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Organizational factors and risk management in the mining industry: an updated systematic literature review

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Abstract

Organizational factors are considered part of the broader human factors domain and have long been suspected to have a significant influence on individual and group behavior in the workplace, although there is little research on their influence in mining workplaces. This paper provides an update of a systematic literature review (SLR), reported according to the Preferred Reporting Items for Systematic Review and Meta-Analysis: The PRISMA Statement 2009. The SLR examined the relationship between organizational factors and residual risk management in the context of accident causation in mining. Six electronic databases were searched for peer-reviewed studies published between 1980 and 2018. Following eligibility criteria, 28 studies were selected for quality assessment and reviewed. The results of the SLR included the identification of several organizational factors that are common in the mining industry, as well as the existence of a conceptual relationship between organizational factors, residual risk management and accident causation. The SLR also identified research gaps associated with the lack of empirical research around the topic. In light of these gaps, further research is recommended to examine the nature and extent of the influence of organizational factors on residual risk management, with particular focus on examining the influence of organizational factors on the functioning and effectiveness of risk controls. It is envisaged that by improving the efficacy of risk controls, mining companies can ultimately improve their safety performance and make it more sustainable.

1. INTRODUCTION

1.1. Rationale

Mining companies carry an obligation to conduct their operations in a safe and sustainable manner. The International Council on Mining and Metals (ICMM) reports that its members are committed to safe and sustainable mining by ensuring that health and safety is at the center of all operations and processes (International Council on Mining & Metals, 2019). Despite these commitments and undertakings from industry bodies such as the ICMM, serious accidents continue to occur in the mining industry (Aliabadi, Aghaei, Kalatpour, Soltanian, & SeyedTabib, 2018; Department of Mines and Petroleum, 2016; Dragan, Georges, & Mustafa, 2017). Effective risk management strategies have been identified as the keystone for accident prevention in the mining industry (Department of Natural Resources and Mines, 2017; International Council on Mining & Metals, 2019). The mining industry applies a suite of risk management strategies that are often categorized as “the hierarchy of controls” (Horberry, Burgess-Limerick, & Fuller, 2013). More recently, stakeholders including regulators in the mining industry have advocated for an approach that recognizes the centrality of humans in the design, implementation and operation of critical controls (Mason, 2016). According to this approach, human factors (HF) are recognized as possible contributors to workplace accidents, especially during accident investigation and in subsequent risk management processes. The work of Reason (1990, 1997, 2008, 2016) on active and latent failures illustrates the contribution of human attributes and fallibility on accident causation and often provides the basis for investigating human factors in complex high-risk industries.

The Health and Safety Executive (HSE), a regulatory body in the United Kingdom (UK) defines HF as *environmental, organizational and job factors*, *including human and individual characteristics, which influence workplace behavior in a way which can affect health and safety* (Health and Safety Executive, 2009, p. 5). HF are now widely recognized as important contributory factors in accident causation with calls to sufficiently investigate their influence as root-causes to workplace accidents (NOPSEMA, 2015). HF, by their very nature, are complex and therefore require careful consideration if their understanding is to be harnessed to improve safety performance in mining. The practice of assigning ineffective controls to identified safety-related risks or the failure to address deficiencies in risk controls following accident investigations is not uncommon in mining. Repeat or recurrent accidents regularly occur in the mining industry (Department of Mines and Petroleum, 2016), indicating a deficiency in critical control management (pre-event) and during accident investigation processes (post-event).

The HF definition includes interrelated aspects that should be considered when examining HF in sociotechnical systems. These aspects can be divided into four major categories: job factors, individual factors, environmental factors and organizational factors (NOPSEMA, 2015). Despite having a significant influence on individual and group behavior, the Health and Safety Executive (2009) suggested that organizational factors are often overlooked during accident investigations. In their review of the role of behavioral factors on safety management in underground mines, Paul and Maiti (2007, p. 451) also acknowledged the increasing importance of organizational factors as “antecedents to the sequence of an injury”. Other industry stakeholders, including regulators (Mason, 2016) also concur and advocate for a better understanding of organizational issues in order to create safe and sustainable workplace cultures (Hopkins, 2006; Taylor, 2010).

Industry experience and research have shown that organizational factors in complex socio-technical systems can be divided into several attributes such as organizational safety culture, standards and procedures, training and competence, safety-critical communication, resource allocation, decision-making, safety leadership and organizational learning (Cooper, 2002; Health and Safety Executive, 2005). Following this approach, this updated systematic literature review (SLR) sought to identify organizational factors that are prevalent in the mining industry and examine their relationship with other variables such as residual risk management, accident causation, repeat accidents and critical controls. As lagging indicators, repeat or recurrent accidents are themselves a measure of how well mining companies manage their safety-related residual risk. When companies experience repeat accidents, it implies that the risk controls or barriers implemented by the organization to mitigate against residual risk have failed, are ineffective or ill-targeted (International Council on Mining & Metals, 2013; Wilkinson & Petrie, 2014). This assumption is crucial in understanding the importance of improving risk controls and any practices related to residual risk management as a means of achieving sustainable safety performance in the mining industry. Therefore, the scope of the SLR included the relationships between human factors (in general), organizational factors (in particular) and residual risk management in so far as accident causation in the mining industry is concerned.

This SLR is an update of a previously published SLR on a similar topic, entitled: *Organizational Factors, Residual Risk Management and Accident Causation in the Mining Industry: A Systematic Literature Review* (Nyoni, Pillay, Rubin, & Jefferies, 2018). Similarly, it is being reported according to the Preferred Reporting Items for Systematic Review and Meta-Analysis: The PRISMA Statement 2009 (Moher, Liberati, Tetzlaff, & Altman, 2009). The previous published SLR did not present detailed results as it was still under development. In contrast, this updated SLR presents full results of the SLR and elaborates on research gaps thus providing a clearer agenda for future research efforts.

1.2. Objectives

The main objective of the SLR was to examine the relationship between organizational factors, residual risk and accident causation, including how these variables relate to the overall safety management processes in the mining industry. Specifically, the SLR sought to answer the following research questions:

a) What is the relationship between organizational factors and accident causation in the mining industry?

b) What is the relationship between organizational factors and residual risk management in the mining industry?

c) What are the critical controls used to address organizational factors in the mining industry? Critical controls may also be error risk controls used to address human factors issues in the mining industry.

2. METHODOLOGY

A review protocol (Nyoni, Pillay, Rubin, & Jefferies, 2019) was developed to guide the SLR and is publicly accessible using the following link https://doi.org/10.24840/2184-0954_003.002_0005 Consequently, similar details regarding the methodology such as eligibility criteria, information sources, search strategy, study selection, data collection processes, data items and risk of bias (Moher et al., 2009) have been left out of this SLR publication to avoid repetition. No aspects of the research methods were modified between the published protocol (hereinafter referred to as the SLR protocol) and the conduct of this SLR.

3. RESULTS

3.1. Study selection

Scopus yielded 222 article records while Web of Science and Proquest yielded 16 and 5 article records, respectively. The rest of the databases did not yield any results. A sum of 244 records were identified from the selected databases and online information sources using the literature search strategy described in section 2.6 of the SLR protocol. Figure 1 presents the results of the study selection, showing exclusions made, both at abstract and full-text screening, in accordance with the eligibility criteria described in the SLR protocol.

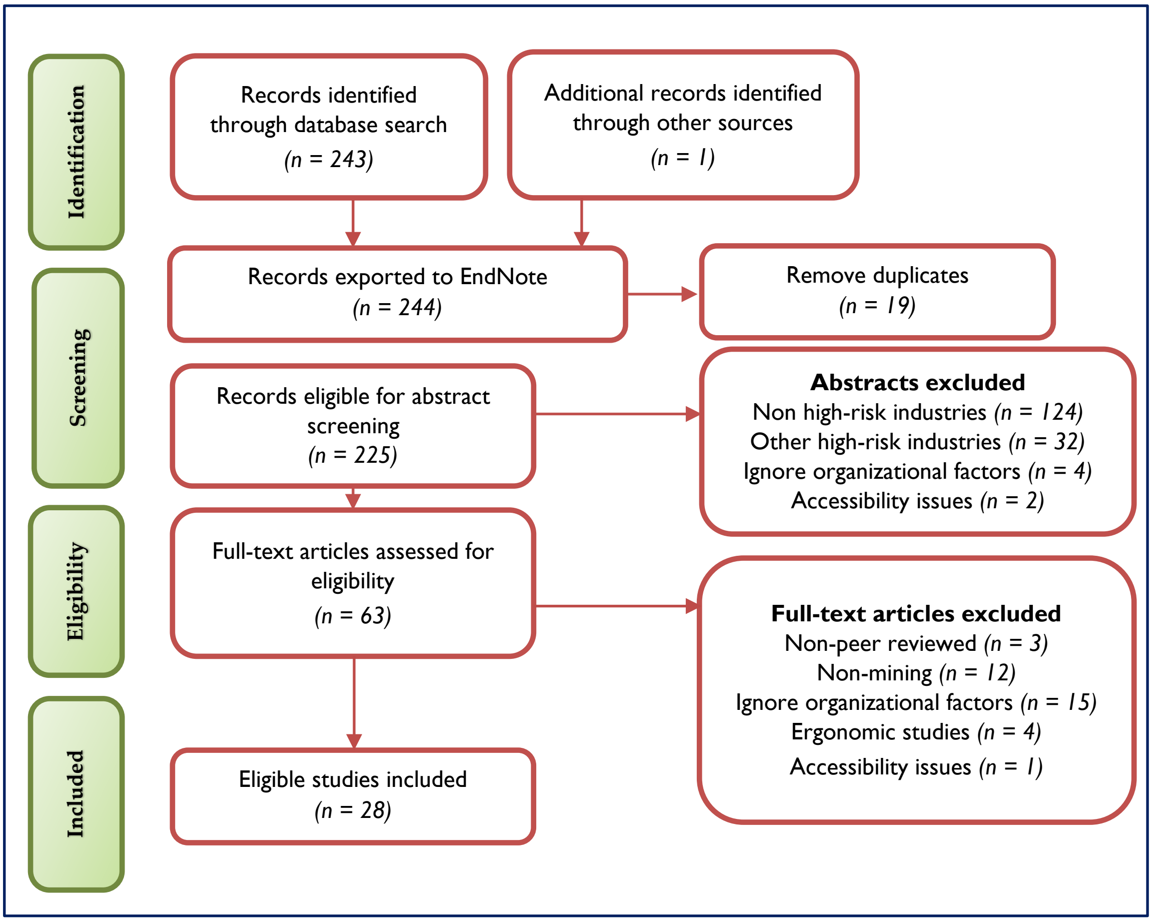

Figure 1. Results of study selection

3.2. Study characteristics

Table 1 summarizes the study characteristics with respect to research designs. Although some studies overlapped in design characteristics, 61% of the studies were based on unobtrusive research methods that include historical research designs (Bhattacharya, 2012b; University of Southern California, 2018) and reviews. The studies based on historical research designs typically involved collecting and analyzing secondary data such as official accident records, reports and archives in order to develop and interpret trends in mining accidents.

Table 1. Summary of study characteristics

Type of Design	Number of studies
Historical research	17
Cross-sectional	1
Descriptive	2
Case study	3
Cohort	1
Longitudinal	1
Literature review	1
Conceptual	1
Observational	1

Consequently, the ratio of studies that utilized secondary to primary data collection methods was 3 to 1. This feature raises questions of validity and trustworthiness regarding any inferences made in those studies utilizing secondary data since the methods and tools used to collect the secondary information are often subject to debate and controversy (du Preez, 2016). A review of the issues surrounding measurement and reporting of work health and safety performance to regulators in Australia by O'Neill, Martinov-Bennie, and Cheung (2013) identified selective and inconsistent reporting of safety information by organizations. The Queensland Department of Natural Resources and Mines (2017, p. 12) also cited "poor quality" safety data reported by mining companies to its Mines Inspectorate unit, as a limiting factor to rigorous data analysis. This trend generally raises skepticism regarding quality and credibility of inferences made as a result of secondary data analysis utilizing statistics collected from government regulators. Furthermore, a poor reporting system is normally an indication of an ineffective safety management system and forms part of organizational attributes as suggested by Hsu, Lee, Wu, and Takano (2008).

Another problem associated with the high number of studies utilizing secondary data is the lack of empirical research examining how organizational factors actually influence accident causation in the mining industry. This review found out that 68% of eligible studies relied upon non-empirical data in their analyses. These studies were either analyses of accident statistics from government regulators or simply theoretical papers reviewing organizational factors in the mining industry. Notwithstanding the value of secondary data analysis (Bhattacharya, 2012a; Smith, 2008), particularly in exposing accident trends and identifying causes, lack of empirical research exploring the relationship between organizational factors, residual risk and accident causation deprives the mining industry of objective and verifiable data that can be used to inform interventions and behavioral programs aimed at improving safety performance in mining workplaces. Empirical research is also likely to provide answers to questions related to *why* and *how* organizational factors, commonly categorized as latent failures in accident investigations (Lenné, Salmon, Liu, & Trotter, 2012; Reason, 1997), contribute to the erosion of risk controls or barriers leading to workplace accidents.

Figure 2 shows the distribution of eligible studies based on the type of industry and industry sub-sector. From this categorization, 36% of eligible studies focused on coal mining while 14% covered multiple high-risk industries such as nuclear, transportation and manufacturing including mining. Only 1 study focused solely on metalliferous mining while 36% covered general mining and had no specific scope in terms of industry sub-sector. Based on this distribution, it is evident that research concerning organizational factors in the mining industry has focused more on coal mining than other sub-sectors such as metalliferous mining and quarrying. Although there is no scientific evidence to explain this trend, it is widely accepted that coal mining historically accounts for accidents with extreme severity, often classified as disasters in which multiple fatalities are recorded (Pons, 2016). Consequently, interest from researchers and scholars could be informed by the need to address the social phenomena (applied research) or to inform government policy (policy research). Contextually, the review also found that of the 36% studies that focused on coal mining, 50% of those studies concerned the Chinese coal mining industry. This finding reflects the attention researchers in China have given the coal mining industry in China as a means for influencing government policy (Yin et al., 2017). Furthermore, Yunxiao and Yangke (2014) support this claim by stating that China accounts for over 80% of fatalities in the world's coal mining sector. Evidently, differences in context and geographical regions are likely to influence safety-risk management practices and in particular organizational factors, including the attention stakeholders affords safety-related research (Hsu et al., 2008).

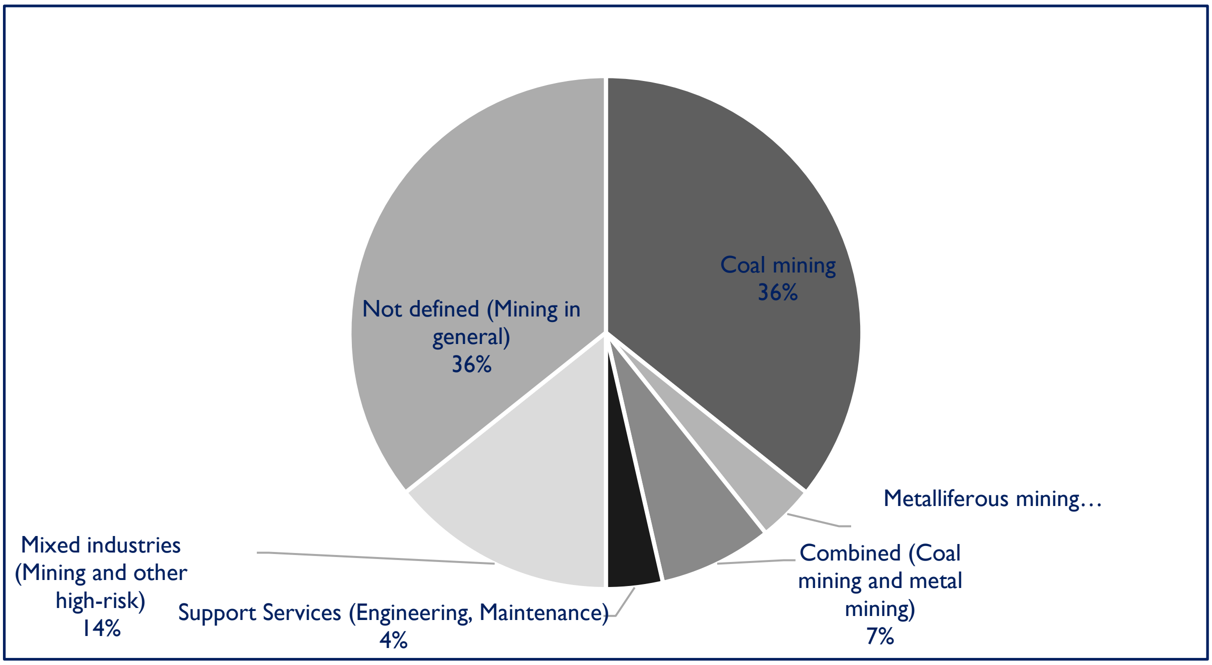

Figure 2: Distribution of studies by industry sub-group

3.3. Study characteristics

The results of the quality appraisal using the Mixed Methods Appraisal Tool (MMAT) are shown in Table 2. The results show that most qualitative studies lacked methodological rigor as evidenced by the inadequacy of data collection methods in addressing the research questions. In addition, gaps were also observed regarding the analysis and interpretation of some qualitative data. Quantitative studies exhibited more rigor compared to qualitative studies. However, a significantly high number of quantitative studies (>50%) failed to address the risk of bias. Similarly, mixed methods studies had limited information regarding how they addressed issues of quality. Consequently, it was difficult to evaluate whether the research design adequately addressed the research questions.

3.4. Results of individual studies

Appendix 1 presents results of individual studies as captured in the data extraction form. Non-empirical studies constituted 68% of the eligible studies while the remaining empirical studies were split between 4 qualitative studies and 5 studies that utilized a mixed methods approach. All qualitative studies were based on theoretical frameworks that principally shaped the methodological approaches. For instance, Dodshon and Hassall (2017) acknowledged that the theoretical biases contained in their literature review informed the survey tools used to collect practitioners' perspectives on accident investigation. Prior to examining human factors in mining accidents, Caples (1998) also stated their own theoretical biases and accident causation models including a model for understanding how human factors affect an accident sequence. Consequently, it was observed that qualitative studies that were built around a theoretical framework articulated the relationship between organizational factors and accident causation more succinctly. Not only is this consistent with qualitative research practice, but also important for designing future empirical research around organizational factors in the mining industry.

Table 2. Outcomes of the Quality Appraisal using the MMAT (Hong et al., 2018)

Qualitative								
Study ID	**Author/s**	**S1**	**S2**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Caples, (1998)	Y	Y	Y	C	C	C	C
2	Dodshon, and Hassall, (2017)	Y	Y	Y	Y	Y	Y	Y
3	Mallett, Vaught and Brnich (1993)	Y	Y	Y	C	C	C	C
4	Peters, and Wiehagen, (1988)	Y	Y	Y	Y	Y	Y	Y
Quantitative								
Study ID	**Author**	**S1**	**S2**	**B1**	**B2**	**B3**	**B4**	**B5**
1	Chen, et al. (2012)	Y	Y	Y	C	C	C	Y
2	Drury, Porter and Dempsey, (2012)	Y	Y	Y	Y	Y	C	Y
3	Ghosh, Bhattacherjee and Chau, (2004)	Y	Y	Y	Y	Y	Y	Y
4	Lenné, et al. (2012)	Y	Y	Y	Y	Y	Y	Y
5	Li, J., Li, Y., and Liu, (2015)	Y	Y	Y	Y	Y	C	C
6	Nasarwanji, (2016)	Y	Y	Y	Y	Y	Y	Y
7	Patterson, and Shappell, (2010)	Y	Y	Y	Y	Y	Y	Y
8	Ruckart, and Burgess, (2007)	Y	Y	Y	Y	Y	Y	Y
9	Uchino, and Inoue, (1999)	Y	Y	N	C	C	C	C
10	Verma, and Chaudhari, (2017)	Y	Y	Y	Y	Y	Y	Y
11	Yin, et al. (2017)	Y	Y	Y	Y	Y	C	Y
12	Yunxiao, and Yangke. (2014)	Y	Y	Y	Y	Y	C	Y
13	Aliabadi, et al. (2018)	Y	Y	Y	Y	Y	Y	Y
Mixed Methods								
Study ID	**Author**	**S1**	**S2**	**C1**	**C2**	**C3**	**C4**	**C5**
1	Aalipour, and Barabadi, (2015)	Y	Y	C	Y	Y	Y	C
2	Donovan, et al. (2017)	Y	Y	C	Y	Y	Y	Y
3	Paul, and Maiti, (2007)	Y	Y	C	Y	Y	Y	Y
4	Yulianto, Haramaini and Siregar, (2015)	Y	Y	N	Y	Y	Y	C

Key
Y Yes
N No
C Cannot Tell. Limited information to be able to make a judgement

3.5. Relationship between variables

Three variables whose relationships with organizational factors were of interest in this review were residual risk, risk controls and accident causation. Figure 3 illustrates these relationships using a basic Venn diagram.

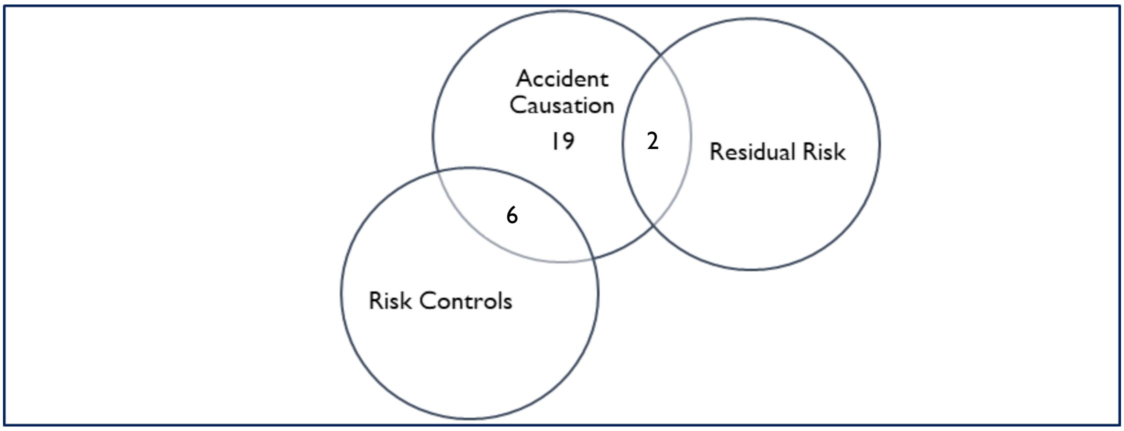

Figure 3. Relationship between variables

Taking each shape to represent studies that featured some form of relationship between organizational factors and the variable, it is evident that about two-thirds of the reviewed studies acknowledged a linkage between organizational factors and accident causation. In particular, six studies (Aliabadi et al., 2018; Lenné et al., 2012; Patterson & Shappell, 2010; Verma & Chaudhari, 2017; Yulianto, Haramaini, & Siregar, 2015; Yunxiao & Yangke, 2014) investigated accident causation using HF tools such as the human factors analysis and classification system (HFACS) developed by Wiegmann and Shappell (2007), including a modified (HFACS-MI) tailored for the mining industry. The major outcomes of the accident analyses using the HFACS tool included the identification of organizational factors as causes or contributory factors of accidents in the mining industry. Commonly cited organizational factors in the analyses included supervision, organizational processes, organizational climate, communication, unsafe leadership and resources management (Lenné et al., 2012; Patterson & Shappell, 2010).

According to Caples (1998), organizational factors or latent failures determine the adequacy or robustness of defenses or risk controls, whose failure or inefficacy would typically result in an incident. Out of the 19 studies that acknowledged a relationship between organizational factors and accident causation, 6 also reviewed the impact of risk controls or barriers in accident prevention. This tripartite relationship is critical in so far as understanding the influence of organizational factors and other latent conditions on risk controls is concerned. The work of Reason (1998, 2016) using the Swiss Cheese Model (SCM) also emphasizes the importance of barriers that address latent failures associated with the organization.

Although 2 studies explored the relationship between organizational factors, accident causation and risk (in general), none of the studies were empirical. Further, the 2 studies utilized the term risk to loosely refer to aspects of risk management practices, for example, failure to conduct adequate risk assessments (Patterson & Shappell, 2010). Evidently, the term *residual risk* is not popular in published literature as it was not used in any of the studies. Although there is no anecdotal evidence to suggest that the adoption and use of the term *residual risk* would in practice, result in improvements in safety performance of mining companies, understanding residual risk has the potential to direct focus towards control effectiveness as guided by the concept of acceptable risk (Manuele, 2010). Despite the importance of the relationship between organizational factors, accident causation and residual risk, it is also important to note that 32% of eligible articles did not discuss any relationship between organization factors and these variables of interest. The implication of isolated and fragmented research around these key variables is that mining companies are deprived of potentially valuable information associated with the failure of risk controls.

3.6. Organizational factors in the mining industry

Of the 28 studies reviewed, 27 identified a list of organizational factors and attributes either exclusively or as part of the broader human factors. Using guidance from the UK Health and Safety Executive (2009, 2018) regarding human factors and organizational factors in socio-technical systems, an attempt was made by the authors to categorize the organizational factors and attributes mentioned in line with traditional industry nomenclature on HF (Davoudian, Wu, & Apostolakis, 1994; Health and Safety Executive, 2018; Reason, 1997, 1998). Table 3 summarizes the list of organizational factors and attributes identified by the 27 studies.

Following the identification of organizational factors that are influential in the mining industry, it was also evident that researchers and scholars have not gone a step further to investigate the extent of this influence. In the only study that attempted to examine this influence, Aliabadi et al. (2018) used quantitative analyses as a way of determining the effects of human and organizational deficiencies on workers' safety behavior at an iron ore mine site in Iran. The study also found that supervision significantly influenced workers' violations and workers' errors (Aliabadi et al., 2018). Although human error was not a variable of interest in this SLR, findings such as the effect of supervision on workers' behavior provide crucial insights into how latent failures may interact with active errors (workers' violations and errors) resulting in workplace accidents.

Table 3. Organizational factors and attributes common in mining industry

Organizational Factors and Attributes	Number of Studies
Safety culture (including safety climate)	14
Safety critical communication	12
Leadership (including safety and operational leadership)	10
Procedures and Standards (including management violations)	8
Supervision (Middle level and front-line)	7
Risk perception (including risk-taking behaviors)	6
Management decisions (including commitment and errors)	5
Resource management and allocation	3
Organizational learning (Learning from past incidents)	2
Training and competence (including skill-based errors)	2
Shift work patterns	1

4. DISCUSSION

4.1. Summary of evidence

The SLR identified several organizational factors and attributes, listed in Table 3, associated with accident causation in the mining industry. Most of these organizational factors and attributes were identified through system-based accident analysis models such as the HFACS and HFACS-MI using existing data from government repository and archives such as regulators. The recognition of organizational factors as contributing or causal agents to accidents is vital in shifting industry focus regarding accident investigation from a person-oriented approach (Patterson & Shappell, 2010) to a systems or organizational approach (Dekker, 2002; Patterson & Shappell, 2010). As argued by Patterson and Shappell (2010), a systems or organizational approach to accident investigation enables the identification of root-causes of accidents thereby providing mining companies with improved opportunities in preventing repeat accidents, and ultimately improving safety performance. Although the issue of repeat accidents has not been adequately researched in the mining industry, they continue to limit the success of workplace safety strategies and hence should be the focus of mining companies. In the mining industry, it is generally accepted that repeat accidents are a result of failure to adequately identify and control risks (International Council on Mining & Metals, 2013; Wilkinson & Petrie, 2014). This is evident in a post-event analysis of four fatal mining accidents commissioned by the Mines Safety Advisory Council (MSAC) in New South Wales (NSW) Australia, which made similar findings regarding the relationship between risk control failure and accident causation before recommending greater focus on risk control implementation and effectiveness (Dodshon & Hassall, 2017; Wilkinson & Petrie, 2014).

Concerning study characteristics, the SLR found a limited number of empirical studies that focused on the relationship between organizational factors and the variables of interest (accident causation, residual risk and risk controls). The lack of empirical studies on this crucial relationship exposes a research gap that requires attention. More importantly, lack of empirical qualitative research on this relationship deprives the mining industry of much-needed meanings behind the statistics and trends of lagging indicators such as injury frequencies and unsafe acts. As argued by most qualitative researchers (Leavy, 2017; Lincoln & Guba, 1985), empirical qualitative research in naturalistic settings can produce rich and meaningful insights in understanding why people do what they do. Although some isolated work on reviewing the role of human factors in mining accidents using accident analysis tools such as HFACS (Patterson & Shappell, 2010) has previously been done, more research is required to understand and address how organizational factors such as supervision, leadership, management commitment, resource allocation, safety-critical communication and safety culture influence the effectiveness of risk controls. Conceptually, such research would shed more light into how organizational factors contribute to the erosion of risk controls that subsequently leads to the initiation of unwanted events.

Although organizational factors somehow overlap in their influence, it would be worthwhile to also investigate the most influential factors or attributes such as supervision, safety culture and safety-critical communication and seek to develop conceptual models on the inter-relationships between the attributes. Furthermore, information about these relationships is even more crucial as mining companies shift towards risk-based safety management systems. Risk-based safety management systems require mining companies to prioritize their efforts and resources according to risk level. For instance, if, through empirical research, it is found that supervision significantly contributes to the erosion of risk controls, mining companies could be urged to invest more in strategies that improve operational supervision. Future research should therefore be guided by the need improve the efficacy of risk controls within the framework of organizational factors.

4.2. Research gaps and future research agenda

The SLR identified several research gaps that offer opportunities for further research. A summary of the research gaps outlined below will inform the direction and agenda of any future research around the topic:

a) *Organizational factors contribute to accident causation.* Over two-thirds of the studies reviewed acknowledged an existing relationship between organizational factors and accident causation in the mining industry. Although several studies used the HFACS to reveal this association, no study further examined the relationship to understand how organizational factors achieve this contribution in mining workplaces.
b) *Organisational factors and residual risk.* Only 2 out of 28 studies explored a somewhat less coherent relationship between organizational factors, residual risk and its management. Furthermore, no study referred to the concept of residual risk despite its significance in understanding the failure of risk controls in mining workplaces.
c) *Lack of empirical research in metalliferous mining.* Comparing the different mining sub-groups, metalliferous mining received less research attention compared to other sub-groups such as coal mining and quarries. This is despite its significant contribution to workplace injuries as reported by various state regulators in Australia (Department of Mines and Petroleum, 2016; du Preez, 2016).

Given the research gaps identified by the SLR, it is crucial for the research community to partner with the mining industry in seeking deeper insights into the role and contribution of organizational factors on residual risk management. Hopkins (2006) suggests using ethnographic techniques for such empirical research that seeks to understand how organizational attributes influence workplace safety. Ethnographic techniques would typically allow the researcher to immerse themselves into the natural settings of mining employees (Glendon & Stanton, 2000; Nævestad, 2009), thus enabling the researcher to gain deeper insights into the shared assumptions and meanings underlying how they view and manage residual risk. This approach is also likely to illuminate the influence of organizational factors on these shared basic assumptions, which in turn determines how mining employees view, approach, manage or control residual risk. By understanding failure mechanisms of residual risk controls from this interpretive perspective (Glendon & Stanton, 2000) in natural settings, the mining industry's current efforts of improving safety performance through safety-cultural initiatives would be enhanced.

5. CONCLUSIONS

Through the outcomes of this review, it is now possible to focus further empirical research towards understanding the relationship between organizational factors and key variables such as residual risk and accident causation. Although the relationship between organizational factors and accident causation is apparent as evidenced by studies that have identified organizational factors as contributing factors to mining accidents, the linkage between organizational factors and residual risk management in the mining industry still lacks scientific backing. Evidently, the lack of empirical research provides an opportunity to conduct qualitative empirical research focusing on the *'how and why'* thus adding to an in-depth understanding of human behavior in the workplace as influenced by organizational attributes. The identification of factors such as supervision, leadership, safety culture and communication also provide direction of focus towards the influential organizational factors that could be investigated further in order to determine the extent or magnitude of influence including prioritizing those factors for intervention programs in mining operations. Conceptually, it is clear that attributes such as safety culture, supervision, leadership, safety-critical communication, resource allocation and management decisions usually overlap in their influence on shaping how risk controls are designed, implemented and maintained in an organization. Critical control management is an important subject for mining companies, despite the lack of clarity from published literature. Mining regulators and industry bodies emphasize its significance in accident prevention and should therefore form part of the relationships requiring further research. These relationships could be used to inform theoretical models around the role and contribution of organizational factors (viewed as part of workplace interactions) on the management of residual risk. This approach is compatible with using ethnography as a research methodology since it allows for qualitative research frameworks such as symbolic interactionism (SI) to guide the research process. From a HF perspective, organizational factors or attributes such as supervision, leadership, communication, resource allocation, management decisions and commitment, including their interrelationships, all constitute interactions at the workplace. Therefore, by examining these factors and their relationships through the lens of SI, a deeper insight into how they influence residual risk management practices at the workplace can be achieved. Consequently, mining organizations can utilize the rich and insightful data from ethnographic studies to gain a full appreciation of the safety statistics that have been accumulated for decades. Ultimately, this in-depth understanding and knowledge of the influence of organizational factors on residual risk management should assist mining companies to improve the effectiveness of risk controls and foster sustainable safety cultures.

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Appendix 1. Results of individual studies

ID	Author(s)	Study Design	Sub-Themes	Industry	Sub-group	Condition being studied	Identified Organisational Factors	Variables of interest		
								OF vs AC	**OF vs RR**	**RC**
1.	Aalipour, and Barabadi, (2015)	Case Study Questionnaire survey Literature survey Consultation with mining experts	Workplace Safety, Operational performance	Mining	Engineering/ Workshops	Maintenance of mining equipment, Workplace factors	Documentation, Communications, Safety culture, Boss Decisions, Duties &Responsibilities, Contract, Salary, Breaks, Safety	No	No	No
2.	Caples, (1998)	Historical research design Qualitative research Literature Review	Accident causation, Human Factors	Mining	Australian mining	Accident causation, Human Factors, Organisational Factors, Human error and fallibility, Incident Investigation	Safety culture, Supervision, Culture of "undiscussables", Communication	Yes	No	Yes
3.	Chen, et al. (2012)	Historical research design Statistical analysis Secondary data analysis/ Existing data analysis Non-empirical	Accident causation	Mining	Coal mining China	Accident Causation, Human factors - behavioural and organisational factors	Fallible decisions by management, Management commitment, Unsafe behaviours and workplaces, Defective designs, Violation of procedures/ legal requirements	Yes	No	No
4.	Dodshon, and Hassall, (2017)	Qualitative research Cohort Survey	Organisational learning, Risk control management	Multiple industries	Mining Construction Postal and Transportation Warehousing	Incident investigation, Practitioner's perspectives	Organisational learning, Communication - Lessons from accidents	Yes	No	Yes
5.	Donovan, et al. (2017)	Historical research design Case study analysis Content analysis	Decision-making, Critical Decision Method, ACCIMAP	Mining	Open-pit	Safety Leadership, Decision making, Risk management	Safety leadership, Communication	Yes	Yes	No
6.	Dragan, et al. (2017)	Historical research	Accident causation	Multiple industries	Mining Nuclear	Human and organisational performance,	Leadership, Company culture, Safety culture,	Yes	No	Yes

		Non-empirical				Leadership, Complex adaptive systems	Communication, Decision-making, Organisational clarity			
7.	Drury, Porter and Dempsey, (2012)	Historical research Existing data analysis Non-empirical	Repeat accidents, Hierarchical Task Analysis	Mining	Coal mining Metalliferous mining	Mine accidents, Mobile equipment accidents, Repeat accidents	Nil	No	No	No
8.	Ghosh, Bhattacherjee and Chau, (2004)	Case study	Human factors, Individual factors, Organisational factors	Mining	Coal Mining India	Individual factors, Risk perception, Unsafe workplaces, Supervision, Leadership, Safety culture	Leadership, Unsafe workplaces, Supervision, Safety culture, Risk perception	Yes	No	No
9.	Hermanus, (2007)	Historical research Existing data analysis Non-empirical	Occupational accidents, Mine safety, Mine health, Effects of mine accidents, Causes of mine accidents	Mining	South Africa	Accidents trends, Causes of accidents, Effects of accidents	Leadership, Proactive risk management,	Yes	No	No
10.	Lenné, et al. (2012)	Historical research Existing data analysis Non-empirical	Accident causation, Active failures, Latent failures, Supervision, Organisational influences/ factors	Mining	Australian mining	Accident causation, Unsafe acts, Latent failures, Supervision, Organisational influences	Supervision, Poor safety risk culture, Violation of procedures, Organisational climate, Inappropriate operations	Yes	No	No
11.	Li, J., Li, Y., and Liu, (2015)	Longitudinal design	Employee safety behaviour, Individual psychological factors, Workplace accidents	Mining	Coal mining China	Individual factors, Workplace accidents	Safety culture	No	No	No
12.	Mallett, Vaught and Brnich (1993)	Qualitative research Exploratory design	Emergency response, Human factors, Mine accident	Mining	United States Coal mining	Workers response to emergency warning, Communication, Human factors	Communication, Procedures and safety standards, Workplace culture	No	No	No
13.	Nasarwanji, (2016)	Historical research Existing data analysis Non-empirical	Accident causation, Contributing factors	Mining	Coal mining Metalliferous mining Non-metal mining United States	Causes of accidents, Contributing factors, Workplace safety	Standard operating procedures, Risk perception, Safety culture	Yes	No	Yes

14.	Nygren, et al. (2017)	Historical research design Literature Review Non-empirical	Contract work characteristics , Organisational factors and conditions, Cultural conditions, Workplace safety	High-risk industries	Mining Construction Petrochemical	Workplace safety	Communication barriers, Hierarchies and power asymmetries organizational factors, Inadequate regulatory control conditions , Complex work and safety, Core-periphery structure, Pyramid subcontracting, Disorganization effects, Unstable social relations Division (and diffusion) of responsibility, Fragmentation of production processes and work tasks	No	No	No
15.	Patterson, and Shappell, (2010)	Historical research Secondary data analysis Non-empirical	Accident causation, Accident investigation, Human error, Human factors	Mining	Australian mining	Workplace safety, Accident causation, Human factors	Organisational climate, Organisational process, Resources management, Unsafe leadership, Communication	Yes	Yes	No
16.	Paul, and Maiti, (2007)	Cross-sectional design	Workplace safety, Workplace behaviour	Mining	India	Behaviour-based safety, Individual behaviour	Risk-taking culture, Job dissatisfaction	No	No	No
17.	Peters, and Wiehagen, (1988)	Qualitative research Descriptive	Ground-fall accidents, Workplace safety, Causes of accidents	Mining	Coal mining Underground mining United States	Accident causation, Human factors, Ground-fall accidents	Safety culture, Risk perception, Supervision, Risk-taking culture	Yes	No	Yes
18.	Randolph, (1992)	Historical research Existing data analysis Non-empirical	Human-machine interface, Team work, Organisational attributes/factors	Mining	United States	Human factors, Causes of accidents in US mining	Communication, Leadership - mining managers, Worker participation, Training and competence	No	No	No
19.	Ruckart, and Burgess, (2007)	Historical research Existing data analysis Non-empirical	Human Error, Workplace safety, Shift work patterns	Mining Manufacturing	United States	Human error, Accident causation, Contributing factors	Shift-work patterns, Procedures and standards	No	No	No
20.	Stephan, (2001)	Historical research Secondary data analysis Non-empirical	National culture, Industry culture, Organisational culture, Safety culture	Mining	Coal mining	Organisational culture, Safety culture	Organisational learning, Communication - Lessons from accidents	Yes	No	No

21.	Terezopoulos, (1996)	Historical research Content analysis Non-empirical	Human factors, Human error, Leadership, Safety culture, Safety audits	Mining	United Kingdom United States Australia	Safety leadership	Safety leadership, Communication, Safety Training, Safety awareness, Safety culture	Yes	No	No
22.	Uchino, and Inoue, (1999)	Historical research Content analysis Non-empirical	Safety Performance, Human factors, Accidents	Mining	Coal mining Japan	Mine accidents and injuries	Communication, Inappropriate facility	Yes	No	No
23.	Verma, and Chaudhari, (2017)	Historical research Existing data analysis Secondary data analysis Non-empirical	Mine accidents, Unsafe action, Precondition for unsafe actions, Unsafe leadership, Organizational influences	Mining	Underground mining Open cast mining India	Mine accidents, Accident causation	Organisational climate, Organisational process, Resources management, Unsafe leadership, Communication	Yes	No	No
24.	Xia, (2010)	Conceptual design Existing data analysis Non-empirical	Individual behaviour, Group behaviour, Organisational behaviour, Safety culture, Mine safety	Mining	Coal mining	Mine safety, Organisational safety culture, Unsafe behaviour	Management error, Decision making, Leadership, Safety culture	Yes	No	No
25.	Yin, et al. (2017)	Historical research Existing data analysis Case-study approach Non-empirical	Accident causation, Repeat accidents, Human error	Mining	Coal mining	Accident causation, Unsafe behaviour, Human error, Workplace safety	Supervision	No	No	No
26.	Yulianto, Haramaini and Siregar, (2015)	Mixed-methods approach Historical research design Existing data analysis Non-empirical	Mine accidents, Unsafe action, Precondition for unsafe actions, Unsafe leadership, Organizational influences	Mining	Coal mining	Mine accidents, Organizational factors, Unsafe leadership, Unsafe acts	Management commitment, Organization working environment, Application of safety procedures, Unsafe leadership	Yes	No	Yes

27.	Yunxiao, and Yangke. (2014)	Historical research Existing data analysis Secondary data analysis Non-empirical	Organizational influences, Unsafe supervision, Precondition for unsafe acts, Condition of operators, Personnel factors, Unsafe acts	Mining	Coal mining China	Mine accidents, Organizational influences, Unsafe supervision, Precondition for unsafe acts, Condition of operators, Personnel factors, Unsafe acts	Organisational climate, Operational process, Resource management, Inadequate supervision, Planned inappropriate operations, Failure to correct problems, Supervision violations	Yes	No	No
28.	Aliabadi, et al. (2018)	Historical research Existing data analysis Secondary data analysis Non-empirical	Accident Causation, Organisational deficiencies, HFACS	Mining	Metalliferous Iranian mining industry	Mining accidents, Organizational deficiencies, Unsafe supervision, Unsafe acts	Supervision, Safety culture, Work pressure, Safety management	Yes	No	No

Key – Variables of Interest

OF vs AC Refers to studies that explored the relationship between organizational factors **(OF)** and accident causation **(AC)**
OF vs RR Refers to studies that explored the relationship between organizational factors **(OF)** and residual risk management **(RR)**
RC Refers to studies that focused on risk control measures **(RC)** as part of their discussion on residual risk management