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Understanding the mining safety research field: exploring safety measures and programs in international research

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Abstract: Due to the risks inherent to mining workplaces, a variety of methods for improving safety have been explored in the mining industry research field. This article aims to provide an overview on the safety measures studied in this field to determine the subjects in focus and to identify potential gaps in the research field. 54 research articles focusing on safety measures in the international mining industry were reviewed through thematic analysis. Ten themes for safety measures were identified in the mining industry research field, with safety culture development and safe behaviours being the most common. With the scope of the research field and its gaps presented, the article discusses the implications of the rarity and commonness of certain themes and gives recommendations for future research. This includes recommending the exploration of different safety perspectives, socio-technical theory and neo-institutionalism.

Keywords: mining; safety research; safety measures; international research; safety management; literature review; safety culture; organisational safety.

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1 Introduction

There are few industries where safety is as important as in the mining industry. Due to the utilisation of heavy mining machinery and vehicles, potentially harmful gasses in the working environment, and the ever-present risk of cave-ins, accidents can have significant effects on both the people in the mines and the mining operation as a whole. Much effort has thus been put towards researching measures to reduce the amounts of accidents and risks that occur while also mitigating the severity of their effects. These studies often apply a variety of different organisational perspectives, i.e., focusing on issues connected to the organisation of and social systems within companies, for the development and implementation of improvements to safety. This, however, raises the question: Which specific perspectives of organisational theory are being investigated in the safety-focused, mining-related research?

An example of this research approach can be found in Lööw and Nygren (2019). According to the authors, the decline in accident rates within the Swedish mining industry from the 1980s and onwards coincided with developments of the industry's own safety initiatives. Safety initiatives in the Swedish mining industry have also changed from being primarily focused on technological developments to include more organisational aspects since the early 2000s. While Lööw and Nygren (2019) did not directly investigate the causal effects of these changes on the accident rates in question, they conclude that the accident rates may have been lowered due to different types of safety-related issues requiring different kinds of solutions, whose requirements were now being met. This includes a wider range of subjects regarding safety measures beyond only physical risks and issues connected to, e.g., the implementation of technology or formal rules and regulations for safety.

However, while many different subjects are covered in contemporary research, there may be gaps in the research field, leaving certain aspects of mining industry safety unexplored. The purpose of this article is thus to explore perspectives on safety development that have been highlighted in research. With such an overview, the goal is to present a description of predominant perspectives applied to different safety-related problems and subjects, and to identify potential gaps in the research field.

Before moving forward to present our methodology, it is important to clarify the terminology applied in this study. It is common in the organisational research field to use the term 'health and safety management systems' (HSMSs) when discussing broader initiatives for improving safety in organisations, and the mining industry field is no different. Osborne and Zairi (1997) define 'health and safety management' as management efforts to control the risk of harm to the organisation's employees. Haas and Yorio (2016) similarly describes HSMS as a collective term for an organisation's efforts to establish and achieve their occupational health and safety goals and objectives. Implementing safety management systems can, according to the ISO (2018), help manage occupational health and safety risks by way of reducing workplace incidents, reducing absenteeism, and creating positive health and safety cultures in the organisation. For that purpose, most if not all mining organisations employ some form of strategic efforts for developing or improving the safety performance of the mining workplaces. In this article, these efforts are seen as a subset of the broader term of safety measures, i.e., as being a

part of the efforts to improve safety by focusing on the organisation of and social systems within companies. Although Haas and Yorio's definition of HSMS could be used to describe many of the efforts for safety improvements that will be highlighted in this article, there are also examples of articles where broader organisational and social conditions themselves are subjects of safety improvement measures.

2 Methodology

This article is based on organised searches and a subsequent thematic analysis of 54 research articles focusing on safety measures in the international mining industry. The selected literature consists of full-length articles that have undergone peer review processes in scientific journals, i.e., excluding extended abstract, conference papers, etc.

The literature search was conducted in two steps: Firstly, we performed a broader search in the scientific database Scopus with the aim of familiarising ourselves with the available literature and exploring different subjects relating to safety development, using the search terms:

'Safety strategy' OR 'safety culture' OR 'safety initiative' OR 'safety management' AND 'mining industry'

These terms were included as search terms in order to encompass several different perspectives on safety development. They were selected based on the reading of previous examples of safety research, such as Komljenovic et al. (2017) and Lööw and Nygren (2019).

This produced 72 articles which were eventually reduced to 40 after reviewing and discussing the different abstracts. Articles were included based on their descriptions and analyses of strategies on an organisational level seeking to improve safety, while studies focusing on specific technological solutions (e.g., the effects of specific equipment or machinery) were excluded. We also excluded articles focusing strictly on analysing mining accidents, i.e., studies exploring matters such as accident causation without tying it to strategies or measures for safety improvement.

We divided the articles equally between us and read all available texts in their entirety while keeping notes in a separate document. This led to a further reduction of the texts to 19 and a collection of short summaries, key phrases and keywords that we eventually grouped into ten themes highlighting central aspects of the articles, inspired by the methodology of Braun and Clarke (2006). Based on the results of the first search, we then expanded the second search in Scopus to include a number of additional and more precise search terms:

Mining AND 'safety performance' OR 'safety strategy*' OR 'organi*ational safety' OR 'safety climat*' OR 'safety culture*'

These additional and more precise search terms were included to explore specific subjects that were commonly addressed in the articles found in the previous search.

Besides Scopus, the database Web of Science was also included in the second search using the same search terms. In total, the second search produced 206 articles in Scopus and 247 in Web of Science. Based on the title and abstracts we divided 92 articles equally between us for further reading. After reading the texts, and excluding duplicates from the

first search round, we wrote short summaries, including key phrases and keywords, of 35 additional articles and included these into the existing themes. Due to saturation in the available literature, no new themes were consequently developed on the basis of the second round of literature search.

3 Results

In total, 54 research articles were examined and analysed. While several different measures for improving safety were presented or explored in these articles, certain common aspects or themes could be identified among them. The identified themes, and a list of analysed articles, are included in Table 1.

Table 1 Identified themes of safety development approaches with associated articles

Themes of safety development approaches	*Articles (see reference list for full description)*	*No. of articles*
Safety culture development	Bahn (2013a)	18
	Bascompta et al. (2018)	
	Bealko et al. (2008)	
	Chen and Zorigt (2013)	
	Düzgün and Leveson (2018)	
	Foster and Hoult (2013)	
	Haas and Yorio (2021)	
	Han et al. (2019)	
	Jansen and Brent (2005)	
	Jiang et al. (2019)	
	Jiskani et al. (2020)	
	Kohler (2015)	
	Laurence (2005)	
	Morcinek-Słota (2019)	
	Stemn et al. (2019b)	
	Wang et al. (2018)	
	Ye et al. (2020)	
	Zhang et al. (2020)	
Behaviours and attitudes	Amponsah-Tawiah and Mensah (2016)	13
	Bahn (2012)	
	Foster and Hoult (2013)	
	Jansen and Brent (2005)	
	Kapusta et al. (2020)	

Table 1 Identified themes of safety development approaches with associated articles (continued)

Themes of safety development approaches	*Articles (see reference list for full description)*	*No. of articles*
Behaviours and attitudes	Korban (2015)	13
	Laurence (2005)	
	Li et al. (2019)	
	Maiti et al. (2004)	
	Wang et al. (2019)	
	Wu et al. (2017)	
	Wyganowska and Tobór-Osadnik (2018)	
	Zhang et al. (2020)	
Communication	Bahn (2012)	12
	Casey and Krauss (2013)	
	Chen and Zorigt (2013)	
	Foster and Hoult (2013)	
	Gunningham and Sinclair (2014)	
	Haas and Yorio (2019)	
	Laurence (2005)	
	Parker et al. (2017)	
	Wang et al. (2018)	
	Ye et al. (2020)	
	Yu and Li (2020)	
	Zhang et al. (2020)	
Training and knowledge development	Ajith et al. (2020)	18
	Bahn (2012)	
	Bahn (2013b)	
	Es'haghi et al. (2020)	
	Jiskani et al. (2020)	
	Kohler (2015)	
	Laurence (2005)	
	Li et al. (2019)	
	Lu et al. (2020)	
	Maiti et al. (2004)	
	Parker et al. (2017)	
	Paul and Maiti (2007)	
	Stemn et al. (2019a)	
	Vahedian-Shahroodi et al. (2019)	
	Wang et al. (2018)	
	Wang et al. (2019)	
	Wu et al. (2011)	
	Ye et al. (2020)	

Table 1 Identified themes of safety development approaches with associated articles (continued)

Themes of safety development approaches	*Articles (see reference list for full description)*	*No. of articles*
Leadership	Ajith et al. (2020)	17
	Amponsah-Tawiah and Mensah (2016)	
	Balogun et al. (2020)	
	Cui et al. (2013)	
	Donovan et al. (2018)	
	Es'haghi et al. (2020)	
	Gunningham and Sinclair (2014)	
	Komljenovic et al. (2017)	
	Kowal (2019)	
	Li et al. (2019)	
	Lu et al. (2020)	
	Parker et al. (2017)	
	Willmer (2017)	
	Ye et al. (2020)	
	Yu and Li (2020)	
	Zhang et al. (2016)	
	Zhu et al. (2020)	
Ownership and accountability	Foster and Hoult (2013)	9
	Gunningham and Sinclair (2014)	
	Haas and Yorio (2021)	
	Jansen and Brent (2005)	
	Jiskani et al. (2020)	
	Laurence (2005)	
	Lu et al. (2020)	
	Maiti et al. (2004)	
	Zhang et al. (2020)	
Risk and safety management	Bahn (2012)	10
	Fang et al. (2018)	
	Haas and Yorio (2016)	
	Kohler (2015)	
	Korban (2015)	
	Laurence (2005)	
	Stemn et al. (2019c)	
	Valluru et al. (2020)	
	Wang et al. (2019)	
	Zhang et al. (2020)	

Table 1 Identified themes of safety development approaches with associated articles (continued)

Themes of safety development approaches	*Articles (see reference list for full description)*	*No. of articles*
Regulations, rules and laws	Chen and Zorigt (2013)	9
	Düzgün and Leveson (2018)	
	Kohler (2015)	
	Laurence (2005)	
	Wu et al. (2011)	
	Wang et al. (2018)	
	Wang et al. (2019)	
	Wu et al. (2011)	
	Zhang et al. (2017)	
Social relations	Gunningham and Sinclair (2014)	6
	Han et al. (2019)	
	Maiti et al. (2004)	
	Wang et al. (2019)	
	Wu et al. (2011)	
	Zhu et al. (2020)	
Technological development	Jiskani et al. (2020)	5
	Kohler (2015)	
	Lööw and Nygren (2019)	
	Maiti et al. (2004)	
	Wu et al. (2011)	

3.1 Safety culture development

Safety culture is a commonly recurring subject focused on by researchers as an avenue for improving the state of safety in the mining industry. It is discussed in several of the analysed articles, and is generally used as a collective term for certain organisational aspects that affect safety in different ways (see, e.g., Bealko et al., 2008; Chen and Zorigt, 2013; Foster and Hoult, 2013; Jansen and Brent, 2005; Kohler, 2015; Laurence, 2005; Stemn et al., 2019b; Ye et al., 2020). These aspects include behaviours and attitudes relating to safety, norms and values of the people in and of the organisation itself, organisational policies and practices, and the state of social relations within the organisation. Most of the authors that mention safety culture recommend organisations to develop their culture as a measure of improving safety, and that safety culture is correlated to broader organisational and interpersonal conditions (see, e.g., Bahn, 2013a; Düzgün and Leveson, 2018; Han et al., 2019; Jiang et al., 2019; Morcinek-Słota, 2019; Wang et al., 2018; Zhang et al., 2020). Bealko et al. (2008) mention adopting more preventative practices and policies, Foster and Hoult (2013) and Bascompta et al. (2018) promote a focus on safety culture maturity, and Laurence (2005) discuss how better regulatory frameworks and communication channels as measures for developing the

culture of a mining workplace. Similarly, Ye et al. (2020) recommend promoting a culture within organisations that allows employees to feel comfortable in sharing and discussing safety issues without worrying about reprisal. Haas and Yorio (2021) conclude in their study that assessing safety climates or cultures within an organisation could be useful in learning more about and creating proactive organisational environments. Chen and Zorigt (2013) discuss how environmental factors such as regional values and national cultures can affect organisational cultures.

Common for many of the articles covering safety culture in mining is that the development of such culture is founded on the development of other safety-related subjects such as behaviours, training, relations and communication within organisations. For example, Jiskani et al. (2020) and Zhang et al. (2020) argue that employee involvement, safety communication and leadership commitment is vital in the creation and implementation of an effective safety culture. While many of the articles gathered under this theme thus also fall under the themes for other safety measures, one can argue that their collective stated goal of developing and improving a safety culture calls for the creation of a separate theme.

3.2 Behaviours and attitudes

It is difficult to uphold safe working practices and policies if the people designing and applying them are not acting in the interest of safety or do not consider safety to be important enough to change how they work. Authors like Bahn (2012), Foster and Hoult (2013), Laurence (2005) and Maiti et al. (2004) relate developing positive behaviours and attitudes to safety as part of measures to create a strong safety culture and climate, or vice versa. This can be seen in Foster and Hoult (2013) description of advanced safety culture entailing a common sense of responsibility for safety, or in Laurence's (2005) claim that better regulatory framework encouraging a positive safety culture will lead to better attitudes and behaviours. Jansen and Brent (2005) provide another example by arguing that employees are more likely to enact safe behaviours if they are satisfied with the practical and social support that the organisational culture brings. Other authors like Wu et al. (2017) however, describe the work with addressing attitudes as a unique measure for improving safety in and of itself. Li et al. (2019) describe how a positive safety attitude is a necessity for people to enact safe behaviours. They for example claim that developing safety attitudes has a positive effect on participation and engagement in efforts to create safe workplaces amongst employees. Wyganowska and Tobór-Osadnik (2018) argue that supporting safe behaviours requires creating appropriate working environments. Korban (2015) meanwhile focuses on a lack of motivation in people for safety being a potential cause of human errors that must be addressed. By contrast, Amponsah-Tawiah and Mensah (2016) show that employees who feel safe when conducting work are more likely to develop an emotional attachment towards the company in question and, by extension, a deeper organisational commitment. Leaders and colleagues' attitudes to safety may according to Kapusta et al. (2020), Wang et al. (2019) and Zhang et al. (2020) significantly affect employees' safety behaviours. Managers demonstrating their commitment to safety can according to the authors result in employees being more likely to enact safe behaviours themselves, requiring managers to act as role models.

3.3 Communication

In order for the people within an organisation to understand and adapt to new policies, practices and other changes, proper communication channels must be made available and used to facilitate the dissemination of those measures throughout the organisation. Several authors approach the subject of communication's role in safety improvements within the mining industry (see, e.g., Bahn, 2012; Chen and Zorigt, 2013; Foster and Hoult, 2013; Gunningham and Sinclair, 2014; Haas and Yorio, 2019; Laurence, 2005; Wang et al., 2018; Ye et al., 2020; Zhang et al., 2020). The angle of approach, however, is different for most of them. Bahn (2012) advocate for the importance of communication as part of a person's hazard identification skills, while Chen and Zorigt (2013) explore why proper communication between management and employees is important in order to understand why risks and accidents occur. Laurence (2005) emphasises the importance for management to clearly communicate mine rules and regulations in order to reduce accidents, while Zhang et al. (2020) argue that multidirectional communication between, across and within each level of the organisational hierarchy is necessary to improve safety information communication. Foster and Hoult (2013) instead focus on how the level of communications varies depending on the level of safety culture maturity. Gunningham and Sinclair (2014) describe how to nurture trust between organisational levels in mining organisations for the sake of work health and safety management and mentions communication as one important measure. Ye et al. (2020) argue that common understandings and consensus regarding safety issues can be better developed through teams holding collective reflection on objectives, strategies and processes. In a similar vein, Parker et al. (2017) came to the conclusion that discussions on health and safety may be seen as sensitive subjects to employees based on their study of health and safety in the Australian mining industry. Management needs to show that they can maintain confidentiality and properly utilise such information by addressing reported health and safety issues in order to establish trust. Haas and Yorio (2019) claim that it is vital to take individual factors on a worker level into account when disseminating safety-related information throughout the organisation, i.e., that information and communication practices should be implemented with the receivers in mind. Yu and Li (2020) focus on a different aspect of communication by emphasising the importance of a healthy psychosocial safety climate. They believe that unsafe behaviours can, amongst other sources, stem from unhealthy mental states, and that psychological communication and discussion can help improve the psychological safety climate. Casey and Krauss (2013) on the other hand focus on error management climate, i.e., practices within an organisation connected to communication regarding errors such as unintentional acts, as well as the handling of errors and sharing of error knowledge. The authors suggest that workers are more likely to adhere to and adopt safety measures in their work in organisations where they adopt error management practices, and openly share information regarding safety-related errors.

3.4 Training and knowledge development

There are many examples of research relating to safety in the mining industry that focus on and recommend training and knowledge development as measures for improvement (see, e.g., Ajith et al., 2020; Bahn, 2012, 2013b; Jiskani et al., 2020; Kohler, 2015; Laurence, 2005; Li et al., 2019; Lu et al., 2020; Maiti et al., 2004; Paul and Maiti, 2007;

Stemn et al., 2019a; Wang et al., 2018, 2019; Wu et al., 2011). Generally, these measures entail developing the knowledge of employees, management or everyone involved through organised educational meetings, sessions and seminars. Researchers such as Es'haghi et al. (2020) and Vahedian-Shahroodi et al. (2019) describes the goal of this training to be the establishment of safety-positive behaviours and attitudes. For example, induction and refresher training as means to ensure both new and experienced employees learn and follow rules and regulations is a commonly mentioned strategy (see, e.g., Ajith et al., 2020; Parker et al., 2017; Laurence, 2005). Lu et al. (2020) recommend systematic, comprehensive health and safety training for new employees, and the implementation of continual safety re-education due to training having a significant influence on safety knowledge and the motivation for enacting safe behaviours. Similarly, Wu et al. (2011) recommended enhancing safety training to improve knowledge and consciousness regarding safety amongst employees in order to reduce human errors. Li et al. (2019) believes that safety training is necessary for the employees to better understand the importance of following safety regulations and rules to avoid accidents. Proper education on safety is considered to be an important tool in improving safety behaviours and attitudes of employees, both new and old. Bahn (2012) concludes that specific training efforts for improving workplace hazard identification are better than general safety training, while Kohler (2015) promoted research-based training design to ensure relevant and useful information is being prioritised, and that the focus and delivery of the education is improved. Maiti et al. (2004) identified that training new employees contributes to safer working environments, while also concluding that negatively personified individuals may pose safety risks and should amongst other measures be provided special training with psychological treatment. In a similar sense, Ye et al. (2020) believe that mining employees should not relate safety problems to their individual performance and should instead see them as obstacles for the team to tackle. This should be emphasised when training employees to avoid individuals interpreting safety problems as an indicator of their own lacking performance, as that only serves to further discourage safe working behaviours.

3.5 Leadership

A central subject in the literature is leadership and its relation to safety. This subject consequently focuses on the efforts to improve safety through the work and dedication of management to do so. This can include management engaging with their employees to build relations and trust, prioritising hazard investigations to remove risks and dangers in the workplace, and providing clear directions and instructions for safety work (see, e.g., Amponsah-Tawiah and Mensah, 2016; Li et al., 2019; Lu et al., 2020; Zhang et al., 2016). Komljenovic et al. (2017) argue that the organisation itself represents a new risk in the modern mining company, given that accidents tend to be characterised by organisational factors such as communication practices, safety culture, decision-making processes, etc. For example, a potential risk is that management groups prioritise operational efficiency and performance and neglect more obvious safety concerns. Gunningham and Sinclair (2014) approach the strategy of safety through leadership by way of investigating how trust and mistrust between managers and the people working under them affects the work with health and safety management in the mining industry. Mines with higher safety performance had managers build relations through both formal and informal engagements, showed attentiveness to employees' concerns, and adopted

flatter organisational structures providing more decision-making power to middle managers. This is supported by Ajith et al. (2020), Balogun et al. (2020), Cui et al. (2013), Es'haghi et al. (2020) and Parker et al. (2017), as they recommend better demonstrating management and the organisation's commitment to safety in order to encourage safer employee behaviour. Management must provide proper frameworks, tools and leadership that promotes a safe working environment. Ye et al. (2020) specifically suggest that managers showing interest and engagement in the safety of their employees helps inspire the workforce with hopefulness. A hopeful workforce is better at generating strategies and solutions to problems, meaning they have a greater capacity for enacting safe behaviours. They also recommend promoting employees that are passionate about safety as role models for their peers, preferably including some form of tangible reward, which is supported by Kowal (2019) as well based on surveys of Polish coal mine workers. Donovan et al. (2018) explored safety leadership practices in relation to the Bingham Canyon Mine high-wall incident in 2013. The findings indicate that safety leadership had an impact of the subsequent behaviours and actions throughout the work system more broadly, i.e., on the actions needed to uphold safety amidst a serious incident. For example, key elements supporting the safe outcome were transformational and authentic leadership behaviours, as well as the flow of information across the organisation. In line with this, Willmer (2017) emphasises the importance of leaders actively engaging and communicating with the workforce in order to build shared sense-making regarding safety-related issues. Yu and Li (2020) and Zhu et al. (2020) believe managing psychosocial stress factors through good leadership to be an important method of achieving and maintaining a safe organisational environment. Managing stress factors helps promote safe behaviours in addition to participation in and compliance with safety initiatives. This involves many different efforts, for example focusing on employees' well-being, establishing good relationships and communication, providing clear objectives, and clarifying peoples' roles, expectations and duties.

3.6 Ownership and accountability

Another theme of measures mentioned in research is ownership of, accountability for and involvement in the design of the workplace and the work itself. This type of safety measure entails giving more control and responsibility over workplace practices and the design of the work to the lower levels of an organisation rather than all decisions only being made at the higher levels. The purpose of this is to better accommodate the needs and wants of the people affected by the design of the work, as well as increasing people's involvement and engagement in safety. Flatter organisational structures and devolved decision-making is something that Gunningham and Sinclair (2014) support, as many of the safer mines they investigated had such organisations. This notion also supported by Haas and Yorio (2021), who argues that workers having low levels of task autonomy can negatively impact the perceived safety climate. A lack of autonomy to potentially deviate from rules and processes could cause risks to go unnoticed and hinder deeper engagement in health and safety initiatives. Haas and Yorio (2021), Zhang et al. (2020) and Jiskani et al. (2020) suggest that more proactive approaches encouraging worker participation in such initiatives can help counteract negative impacts.

Ownership and accountability also involve people being more involved in their work by showing concerns for safety risks and issues, providing feedback, and participating in

the development of the workplace, either actively or by way of designing the measures and changes to be made. According to Jansen and Brent (2005), Lu et al. (2020) and Maiti et al. (2004), employees more involved in their work often show better safety practices and is linked to fewer work injuries occurring. Measures to increase employee involvement in safety can range from a higher level of visible management involvement as encouragement to including them in the discussions on workplace changes. Laurence (2005) draws similar conclusions in that a workforce more involved in the creation and application of rules and regulations leads to those rules being more effective in reducing risks and injuries. This also includes managers and other roles being more involved, as the Minerals Industry Risk Management (MIRM) Maturity Chart presented by Foster and Hoult (2013) state that more proactive and maturely developed organisations have everyone involved in and taking responsibility for preventing accidents and incidents.

3.7 Risk and safety management

As mentioned in Section 1, HSMSs are commonly described as a collection of an organisation's initiatives, activities and other elements that aim to reduce occupational injuries and losses. Some authors have thus focused on developing initiatives for improving safety through HSMS improvements. This involves the development and refinement of health and safety-focused standards and procedures meant to protect people from accidents. One example of researchers approaching this subject include Wang et al. (2019), who found that a balanced and moderate amount of work pressure, such as pressures to perform, can be beneficial for the employees' safety behaviours. To that end, they recommend management to perform regular testing and evaluation of the working pressure of their workforce to ensure tasks are reasonable but engaging. Fang et al. (2018) similarly recommend improving the safety management capabilities of managers and safety management systems as methods for ensuring safe behaviours of mining employees. Another example includes Korban (2015), who concludes through surveys on issues relating to operational health and safety management that workplace hazard investigations were the most significant and important measures to develop and focus on. Zhang et al. (2020), meanwhile, argue that effective safety management activities must include both reactive and, most importantly, proactive measures and activities for improving safety. Furthermore, these activities must include the contractors employed in the mine.

A major part of safety management systems is the improvement of people's risk management capabilities. Similar to how improvements relating to safety culture are commonly based on other safety-related subjects, many of the improvements that focus on risk management involve other safety measures such as training or communication. The application of this subject in mining-related research varies between different authors. Bahn (2012) focuses on the risk assessment capabilities of the employees in the mining industry by studying the state of hazard identification at several mines. Their recommended improvements to the employees' abilities to identify risks and hazards includes improved risk-related training, processes for risk control, documentation and communication about risks. Valluru et al. (2020) argue that the risks faced by subcontractors must similarly be identified, understood and analysed, albeit using different approaches suitable for the variation brought by working with an externally sourced workforce. When discussing risks and hazards, Kohler (2015) identifies the need for the development of tools, documentation and training for increasing the risk

assessment capabilities of miners, and for the use of a human-centred approach to further reduce accidents through the design of the workplace. Furthermore, they promote the idea that behavioural, cognitive and social sciences may have significant potential applications in improving risk assessment and management. Korban (2015) concludes that the quality of hazard and risk investigations should be viewed as integral parts of any management systems due to their importance based on surveys and assessments of the significance of different safety-related problem areas. While they do not present specific ways of working with hazard and risk investigations, their research can be used to advocate the importance of strategic work with the subject. This is something Stemn et al. (2019c) focuses more on, presenting several recommendations for improving incident and risk investigations. These include training of investigators in subjects like accident causation and various investigation methods, including a focus on present/absent/failed controls in the analysis stage of investigations and identifying latent causes, and taking measures to improve the utilisation of post-investigation findings. Laurence's (2005) measures for improving safety that relate to risks are of two different designs. The first is a recommendation to improve the design and implementation of rules and regulations to better advocate for proper risk assessment and management, for example by way of making risk-related rules more readily available and accessible. They consider rules and regulations to be an effective method of communicating the importance of risk management and ensuring that assessments are being done. Laurence's (2005) other recommended measure is to use risk assessment procedures as an opportunity to involve employees more in the work with health and safety in the organisation. This is because a workforce more involved in changes and measures in the workplace are more likely to be more accepting of those measures. As for monitoring the different activities implemented to uphold safe working conditions, Haas and Yorio (2016) recommend a mix of performance measurements focusing on company-specific safety interventions, organisational performance as well as worker performance.

3.8 Regulations, rules and laws

Several authors researching safety-related subjects in the mining industry conclude that the regulations, rules and laws in place in the mines have a significant impact on the safety performance of those workplaces (see, e.g., Chen and Zorigt, 2013; Kohler, 2015; Laurence, 2005; Wu et al., 2011; Wang et al., 2018, 2019). Measures involving the design and implementation of rules and regulations for improving safety can be separated into two categories depending on who they are applied to. The first category includes rules and regulations within mining organisations that promote safe behaviours and attitudes among the employees and managers. Research on such measures focus on how rules and regulations can be designed to ensure that they encourage the desired safety-related behaviours. Laurence (2005) gives a number of examples of how those rules can be designed to ensure that employees and middle managers better understand and follow them. These included clearer definitions and language, content that represent the conditions of the workplaces better, and prioritising creating higher quality regulations rather than a large quantity of them. Kohler (2015) comes to a similar conclusion in that rules and regulations are necessary for effective safety systems, but that defining regulations for every risk and danger that occurs can make them overly prescriptive. In addition, they believe that a large volume of regulations can reinforce the

misconception that compliance with them will eliminate the risk of accidents and ensure good outcomes instead of primarily serving to reduce and manage the outcomes of risks and dangers. An improvement would instead be implementing performance-based regulations and risk-based approaches. Regulatory safety measures are differentiated from those focusing on behaviours by analysing what the authors determine to be the solution and what they determine to be the outcome. Safety measures focusing on rules and regulations, for example one from Wu et al.'s (2011) study, define positive safety-related behaviours and attitudes as the results of effective regulations. Similarly, Zhang et al. (2017) highlight the important role that formal authorities play regarding strengthening and prioritising safety regulatory practice vis-à-vis mining companies and that this, in turn, can lead to improved safety training. Other authors studying mining workplace safety, such as Chen and Zorigt (2013), see negative safety-related behaviours and attitudes as a sign of a lacking health and safety management implementation in need of improvement. They argue that the development of better rules and regulations would address these behaviours. Wang et al. (2019) argues that employees not complying with safety rules and regulations may stem from those regulations being interpreted as unreasonable. As such, they recommend recurrent and frequent updates of safety rules and regulations to keep them relevant and ensure they're accepted.

The other category of rule and regulation meant to improve safety involve regulations to the organisations themselves. Examples include laws for workers' rights, industry standards for safety and government interventions aimed at improving the safety performance of the mining industry. Düzgün and Leveson (2018) believe that those types of well-established safety regulations and laws, enforced by governmental authorities, are necessary for effective mine safety systems. They argue that government safety authorities must provide support and incentives for mining organisations to conduct proper risk assessments and effective risk management in order to ensure that mining companies take effective measures. The effectiveness of these kinds of regulations is investigated by Chen and Zorigt (2013), who concludes that acts and regulations on organisational levels had a positive relation with improving operational health and safety implementations.

3.9 Social relations

Social relations between employees and managers, and between people in general, are connections that have been explored by researchers as important assets for improving the safety performance of organisations. For example, by analysing psychological perspectives on safety in the Chinese coal mine industry, Han et al. (2019) concluded that interpersonal relations and connections within the organisation can have significant impacts on health and safety. Issues with interpersonal connections can result in lacking cooperation, and thus requires initiatives to ensure good communication and relations between supervisors, managers and employees. Some of the research on this subject focused on the negative effect on safety performance that negative social relations can have. Maiti et al.'s (2004) study, with the aim to properly understand factors associated with workplace injuries in the mining industry, involved examining the relations between social aspects and workplace accidents and injuries. People that showed negative personality traits, such as the negative aspects of rebelliousness, impulsivity and depression, were more likely to be involved in workplace accidents and injuries. Their recommended long-term solutions involved proper counselling of negative behaviours

and special training with psychological treatment. Furthermore, social support from co-workers and through positive management-worker interaction was shown to have a negative relationship. This, they argued, indicate that healthy social interactions amongst workers, with supervisors and with management help reduce employee job-stress, boredom and dissatisfaction with their work, which were all positively related to job hazards. Wang et al. (2019) also concluded that coal miners receiving social support and safety reminders from their family, colleagues and leaders were more likely to adopt a positive attitude to safety and enact a safer behaviour. Potential sources of such support included the sharing of tips on safety issues with colleagues and leaders.

Another suggested method of improvement through social relations from Wang et al. (2019) would entail promoting safety propaganda to the employees' families in order to increase their external support for safety. The subject of stress is mentioned by Zhu et al. (2020), who conclude that leadership efforts focusing on interpersonal interaction and communication between managers and employees had the most significant impact on work-related stress. A reduction in stress was in turn related to improved safety behaviours. Gunningham and Sinclair (2014) investigate this by focusing on how mistrust between employees, site managers, corporate managers and trade unions in the mining industry can impact the safety of the mine workplace. This impact is caused by issues like mismanagement of responsibilities, resentment and resistance to corporate interventions, and high turnover. They recommend measures for improving levels of trust include employee ownership of work health and safety initiatives, flatter organisational structures and decision-making, and more active responses from management to employees' health and safety concerns. According to Wu et al. (2011), stable social relations in mining also require proper coordination between governments, employers and employees in order to, amongst other goals, resolve social problems. The researchers recommend the establishment of a cooperation agency involving all parties for the purposes of alleviating conflicts to accomplish this; however, they did not give very detailed explanations as to how this agency would operate.

3.10 Technological development

While many of the research articles covering safety in the mining industry focus on organisational measures such as behaviours, safety culture and regulations, another common focus lies with technological solutions. Much of the research, however, focused on the application, implementation and effectiveness of specific technological solutions. In this article, we are instead focusing on the strategic use and improvement of technological development to improve safety.

Kohler's (2015) recommendations for future directions of work with safety are divided into two categories, where one's called evolutionary developments. This category covers technological and design-based solutions to existing and future hazards relating to accidents and safety. The researcher states that technological developments are more likely to succeed in addressing hazards if they increase the focus on human-centred engineering, designing the technologies with the needs and circumstances of the people using them in mind. Furthermore, Kohler (2015) states that one of the elements required for a successful national safety system are technology enablers. These include technologies that assist people with better following safety regulations and measures to improve safety, such as ventilation control for managing dust levels or technologies that

assists people getting to safety during evacuations. Wu et al. (2011) and Jiskani et al. (2020) similarly recommend investments into modern machinery and other workplace improvements as a way to improve safety. Other authors like Maiti et al. (2004) are wary of overreliance on engineered solutions to safety-related problems, however. They instead emphasise that improving safety through technological development must be coupled with measures focused on developing behaviours and attitudes, specifically supporting employees' coping and management of risks. Lööw and Nygren (2019) support such a view by arguing that a focus on technological development needs to be coupled with a focus on organisational issues as well, i.e., taking the complexity of the mining environment and the interrelatedness of different factors into account.

4 Discussion

The purpose of this article was to explore perspectives on safety development that have been highlighted in research, i.e., issues connected to the organisation of and social systems within mining companies. Through analysis of the reviewed literature, certain perspectives of interest representing both notable subjects and gaps in the research field have been examined.

4.1 International perspectives

The results show that the mining industries of several countries have been in focus, with examples from China, the USA and Australia being the most commonly studied. Other nations such as Canada, South America and Sweden saw less representation amongst the articles included in this study. According to Hofstede et al. (2011), the cultural dimensions of a nation's society can affect the design, definition and structure of organisational cultures in that nation's industries. Furthermore, Cooper (2000) theorises that organisational cultures and safety cultures are affected by the values of people in the surrounding societies. Local societal cultures could for example promote self-reliance and discourage complaining, causing people to become less inclined to report risks and dangers in their workplace. The variety of countries covered in the reviewed articles therefore requires recognising that their cultural differences may contribute to differences in managing and improving safety. This study does not aim to analyse and compare the similarities and differences of each nation's cultural and societal values. Furthermore, while certain nations are more abundantly represented in the research field, the results of the literature review show similarities in the mining industry research from different nations. However, it must be acknowledged that cultural differences combined with the abundant representation of certain nations over others in the research field could skew attempts at generalising the results of the present study. To that end, analysing the differences in cultural values and norms between the mining industries of different nations is instead recommended as a subject of potential future research in relation to organisational matters such as safety culture, leadership and social relations.

Analysing the sources and contexts of the reviewed articles revealed an abundance of research analysing or investigating coal mining industries of different countries, the most common being the Chinese, the USA and the Australian coal mining industries. Coal mining being well-represented in research could be because of several different reasons. It is possible that coal mining requires a particularly dangerous type of process,

equipment or takes place in dangerous environments in comparison to the excavation of other minerals. Coal mining industries would thus be in greater need of improvements, potentially increasing coal mining organisations' willingness and availability to participate in safety-related research projects. Another possibility is that coal mining is simply more common in comparison to other types of mineral excavation, and that the high representation of Chinese, US and Australian mining research in the field could be due to the scale of their coal mining industries. It was noted, however, that the types of issues and solutions being investigated in coal mining analyses are similar to those found in other types of mining analyses. It is thus possible to conclude that coal mining, while being more abundantly represented in research, does not skew the analyses of safety measures towards any particular methods or perspectives unique to coal mining.

4.2 Prevalence of themes and cultural perspectives

Analysing the articles examined in this study, the most common themes were shown to be safety culture development, training and knowledge development and leadership, followed by behaviours and attitudes, and communication (see Table 1). Conversely, themes such as social relations or technological development were significantly more uncommon in comparison.

Safety culture has according to Lööw and Nygren (2019) received a great deal of attention in practice by different mining companies since the early 2000s and onwards. This increase is evident in the mining industry research field as well, as safety culture has become one of the most commonly approached organisational subject in safety-related research. In this study, mentions of safety culture and its development were frequently found in the analysed literature, both described as a method for safety improvement, as the stated goal of methods focusing on other themes, and as a symptom signifying a need for improvement. As most researchers in the field have involved the subject of safety culture to some extent in their studies, it has seemingly been established as an integral part of safety-related mining research. It is a broadly defined subject, with many different interpretations and definitions existing in the field. One alternative for categorising these definitions is to compare them to Edwards et al.'s (2013) conceptualisations of safety culture. Of the three concepts described in their study, we identified the normative concept of safety culture to be the most widely applicable categorisation in safety-related mining research. Normative conceptions of culture interpret it as a substance one can and should possess, and a culture is evaluated by determining whether certain desired characteristics are present or not amongst groups and individuals. In a normative conceptualisation of safety culture, safety-related beliefs, values and attitudes are seen as goals to be strived for and obtained, and the focus often lies on the positive effects of culture. By establishing these values and attitudes, an organisation 'obtains' a safety culture and strengthens it. This conceptualisation is very prevalent in mining industry research; many of the articles we have studied have included safety-positive values and behaviours as established goals for their safety-improving measures. Of note are the articles that focus on measuring the safety maturity of mining organisations to judge their safety performance in order to identify and achieve the 'most mature' safety culture. The leadership-focused initiatives that promote establishing trust between employees and managers, and displaying an engagement to safety, are other examples that have a normative perspective on culture. Organisations that have created such trust and

engagement for safety will improve their safety performance according to this perspective according to the research and will thus achieve strong safety cultures. This prevalence of normative perspectives on safety culture in mining research can be contrasted with the relative rarity of studies approaching the subject from other perspectives. It raises the question as to whether the field could use more research that seeks to understand the circumstances of different safety cultures rather than primarily seeking to address perceived issues and to improve them normatively. However, while this appears to be the most common perspective on safety culture, we did identify other implicit interpretations by analysing the application of other themes, such as behaviours and attitudes.

The theme of behaviours and attitudes is similar to that of safety culture development as it is found in a range of different articles, even in those were behaviours and attitudes are not the primary themes. One example of this can be found in the leadership category, where many of the researchers promoting measures for leadership improvement did so with the intended goal of developing safe behaviours. Rather than addressing the development of safe behaviours as methods for improvement, they thus include the subject as a goal or a desired effect of initiatives focusing on other themes. Other examples state that unsafe behaviours are one of the primary causes for workplace accidents and are often attributed to a perceived lack of knowledge of workplace hazards and safe methods of work. They describe such behaviours as symptoms of an inadequate safety performance or culture, which must be addressed through methods such as comprehensive leadership efforts, training and knowledge development, improved communication and more. The theme of behaviours and attitudes thus makes an appearance in much of the research on methods for safety improvement, even when other themes are the primary focus of the solutions. These results suggest that workplace behaviours and attitudes, similarly to the subject of safety culture, are currently another integral part of most safety-focused research in the mining industry research field. One possible explanation for this could be found by relating this theme to another of Edwards et al.'s (2013) conceptualisations of safety culture, namely pragmatic safety culture. The pragmatic conceptualisation of culture focuses on practices such as routines for handling objects, treatment of individuals and approaches to understanding our environments, putting an emphasis on behaviours. To define a practice as a cultural one, however, it must be possible to relate that practice to underlying values and reasons. Furthermore, cultures are in this perspective understood as patterns of shared behaviour within groups or between individuals. The pragmatic perspective of safety culture focuses much on safe behaviours and safety outcomes in organisations, as safety is ultimately considered to be a collection of behaviours conducted by individuals and the results thereof. When analysing these behaviours, it is primarily done by evaluating the influence of shared values and beliefs on the general culture. Much of the research analysed in our literature review that involved behaviours focused on the practices of people and groups as avenues for development, which can be related to the pragmatic perspective. The prevalence of research including or focusing on safe behaviours and attitudes thus indicates that the pragmatic perspective is comparably pervasive in the mining industry research field as the normative perspective. As this would suggest that two of Edwards et al.'s (2013) conceptualisations of culture are prevalent in this research field, we would suggest it is relevant to study their third and final perspective as well.

Of Edwards et al.'s (2013) conceptualisations of safety culture, the final remaining perspective – the anthropological – is not seen as often as the normative and pragmatic

perspective in the mining industry research field. The anthropological perspective focuses on underlying values and beliefs as determinants of cultures and is more focused on mental qualities than the pragmatic perspective. Culture is considered as something that is possessed by all and is comprised by factors that ensure that conduct is repeated. Rather than evaluating the presence or absence of certain factors to determine the quality of the culture, this perspective focuses on analysing the factors shared between the participants of the culture. The anthropological conceptualisation of safety culture defines it in a similar way to most other safety culture research: as a set of safety-related factors, such as attitudes or values, shared between members of an organisation. Unlike the normative perspective, which considers safety culture as something only organisations with safety as an overriding priority have attained, the anthropological perspective does not require the existence of specific types of values and attitudes in order to discern a safety culture. This allows for analysing both positive and negative effects of culture, something we believe the current perspectives on safety culture in mining industry research sometimes lack. Further examples of the anthropological conceptualisation's potential applications to the research field lies in its relation to power. Since safety culture is considered to be a set of shared safety-related standards, it can be greatly affected by the power to influence these standards that people in higher positions hold. According to Edwards et al. (2013), however, this power is reliant on psychological factors held by the employees, such as respect for their leaders or value of money over safety, in order to affect the likelihood of compliance. This perspective on power could thus present new potential avenues in the study of themes such as leadership development or social relations.

4.3 Technological development and the involvement of the user

As mentioned previously in Subsection 4.2, we noted that although most of the themes for safety measures were referenced with relatively similar frequency across the reviewed literature, the subject of technological development has comparatively few examples. This literature review excluded articles that seemed to focus on the applications and benefits of specific technological solutions in the form of, e.g., machinery and work equipment. With this theme, we instead refer to articles that promoted systematic or strategic technological development for the purpose of improving safety in a broader organisational context. The lack of articles under this theme could be the result of them being excluded from our search for their narrow goals or research subject. It is also possible that the fact that a steady technological advance helps improve safety is taken for granted in the mining industry, causing few researchers to approach the subject. One potential risk should this assumption be correct, however, would be that improvements to the development and implementation processes for technological solutions in mining organisations could be left unexplored. Given the transformative nature of what has been called the fourth industrial revolution, where aspects such as digitalisation, automation and the use of augmented reality may become top priority for mining companies worldwide, workers might find themselves in a radically different work environment than before (Lööw et al., 2019). This in turn could lead to new types of safety risks that need to be addressed and handled as part of the continuous technology development rather than as an afterthought once the technology is in place. This may be especially important to consider given the prevalence of multi-employer worksites in the modern mining

industry, i.e., mining operations where multiple companies are involved in intricate work processes and business arrangements via outsourcing (Lööw and Nygren, 2019). The technology that one company implements on a multi-employer worksite consequently needs to be assessed in terms of potential risks for the employees of other companies working within the same operation.

Of the few articles advocating strategic technological development for the improvement of safety, none of them directly approached one organisational theory we believe could be relevant to the research field, namely the socio-technical perspective. According to Mumford (2006), the socio-technical theory's core values revolve around the importance of valuing employee well-being and satisfaction in workplace development, and the importance of a democratic development and implementation process. Firstly, it is believed that technology should not be the controlling factor when implementing new work systems, and that an equal attention must be paid to providing employees with a satisfying and high quality work environment. Values similar to those of this theory have been approached in mining-related research in the past, one of the earliest examples being Trist and Bamforth's (1951) study of the social and psychological consequences of mechanising coal mining through the 'longwall' method. Based on the results of our study, however, it seems that this theory has not been utilised in recent safety-related research in the mining industry research field. The socio-technical perspective is lacking in the research focusing on technological development for safety improvement that we analysed. Furthermore, there were no instances of researchers discussing the importance of accommodating people's well-being and workplace satisfaction during technological development and implementation beyond improving safety with the help of such technologies. It is possible that this subject has been approached in articles that ended up being excluded from this study, but we still believe that socio-technical theory is an important subject for this area of the research field to examine further. The importance of democracy in socio-technical theory relates to the inclusion of the employees who will work with the new systems or in the new environments when developing or implementing changes according to Mumford (2006). Employees' involvement is said to help bring proper attention to their needs and perspectives of the changes, while also ensuring that experiences and knowledge can be utilised to improve the design of and process of implementing changes. Values similar to socio-technical theory's focus on democracy can be found in several of the articles we analysed, especially in those we categorised under the theme of 'ownership and accountability'. They promote adapting safety measures to the needs and wants of the employees, and the inclusion of employees in the implementation work, in order to improve engagement for and involvement in the measures for improving safety. While studies exploring these subjects were present in the articles we analysed, they were however relatively rare. Further exploring the role and potential benefits of employee involvement in decision-making and change implementation is thus another potential route for future research that we can recommend.

Another example of areas that could benefit from the inclusions of socio-technical studies are the themes of knowledge development and safe behaviours established in this study. These themes indicate that research trends in this field place much focus on efforts to improve the safety performance of the lower organisational levels of mining organisations, namely employees and individuals. Meanwhile, recommendations aimed at the upper levels of these organisations focus on improvements to leadership and management capabilities. Both types of research thus aim to educate employees and

promote safe behaviours of individuals, either directly or indirectly. Furthermore, when discussing safe behaviours, the focus lies almost exclusively on individual or team behaviours. While research focusing on other themes may include measures that can be construed as improving organisational behaviours, behaviour-focused research rarely approaches that level of perspective, instead directing their solutions towards the lower levels of organisations. As mentioned in Subsubsection 3.6, studies that do promote higher autonomy for lower levels of organisations can be found amongst the articles under the 'ownership and accountability' theme, but most articles under that theme still focus on management efforts. In conjunction with the prevalence of leadership-focused safety initiatives, this indicates an inclination to focus on top-down-controlled development of safety in recent mining industry-related research, which would support the potential application of socio-technical theory in line with, e.g., Donovan et al. (2018). We thus believe that examples of largely unexplored aspects of socio-technical theory such as these two subjects, and the example implying a focus on top-down-controlled measures in safety-related mining research, indicates how the theory presents opportunities for future research on mining industry safety development.

4.4 Dissemination of safety measures

During our studies of the research field, there have been several articles examining the development of safety in the mining industry field instead of just examining specific organisations, some even comparing the industries of different nations. The authors of these articles have all evaluated current or previous states of safety performance in different mining industries, and have made recommendations for measures to improve that performance. Furthermore, several studies, especially under the themes of 'communication' and 'leadership', have examined the application of safety measures to better disseminate them between organisational levels. Few articles, however, have studied how the safety measures utilised in the mining industries are disseminated between or brought in by the organisations in the field. The availability of solutions or channels of communication for spreading safety measures can have a great impact on the organisations' decisions on which initiatives to implement, and ultimately affects how their safety performance develops. We thus believe that it would be worthwhile to further study the circumstances and mechanisms for the dissemination of safety measures within and between organisations in the mining industry field.

One theoretical field that could be of interest for a study on the dissemination of safety initiatives would be neo-institutional theory. Specifically, we believe that inspiration for this type of research can be found in the studies of DiMaggio and Powell's (1983) theories on isomorphism; the development of organisations to become more compatible with their environments and potential reasons for that change. They claim that organisational change is caused either by a desire to improve efficiency, which is called competitive isomorphism, or in order to attain legitimacy and political power, called institutional isomorphism. The mechanisms for the latter type are categorised by DiMaggio and Powell (1983) into three different kinds of isomorphic change: coercive, mimetic and normative isomorphism. Coercive isomorphism covers how organisations can be coerced by stronger organisations in the field into adaptation through formal pressures such as regulations from other organisations, or through informal pressures such as cultural expectations from society. Mimetic isomorphism meanwhile involves

changes implemented as a response to uncertainties. Examples of this type of isomorphism include organisations that imitate other more successful actors in their field when searching for solutions to new or ambiguous problems. Finally, normative isomorphism is described as organisations adopting changes or values based on the common norms and rules stemming from different professions. By participating in formal professional educations and networks, people with certain professions establish shared values, perspectives on issues and methods of work that they then bring back to their respective organisations. We believe that, while organisations' efforts to become more competitive through change is a reasonably well-covered subject in today's mining industry research, the study of other motives for organisational change has potential for further study. These perspectives on organisational change, supplemented with more recent developments in the research field of institutionalism, have potential in examining and helping further understand the decisions made for safety development in the mining industry.

5 Conclusions

With this review of safety-focused mining industry research articles, we have identified ten themes under which the safety measures analysed and/or promoted by these authors are gathered. By mapping the safety measures detailed in recent safety-related research articles, this study outlines the current state of the research field and its relatively recent culture and behaviour-based focus. Furthermore, the categorisation of research contributes to identifying subjects that are underrepresented while also illustrating certain gaps in the literature. Our hopes are that this literature review will provide suitable groundwork for furthering the development of the research field, and that the resulting studies will help improve the safety performance of mining organisations.

As certain research topics have been left largely unexplored, we have outlined subjects with particular potential for future studies. Considering that the cultural values and norms of different nations could impact their strategies for safety measures, analysing the differences between different national mining industries' organisational cultures is one potential avenue for further study. Furthermore, while it is common to explore the roles of safety cultures in this field, there is space for future research to examine different perspectives on safety culture specifically in order to promote a more nuanced understanding of the concept, for example by examining the perspectives proposed by Edwards et al. (2013). Since the promotion of employee involvement in change implementation is becoming more common, we consider socio-technical theory to be a valuable subject to study further, as well as workers' safety in a digitalised and automated mining environment. Finally, due to the apparent lack of research investigating the dissemination of safety measures between organisations in the mining industry field and its effect on safety measure success, we would recommend further research into theories such as neo-institutionalism and isomorphism.

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