific to just them and their tasks [83]. Specific to coal mining, it also appears that these more proactive practices may be missing considering previous research has identified coal mines as more reactive to safety issues [84].

In summary, these results showed significantly different perceptions among different mining sectors, providing an impetus for companies to think of ways to improve the execution of HSMS policies, procedures, and practices to consequently improve safety climate among the workforce. Specifically, because environmental factors such as size and economic demand are beyond industry control, practices around organizational commitment to safety and worker engagement are important considerations to improve system and safety performance.

4.4 Limitations

The results of this research must be considered within its current limitations. First, the sample was voluntary and based on one of convenience in the USA. Researchers did not determine and seek out companies who experienced an influx in incidents in recent years. Those who volunteered to participate likely already had a priority toward safety, which is probably in part why the sample was negatively skewed. Future research can aim to assess locations that have experienced more incidents, near misses, or fines and even benchmark changes in the perceived culture after such occurrences. Along these same lines, any responses provided by participants are subject to social desirability bias [85] and should be considered a limitation of the data. Additionally, researchers did not aim to demonstrate equivalence in demographic distributions among the subsectors, which could be another possible explanation for differences among the subsectors. However, other research has already examined the impact of various demographics in worker perceptions with varying levels of success (i.e., [23, 63], [86, 87]). That said, forthcoming research can look for significant differences in such demographics when determining potential, future interventions.

Finally, it is important to consider that the current study did not include all mining subsectors. A large safety culture initiative in the Australian mining industry surveyed coal and gold mine employees, who were consistently more negative than employees at coal mines, except for the hourly/contractor level, where gold miners were significantly more positive [62]. Specifically, in this study [62], the operator (hourly) group at the “coal face” revealed very negative trends on several of the safety culture factors, especially around job fatalism and the ability to achieve zero injuries. They also demonstrated much riskier patterns on the job. Therefore, initial support exists for similar perceptions of coal miners internationally regarding aspects of priority toward safety within the overall culture. However, this linkage needs to be explored more in-depth in an international study using the same research instrument.

5 Conclusions

Research has argued that, rather than trying to directly affect safety climate perceptions, it is more beneficial to change company safety policies, practices, and procedures (i.e., the HSMS) [88]. In other words, if a disaster were to occur, some may argue a negative culture existed. Although this could be the case it is more likely that there was a breakdown in existing policies or procedures. This study revealed through linear regressions, the interdependencies that may be present and further explored among safety climate, HSMS, and workers’ proactive practices on the job. Specifically, the current results showed that there are significantly lower perceptions of organizational safety climate measures among workers in the coal mining industry. Based on these significant differences, it is important to consider ways that existing HSMS can alter processes to improve the interpretation and execution of safe work practices [65]. Specifically, this paper outlined several potential barriers to implementing solutions in the coal mining industry. These potential barriers were followed by broad, effective implementation ideas in a few key areas around organizational commitment and engagement. Interventions to test the effectiveness of posed solutions are needed to ensure that tailored interventions can be successful for this commodity from both an implementation and adoption perspective.

Although this study focused on differences in organizational factors and can be addressed first through broader organizational interventions, it is possible that the coal mining industry may need to expand into personal-based factors when developing aspects of their HSMS as well. Specifically, another analysis of these results probing a different set of research questions found that personal constructs (e.g., risk tolerance, thoroughness, sense of control) had a relatively stronger effect on the behavioral outcomes when compared to the set of organizational constructs the authors measured [41]. So, there is value in organizations accounting for and responding to both situational and personal factors where possible. In most cases, addressing these situational and personal-based attributes could occur simultaneously to identify new ways to continually facilitate alignment between the HSMS and safety climate. Future applied research should address effective methods of fostering an HSMS that builds in practices and processes to address person-based factors and not only stress the priority of safety on the job.

These results offered connections between perceived safety climate and possible ways that the industry can proceed through an HSMS maturity model in improving their overall culture. Specifically, as discussed earlier, the maturity of an HSMS is often dependent on the resources available to the worksite and employees. Given the interdependencies of safety climate factors and HSMS elements, the results give direction that, if ample resources are not available and an HSMS is not mature yet, starting with aspects of leadership communication and coworker communication may not only be a resourceful first step but also one that is perceived as very impactful among the workforce. The results and discussion provide an opening for future inquiry about the differences in safety climate assessments and future HSMS development and implementation among mining subsectors. Assessing organizational safety climate or culture has been demonstrated as a useful tool for enabling ways to learn about and initiate a more proactive environment [81]. This study is no different. While challenging to create and use one measure, any safety climate tool can help recognize gaps in HSMS that are necessary to improve upon and subsequently can provide feedback to improve perceptions of the safety climate. As these results are further disseminated among the mining industry, it is hoped that the industry improves the monitoring, implementation, and evaluation of its site-specific health and safety practices. However, the ability to further capture changes in safety climate and culture as approaches to HSMS implementation change will be critical to further understand the impact on performance and incident outcomes in the mining industry.

Data Availability

Not available for public dissemination due to consent agreements with participating sites.

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Table 1

Comparison of common HSMS programs (adapted from [16, 20])

Elements of comparison	CORESafety	OHSAS 18001	ANSI Z10	OSHA VPP	UK Coal SMS
Leadership development	X			X	X
Responsibility and accountability	X	X	X		X
Risk management	X	X	X	X	X
Emergency management	X	X	X	Partial	X
Training	X	X	X	Partial	X
Culture enhancement	X				
Communication and collaboration	X	X	X		X
Reinforcement and recognition	X	Intervals	Intervals	Annually	
Change management	X	X		X	X
Resources and planning	X	X			X
Work procedures and permits	X	X	X	X	
Occupational health	X	X	X	X	
Incident investigation	X	X	X	X	X
Behavior optimization	X				
Engineering and construction	X	X	X		
Contractor management	X	X	X		
Assurance	X	X	X	X	X
Documentation and information management	X	X	X		X

Table 2

Breakdown of participation by mining subsector

Mining subsector	Survey count	% of sample	Range of participants per site	Average participants at each site	Mine count
Coal	620	21%	78–280	207	3
Industrial minerals	907	31%	22–244	101	9
SSG	1418	48%	7–127	51	28

Table 3

Time in the mining industry for coal miners versus other miners

Mine subsector	Coal miners	Percent	SSG miners	Percent	Industrial mineral miners	Percent
Under 1 year	59	9.7%	149	11%	68	7.8%
1–5 years	136	22.3%	224	16.6%	164	18.8%
6–10 years	179	29.3%	177	13.1%	158	18.1%
11–15 years	103	16.9%	210	15.5%	120	13.7%
16–20 years	44	7.2%	146	10.8%	82	9.4%
More than 20 years	89	14.6%	445	32.9%	282	32.3%

Table 4

Demographic characteristics of participants

Demographic characteristics	Survey count	Percent
Gender (74 missing)		
Male	2681	93.4
Female	190	6.6
Job classification (98 missing)		
Salaried	584	20.5
Hourly	2263	79.5
Age range (81 missing)		
18–24	143	5.0
25–34	585	20.4
35–44	678	23.7
45–54	798	27.9
55–64	597	20.8
65+	63	2.2
Highest level of education (82 missing)		
Less than high school	78	2.7
High school	1686	58.9
Associate degree/trade certificate	772	27.0
Bachelor’s degree	254	8.9
Master’s degree or higher	73	2.5
Job schedule (92 missing)		
Set shift	2015	70.6
Rotating shift	838	29.4

* Researchers did not aim to demonstrate equivalence in demographic distributions among the subsectors. Rather, this study sought to address differences among mined sectors

Table 5

Factor pattern matrix of organizational safety climate survey constructs*

Survey items	Organizational support	Coworker support	Supervisor support	Worker engagement	Training adequacy
Rules/procedures are sometimes ignored.	0.726				
It does not matter how the work is done as long as there are no accidents.	0.749				
I often have impossible production pressures.	0.675				
Everyone in my crew has confidence in each other to work safely.		0.876			
Everyone in my crew helps each other with problems at work.		0.870			
Everyone in my crew informs each other about potential workplace hazards.		0.832			
My supervisors try to help me do my job as safely as possible.			0.708		
My supervisors help me if I have a problem at work.			0.719		
My supervisors remind me to follow rules.			0.818		
My supervisors closely monitor my work practices.			0.830		
My supervisors take action if I do not follow work practices.			0.727		
My supervisors clearly explain rules to me.			0.836		
My supervisors inform me of work hazards specific to my job.			0.848		
My supervisors encourage communication about problems.			0.777		
I am satisfied with my supervisor.			0.731		
The same rules apply to all employees.				0.524	
I can question the rules/procedures that influence my work.				0.836	
My supervisor makes sure that our concerns are heard before making any new rules or procedures.				0.604	
I am involved in improving rules and procedures.				0.744	
This site provides enough training for me to do my job.					0.858
Training helps me do my job as health/safely as I can.					0.798
Training is not a priority here.					0.570

Factor loadings under 0.40 were suppressed from the table

Table 6

Correlations between organizational safety climate constructs used in the current study

Health and safety construct	1	2	3	4
1. Organizational support				
2. Supervisor support	0.39			
3. Coworker communication	0.27	0.49		
4. Worker engagement	0.37	0.67	0.44	
5. Adequacy of training	0.44	0.60	0.41	0.55

All correlations are significant at the $p < 0.01$ level

Table 7

Regression results comparing the coal subsector to SSG and industrial minerals

Health and safety construct	Mining subsector	Mean	*B*	Std. error	Wald Chi-square	*p* value
Organizational support	SSG	4.33	0.47	0.06	70.29	< 0.001
	Industrial mineral	4.53	0.67	0.06	125.75	< 0.001
	Coal	3.86	Reference group			
Coworker communication	SSG	5.09	0.30	0.05	38.42	< 0.001
	Industrial mineral	5.05	0.26	0.05	24.66	< 0.001
	Coal	4.79	Reference group			
Supervisor support	SSG	4.83	0.25	0.05	25.77	< 0.001
	Industrial mineral	4.88	0.30	0.05	29.78	< 0.001
	Coal	4.58	Reference group			
Worker engagement	SSG	4.55	0.41	0.06	48.81	< 0.001
	Industrial mineral	4.64	0.50	0.06	66.43	< 0.001
	Coal	4.14	Reference group			
Adequacy of training	SSG	5.09	0.31	0.05	36.78	< 0.001
	Industrial mineral	5.32	0.54	0.05	104.59	< 0.001
	Coal	4.78	Reference group			

B is the unstandardized regression coefficient. Std. error is the standard error for the regression coefficient. Wald Chi-square is the test statistic for the regression coefficient derived from the maximum likelihood, robust regression. The *p* value is the probability value for the regression coefficient