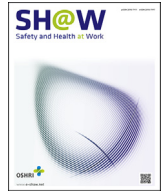




Contents lists available at ScienceDirect

# Safety and Health at Work

journal homepage: [www.e-shaw.net](http://www.e-shaw.net)

Original Article

## Safety Culture: A Retrospective Analysis of Occupational Health and Safety Mining Reports



Emily J. Tetzlaff<sup>1,2,\*</sup>, Katie A. Goggins<sup>1,3</sup>, Ann L. Pegoraro<sup>1,2</sup>, Sandra C. Dorman<sup>1,2</sup>, Vic Pakalnis<sup>4</sup>, Tammy R. Eger<sup>1,2</sup>

<sup>1</sup> Centre for Research in Occupational Safety and Health, Laurentian University, 935 Ramsey Lake Road, Sudbury, ON, P3E 2C6, Canada

<sup>2</sup> School of Human Kinetics, Laurentian University, 935 Ramsey Lake Road, Sudbury, ON, P3E 2C6, Canada

<sup>3</sup> Bharti School of Engineering, Laurentian University, 935 Ramsey Lake Road, Sudbury, ON, P3E 2C6, Canada

<sup>4</sup> Radiation Safety Institute of Canada, 100 Sheppard Ave. East, Suite 760, North York, ON, M2N 6N5, Canada

### ARTICLE INFO

#### Article history:

Received 13 July 2020

Received in revised form

15 November 2020

Accepted 5 December 2020

Available online 15 December 2020

#### Keywords:

Accidents

Mining

Occupational health and safety (OHS)

Post-investigation reports

Safety culture

### ABSTRACT

**Background:** In the mining industry, various methods of accident analysis have utilized official accident investigations to try and establish broader causation mechanisms. An emerging area of interest is identifying the extent to which cultural influences, such as safety culture, are acting as drivers in the reoccurrence of accidents. Thus, the overall objective of this study was to analyze occupational health and safety (OHS) reports in mining to investigate if/how safety culture has historically been framed in the mining industry, as it relates to accident causation.

**Methods:** Using a computer-assisted qualitative data analysis software, 34 definitions of safety culture were analyzed to highlight key terms. Based on word count and contextual relevance, 26 key terms were captured. Ten OHS reports were then analyzed via an inductive thematic analysis, using the key terms. This analysis provided a concept map representing the 50-year data set and facilitated the use of text framing to highlight safety culture in the selected OHS mining reports.

**Results:** Overall, 954 references and six themes, safety culture, attitude, competence, belief, patterns, and norms, were identified in the data set. Of the 26 key terms originally identified, 24 of them were captured within the text. The results made evident two distinct frames in which to interpret the data: the role of the individual and the role of the organization, in safety culture.

**Conclusion:** Unless efforts are made to understand and alter cultural drivers and share these findings within and across industries, the same accidents are likely to continue to occur.

© 2020 Occupational Safety and Health Research Institute, Published by Elsevier Korea LLC. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

### 1. Introduction

Although substantial progress has been made in the control of occupational health and safety (OHS) hazards in mining, the industry still accounts for 8% of fatal accidents at work [1], and similar accidents and disasters continue to reoccur at mine sites around the world. In the mining industry, accidents and disasters are distinguished based on the presence of an incubation period that allows for the accumulation of a series of unnoticed events and typically results in an event in which five or more persons lose their lives [2,3]. After major mining accidents and disasters, various methods of accident investigation and analysis are utilized to try and establish broader causation mechanisms [2,4,5], with the

overarching intention to avoid a future reoccurrence [6]. Across industries, the methods of analysis historically focused on single immediate root causes and one-dimensional event sequencing [7]. However, more recently, industries around the world have shown an increasing interest in the concept of safety culture as a means of reducing the potential for large-scale disasters, and accidents [8]. Safety culture, which is primarily aimed at preventing organizational accidents (as opposed to individual accidents), focuses on the root causes of accidents; not symptoms of accidents, leading to a more effective accident prevention strategy [9].

The concept of safety culture was originally constructed following the Chernobyl Nuclear accident in 1986 [10]. Since then, inquiries into major accidents and disasters across a range of

\* Corresponding author. Laurentian University, 935 Ramsey Lake Road, Sudbury, ON, P3E 2C6, Canada.

E-mail address: [etetzlaff@laurentian.ca](mailto:etetzlaff@laurentian.ca) (E.J. Tetzlaff).

**Table 1**  
Occupational health and safety commission descriptions

Commission	Incident	Inquired	Published	Country
Report of the Tribunal Appointed to Inquire into the Disaster of Aberfan [19]	10/1966	07/1966	07/1967	UK
Report of the Royal Commission on the Health and Safety of Workers in Mines [20]	N/A	08/1974	06/1976	CAN
Towards Safe Production [21]	N/A	07/1980	04/1981	CAN
Improving Ground Stability and Mine Rescue [22]	N/A	10/1984	02/1986	CAN
Report on an Accident at Moura No. 2 Underground Mine [23]	09/1994	10/1994	04/1995	AUS
The Westray Story: A Predictable Path to Disaster – Report of the Westray Mine Public Inquiry [24]	05/1992	05/1992	11/1997	CAN
Report on the Sago Mine Disaster [25]	01/2006	01/2006	07/2006	USA
Upper Big Branch: A Failure of Basic Coal Mine Safety Practices [26]	04/2010	04/2010	05/2011	USA
Royal Commission on the Pike River Coal Mine Tragedy [27]	11/2010	12/2010	10/2012	NZ
Mining Health, Safety and Prevention Review [28]	N/A	12/2013	03/2015	CAN

hazardous industries have frequently identified poor safety culture as a key contributor (e.g., Piper Alpha) [11–15]. A strong safety culture is associated with numerous safety-related outcomes, including performance of safe work practices [16–18], safety program effectiveness [19,20], and reduction in accidents, near misses, and other safety incidents [21,22]. Despite these positive safety-related outcomes, the term safety culture lacks a universally accepted definition [23], and has weaknesses in its conceptualization and utilization in practice [24], which makes it difficult to examine the extent to which cultural influences are acting as drivers in the reoccurrence of accidents and disasters. Despite its origin in accident investigation, it is uncommon for safety culture to be directly addressed in investigations, especially in the mining industry. Instead, it is becoming increasingly common for companies and researchers to apply safety culture retroactively to explain accidents and incidents [25–28] to distinguish between perceived safety culture and actual safety culture.

This raises interest about the role organizational safety culture may be playing in the occurrence of similar accidents in the mining industry. Although safety culture may not have been directly assessed, it may be present in the broader conversation captured in the reports after investigation, potentially providing insight to the contribution of safety culture among similar accidents. Thus, the overall objective of this study was to analyze OHS reports in mining to investigate if/how safety culture has historically been framed in the mining industry. Industries around the world are showing an increasing interest in the concept of safety culture as a means of reducing the potential for large-scale disasters and accidents [8]. Safety culture, which is primarily aimed at preventing organizational accidents, focuses on the root causes of accidents; not symptoms of accidents, leading to a more effective accident prevention strategy. These research results have the potential to help the mining industry identify the presence of the drivers of an unsafe working culture, before they have the opportunity to contribute to the occurrence of an accident.

## 2. Methods

The method used follows a similar protocol to that used by Tetzlaff et al. [29], where the researchers applied a similar big data analysis technique to address repeating recommendations in OHS mining investigative reports from a large multiyear data set.

### 2.1. Mining reports data set

Occupational health and safety reports were selected in consultation with five industry professionals, known for their expertise in mining safety and accident investigation [23]. Based on the objectives of this study, the inclusion criteria were reports on

single accidents, disasters, and broader mining industry reviews that were appointed to investigate new and emerging issues, provide advice on an area where government lacks expertise, access external knowledge, identify key issues on policy problems, and/or provide recommendations for the future [30]. The final list contained 10 reports focusing on OHS, published in English, by five countries between 1967 and 2015 (Table 1) [31–40].

### 2.2. Determination of key safety culture terms

A literature review of Google Scholar, Science Direct, Sage Journals, and Taylor & Francis Online databases, for peer-reviewed journal articles defining safety culture, was conducted until saturation was reached (i.e., repeating articles, repeating definitions). From these journal articles, 34 safety culture definitions were extracted and all definitions were amalgamated into one source document. Using a computer-assisted qualitative data analysis software, 26 dominant terms were identified, based on word count and contextual relevance [41].

### 2.3. Analysis, context filtering, and interpretation

The OHS reports were analyzed via an inductive thematic analysis, an approach that allowed for categories to emerge from the data rather than categories being determined *a priori*. The researchers used the qualitative software Leximancer (Version 4.0, 2011, Leximancer Pty Ltd., University of Queensland) to analyze the text documents. Leximancer conducts conceptual and relational analysis on written words as well as visual text [41]. Leximancer allows for the development of a user-generated thesaurus to analyze new data sets based upon previously identified coding schemes [41]. Therefore, the previously identified key safety culture terms were uploaded and used as the thesaurus for this analysis. Each concept was then filtered to confirm if it accurately reflected the meaning of the retrieved words. Filtering consists of removing synonyms that the software did not identify in the text; removing concepts where the accumulated text excerpts did not justify inclusion in the discussion and removing words that are used in a different context [42].

This analysis provided a concept map that represented the 50-year data set and assisted in the identification and exploration of safety culture within the data. Text framing was then used to highlight safety culture in the selected OHS mining reports [43]. Frames, defined as a device that reflects a pattern of cognition, interpretation, and presentation, are both defined by what they include as well as what they omit and are therefore indicative of broad conceptual categories that provide culturally specific meaning to the reader [44]. Frames have four locations in the communication process: the communicator, the text, the receiver, and the

culture [43]. In this study, the communicator is the organization or regulatory body that produced and published the OHS report; the text is the inclusion or exclusion of safety culture–related terminology; the receiver represents all stakeholders in the mining industry that are influenced or affected by the OHS reports; and the culture refers to the commonly presented frames that represent the mentality or commonly demonstrated thinking of a social grouping. By investigating the association between textual elements within the document and the overall framing of the story, changes in the relative proportion and stability of frames during a given time period can be examined. Leximancer and framing theory can be utilized similarly to axial coding in traditional textual analysis, where themes are regrouped or reduced based on related dimensions [45]. These groups will represent how safety culture has been framed in investigative reports in the mining industry.

The researchers then interpreted the visual concept map, output by Leximancer, to accurately capture the nature of the content. Within the visual map, words (concepts) are clustered into higher-level ‘themes’ that are depicted as colored circles, based on frequency of use in relation to each other. The themes are also heat-mapped to indicate importance; where the most dominant theme appears in red, the next in orange, and so on to colder colors such as purples and blues. The location of the themes and concepts on the map also indicate relational relevance, with overlapping themes indicating the strongest relationship, and themes on opposite ends of the map demonstrating a lesser relationship. In addition, the size of the circles indicates prominence within the data set being analyzed. The gray network of lines between concepts indicates the most-likely connection between concepts [41].

### 3. Results

Through this iterative process, supporting words in the thesaurus were identified, resulting in a total of 8,279 references on safety culture, being identified in the text set. However, after filtering the text it was determined that 7,315 references could not be justified for inclusion. For example, the text excerpts regarding behavior related to both human behavior and the behavior of the underground environment (e.g., “soil mechanics has been defined as the scientific study of the behavior of an aggregation of discrete

particles” [31]). Therefore, only human behavior text references were retained in the analysis, and additional references were removed. As a result, 954 references were included in the analysis (Table 2).

The 2-stage analysis identified six themes: safety culture, attitude, competence, belief, patterns, and norms, in descending order of prominence in the data set. Within the themes, key safety culture terms that are semantically related within the OHS reports were visualized within the same cluster (Fig. 1). Of the 26 key terms originally uploaded into user-generated thesaurus, 24 of them were identified within the text, and two were not directly or indirectly identified (morals [n = 0]; rituals [n = 0]). From the key terms in each cluster, the underlying text references were then used to understand the context behind each seeded term to ensure contextual relevance. Once the themes were identified, the researchers reduced them into two frames according to whether or not they related directly to the (a) The Individual (Table 3) and (b) The Organization (Table 4). The frames and their subthemes are described in the following passages using textual examples.

### 4. Discussion

This historical analysis of the emergence and presence of safety culture in OHS reports in mining, provided the unique opportunity to identify how safety culture was captured in the post-investigation reports, potentially providing insight to the contribution of safety culture amongst similar accidents. The results made evident two distinct frames in which to discuss the data: the role of the individual, and the role of the organization, in safety culture.

#### 4.1. Role of the individual in safety culture

The role of the individual provided evidence for how the mining industry has portrayed the influence of human error and human factors in contributing to the safety culture of a workplace and subsequent ability for an accident to occur. From the individual perspective, safety culture is influenced by the various factors which determine a worker’s attitude towards safety (i.e., values, past experiences); determined by how individual characteristics contribute

**Table 2**  
The number of references for each safety culture key term over a 50-year timeline

Frame	Theme	Safety culture key terms	1967[19]	1976[20]	1981[21]	1986[22]	1995[23]	1997[24]	2006[25]	2011[26]	2012[27]	2015[28]	
The Individual	Attitudes	Attitude	0	2	123	1	2	27	0	2	5	0	162
		Behavior	2	4	88	0	0	12	0	0	11	1	118
		Characteristics	0	0	38	0	0	0	0	1	6	1	46
		Feelings	0	0	16	0	0	1	0	1	1	1	20
		Perceptions	0	1	11	0	3	4	0	0	0	0	19
	Competence	Thoughts	0	0	12	0	0	1	0	0	0	0	13
		Psychological	0	0	4	0	0	0	0	0	0	0	4
		Competencies	8	5	18	6	0	61	0	1	17	3	119
		Values	0	0	2	1	0	2	0	1	2	0	8
		Norms	0	0	0	0	1	0	0	3	1	0	5
	Patterns	Patterns	1	0	8	0	0	0	0	0	2	1	12
		Experiences	0	0	6	0	0	0	0	0	1	0	7
		Mental	0	1	6	0	0	0	0	0	0	0	7
		Ethical	0	1	0	0	0	5	0	0	0	0	6
		Interpretations	0	0	4	0	0	0	0	0	0	0	4
The organization	Belief	Situational	0	0	3	0	0	0	0	0	0	1	4
		Attributes	0	0	0	1	0	0	0	0	0	0	1
		Belief	3	7	31	1	1	19	3	4	7	3	79
	Safety	Commitment	0	4	55	0	0	20	0	5	11	0	95
		Social practices	1	7	22	1	1	33	0	8	8	2	83
		Attention	0	2	23	0	0	26	0	1	13	3	68
		Culture	Safety culture	0	0	0	0	1	0	0	8	37	7
Shared	1	0	8	0	0	3	0	1	6	1	20		
Observable	0	1	0	0	0	0	0	0	0	0	1		
TOTALS			16	35	478	11	9	214	3	36	128	24	

to the formulation of perceptions, expectations and interpretations of how one should behave; and influenced by the technical competence, and ability to identify individual competence.

#### 4.1.1. Determinants of an individual's attitude toward safety

Attitude was the dominant theme and key term within the analysis. The discussion surrounding attitude incorporated how attitudes are shaped, the presence of attitudinal subunits within organizations, and the various factors which influence a worker's attitude toward safety. Attitudes are preceded by cognitive, affective, and behavioral processes, and, in turn, attitudes produce cognitive, affective and behavioral responses [46]. Although there are various definitions of attitude, attitude is always directed toward an object: in this discussion, safety. Therefore, safety attitudes refer to individual and collective beliefs about hazards and the importance of safety, together with the motivation to act on those beliefs.

Weaved throughout many of the attitude references was the underlying influence of management's attitudes in shaping the manner in how a workplace functions. Within the literature, it is extensively discussed that organizations often try to change attitudes without consideration for organizational features [47]. Similarly, changes are often made to organizational systems without regard for individual behavior or attitudes [48]. However, it is known that individuals are neither deterministically controlled by their environments nor entirely self-determining [49]. Therefore, understanding the role of individual attitudes, and the reciprocal relationship between them and the organizational environment, is important for determining how necessary attitudinal change to improve workplace safety can be achieved.

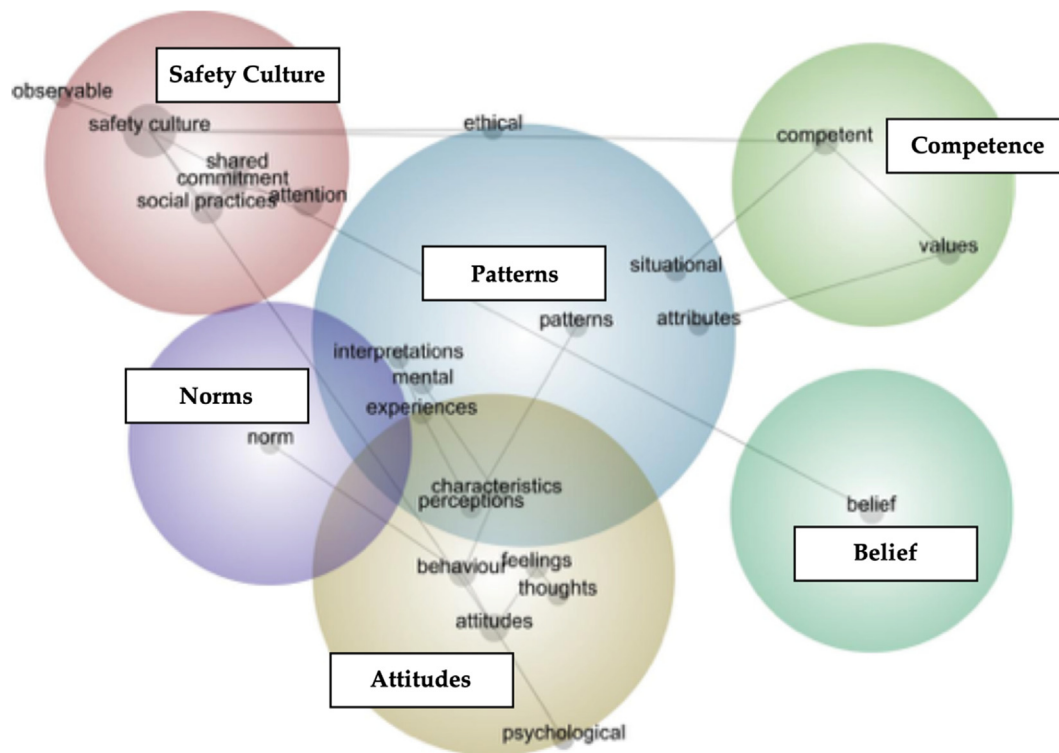
#### 4.1.2. Contribution of personal characteristics toward safe behavior

Individual characteristics and perceptions, which can be fixed or adapted, can influence human behavior. Characteristics were

incorporated into the accident causation discussion as an individual's distinguishable traits can influence their behavior and subsequently affect their OHS. Perceptions were predominantly discussed in three forms: how perceptions are formed, the influence of perceptions on roles and expectations, and how perceptions can influence accidents. For example, the data highlighted how the expectations of another individual are based on what is perceived to be important by the individual forming the perceptions. It has been previously established that psychological and behavioral characteristics of an individual are considered organizational factors that can influence accidents [50] and are often explained using the accident proneness theory [9]. The accident proneness theory assumes there are permanent personal characteristics that make one more likely to have an accident. To reduce the influence of personal characteristics in accident causation, safe behavior strategies should identify behavior's that are not compliant with safe work procedures and address them.

#### 4.1.3. Influence of technical competence

The data around competence related both to the overall knowledge and skills of various individuals and the need for individuals in the mining environment to be technically competent and risk aware. Data surrounding competence also included references to the failure of the system's ability to identify the lack of competence in individuals, and how individuals receive their training, qualifications, and certifications. If workplaces become complacent and view training as a formality, instead of a requirement for ensuring worker safety and safe production, then they are not contributing to a positive workplace safety culture. The need for structured training is supported through competency models [51]; however, there is an increased awareness that valuable learning often happens informally on the job, in groups, or through conversations [52]. This style of unstructured learning



**Fig. 1.** The concept map of seeded safety culture terms used to develop the frames: Frame 1: The Individual: attitude (yellow), competence (light green), patterns (blue), and norms (purple); Frame 2: The Organization: belief (green), and safety culture (red).

**Table 3**  
Text examples of the key safety culture terms related to the frame “The Individual”

Theme	Safety culture key terms	Text examples
<b>Attitude</b>	Attitude	“It suggests a profoundly dangerous <u>attitude</u> that fire bossing a mine is just another burden ... failure to perform them diligently and honestly reflects poorly on the <u>attitudes</u> up the company's chain of command” (p.98) [38].
	Behavior	“Mindset requires supervisory <u>behaviour</u> to counteract the nonchalant <u>attitude</u> often encountered in more experienced workers, who may have adopted hazardous shortcuts and a dangerously complacent approach to occupational risks” (p.94) [36].
	Characteristics	“Human factors are the environmental, organizational and job factors, and human and individual <u>characteristics</u> , which influence <u>behaviour</u> at work in a way which can affect health and safety” (p.27) [39].
	Feelings	“Expressed similar concerns and <u>feelings</u> of distrust vis-a-vis Westray management: Some of the people who were appointed to the safety committee I felt I couldn't trust not to expose any concerns that I had about safety back to management, and therefore making me vulnerable to the tactics of management as far as intimidation and harassment” (p.180) [36].
	Perceptions	“Factors influencing ... expectations are a combination of a range of highly complicated sources such as the economic conditions, management philosophy and <u>attitudes</u> , legislative requirements, other organizational issues, etc.” (p.78) [33].
	Thoughts	“A readiness to assess or evaluate an object in a certain way; it is the intellectual part of an <u>attitude</u> and encompasses the <u>thoughts</u> of an individual” (p.48) [33].
	Psychological	“A person's actions are motivated in one way or another, consciously or unconsciously, and that no <u>behaviour</u> is totally devoid of some underlying <u>psychological</u> mechanism ... <u>attitudes</u> are <u>psychological</u> traits” (p.51) [33].
<b>Competence</b>	Competence	“The regulatory system should drive training programmes that produce a qualified and <u>competent</u> workforce which is aware of the major risks in underground coal mining and how to manage them. Deficiencies and gaps in the regulations are holding back the development of the workforce” (p.338) [39].
	Values	“Employers should create a 'no-blame culture' that <u>values</u> health and safety and that supports workers who raise health and safety concerns” (p.335) [39].
<b>Norms</b>	Norms	“The not-so-subtle message to employees [was] that MSHA [was] costing the company money – and workers shouldn't aid in that process. In an organization where deviance is not the <u>norm</u> , the same information might be used to deliver a very different message. ‘We have some very serious safety problems at this mine, so much so that we've racked up a million dollars in penalties’” (p.101) [38].
<b>Patterns</b>	Patterns	“The information I have seen shows me recurring <u>patterns</u> of causal factors that I know are well established in the literature to increase the likelihood of a process safety event” (p.76) [39].
	Experiences	“Factors such as personal background, skills and abilities, and past <u>experiences</u> would play an important part in this process ... a person's <u>experiences</u> form the backbone of his <u>attitudes</u> ” (p.64) [33].
	Mental	“The quality of the critical relationships are being adversely affected by the existence of an adversarial <u>mentality</u> ” (p.12) [33].
	Ethical	“It is the responsibility of management at all levels through its actions and its example to instill a strong safety <u>ethic</u> in its workforce.’ In the case of Westray, management undeniably failed to do so” (p.155) [36].
	Interpretations	“The individual himself, by his own <u>perceptions</u> , expectations, and <u>interpretations</u> [determines] how he ought to behave. This refers to a synthesis of personalized representations of the requirements within the organization, some of which may be acquired as a consequence of direct <u>experiences</u> and others may develop as a result of indirect influences” (p.64) [33].
	Situational Attributes	“Keen sense of <u>situational</u> awareness” (p.27) [40]. “ <u>Attitudes</u> as object appraisal systems serve to simplify a person's task of assessing new information about objects by providing him with already evaluated categories to which incoming information can be fitted. The object appraisal predominates, <u>attitudes</u> should be malleable, in response to rational presentations of information that lead the person to reappraise the bearing of reality <u>factors</u> on his interests and enterprises” (p.30) [33].

needs to be supported by a learning culture that is embedded in the organization's capacity to adapt or to respond in novel ways while working to remove barriers to learning. Often these discussions also related back to how role conflicts and role ambiguity can affect how an individual interprets their responsibilities towards taking ownership of safety. It is well-established in the literature that occupational stressors, such as role ambiguity, can influence organizational accidents [22,53,54]. A lack of risk awareness, poorly designed training systems, and occupational stressors are all preexisting hazards that make an organizational system vulnerable to failure. The regulatory system should drive training programs that produce a qualified and competent workforce which is aware of the major risks in the coal mining and how to manage them.

## 4.2. Role of the organization in safety culture

The role of the organization was driven by references that broadened the discussion beyond the individual, to the larger organizational practices. It was portrayed from the findings that within the organizational context safety culture is influenced by the commitment that a workplace makes to safety through how responsibilities are shared; persuaded by the dominant social practices (safe or unsafe); and determined by where attention is prioritized.

### 4.2.1. Commitment

The references about commitment not only focused on the need for a commitment to OHS from all stakeholders (e.g., workers,

supervisors, management, unions, ministries, insurance boards), but prompted the industry to broaden the view beyond the behavior of individual work practices and behaviors, to evaluating management decisions (i.e., how miners' work is organized and performed). Consistent with what is widely accepted throughout the literature [55,56], the role of management leadership demonstrates that management's commitment to safety, management style, and management visibility are key indicators of an organization's safety culture [57]. Therefore, there must be commitment from all levels of the organizational structure, initiating with a top-down organizational approach [26,58–61].

#### 4.2.2. Social practices

Findings from the analysis also revealed similarities across the timeframe related to the propagation and penetration of the dominant culture throughout the organizations, which created various socially accepted practices. The data around social practices largely encompassed the lack of group dynamics that support OHS in the workplace and the need for establishing such social practices. Safety compliance refers to the core activities that individuals conduct to maintain workplace safety and

adhere to the safety management system (i.e., wearing personal protective equipment), whereas safety participation describes behavior's that do not directly contribute to an individual's personal safety but assist in developing an environment that supports safety (i.e., attending safety meetings) [62]. It is evident within many of the reports analyzed that safety compliance and safety participation were not normalized practices among workers, supervisors, or management. Emphasis was on the importance of looking beyond organizational standards, to determine if the individual, legislative, and social judgments expressed through work practices and their supervision, in regulatory standards and processes of enforcement is adequate. This is similar to previous findings that similarly indicate the presence of a gap between perceived and actual demonstrations of safety [26,28]. Organizational cultures typically are bias reflecting the values of the dominant group, or subculture, in the organization [26]. This is relevant to note because, although organizational cultures can enhance organizational goals, they can also perpetuate negative behavior, beliefs, attitudes, and values [26,63].

**Table 4**  
Text examples of the key safety culture terms related to the frame “The Organization”

Theme	Safety culture key terms	Text examples
<b>Belief</b>	Belief	“Had MSHA followed the mandates of Congress, and had ICG operated the mine with an eye firmly focused on miners' safety, there is every reason to <u>believe</u> that every person underground that day would have survived” (p.1) [37]. “It's my firm <u>belief</u> that they had no intention of complying” (p.340) [36].
<b>Safety Culture</b>	Commitment	“A genuine <u>commitment</u> to safety means not just examining miners' work practices and behaviors. It means evaluating management decisions up the chain of command – all the way to the boardroom – about how miners' work is organized and performed” (p.4) [38]. “A policy statement confirming the organization's <u>commitment</u> to safety and the obligation upon workers, supervisors and management to contribute to a safe working environment” (p.24) [33]. “Miners' rights to a safe workplace are compromised when the operator's <u>commitment</u> to production comes at the cost of safety” (p.112) [38].
	Social practices	“Disease and injury is not settled simply by setting environmental standards. It is determined by individual, legislative, and <u>social judgments</u> as expressed in work practices and their supervision, in regulatory standards and processes of enforcement” (p.95) [32]. “There is an obvious disconnect between the lofty safety standards ... and the reality of conditions inspectors and investigators [find] (p.95)... <u>Practices</u> such as these can only exist in a workplace where the deviant has become <u>normal</u> , and evidence suggests that a great number of deviant <u>practices</u> became <u>normalized</u> at the Upper Big Branch mine” (p.97) [38].
	Attention	“The response of Westray management to these continuing problems seemed to exacerbate them and divert <u>attention</u> from other serious safety concerns. In the result, the entire safety <u>mentality</u> at Westray deteriorated while management was consumed with its apparent inability to deal with ground control ... Although it is impossible to quantify the contribution of such a major diversion to the disaster, it was likely significant” (p.382) [36]. “Regular risk assessments help focus <u>attention</u> on the hazards that pose the greatest risk to health and safety. They also ensure that the sector is able to identify new or evolving hazards and take steps to mitigate them” (p.6) [40].
	Safety culture	“All partners in [the] mining occupational health and safety system – the Ministry of Labour, the Workplace Safety and Insurance Board, the relevant Health and Safety Associations, the joint occupational health and safety committees or representatives and workers and employers – play a critical role in creating a health and <u>safety culture</u> ” (p.7) [40]. “The role of the mine manager in creating and maintaining a <u>culture</u> that fosters worker participation and identifying and mitigating hazards is key to an effective IRS” (p.56) [40]. “A <u>culture</u> created a climate in which a disaster ... could occur ... such total and catastrophic systemic failures can only be explained in the context of a <u>culture</u> in which wrongdoing became acceptable, where deviation became the <u>norm</u> ” (p.101) [38].
	Shared	“Although the overall responsibility for safety in the workplace lies with the top management and although this responsibility cannot be <u>shared</u> , cooperation of everybody in the workplace is essential for the effective discharge of that responsibility” (p.80) [33]. “The Review heard from various sources ... that research is being done and/or new techniques to reduce injury and illness are being tested but the information is not being <u>shared</u> . When findings that show better ways to improve health and safety are not <u>shared</u> , they can't make a difference” (p.63) [40].
	Observable	“That committee conducts a clinical assessment of each referred claimant to determine if there is silicosis and <u>observable</u> impairment” (p.86) [32].

#### 4.2.3. Attention

Attention predominantly appeared in the data in three forms: the diversion of attention, drawing attention, and communicating the need for attention. First, the diversion of attention was evidenced through competing priorities of the organization, resulting in the diversion away from safety concerns. For example, there was a wealth of evidence related to how a culture of production challenges a culture of safety, which further identifies the consequences of procedures, such as production bonus programs [36]. As management's role is diffused vertically in organizational hierarchies, the dependence on senior management can be challenging with competing concerns in other areas of the organization. This appeared frequently, as it was evident that the diversion of attention weakened the organizations ability to respond and mitigate safety issues. Previous research has similarly shown that the influence of leadership style [64] and management practices [57] are key organizational factors that influence accidents. Secondly, drawing attention was related to the importance of conducting regular risk assessments to draw industry attention to specific hazards that pose the greatest risk to OHS. A similar study examined 39 coal mine disasters to focus on the role and effectiveness of enforcement, and identified that fatal accidents are attributable to various defects, including the attention to hazards [3]. Consistent risk assessments that identify hazards, analyze and evaluate the risk associated with the hazards, and determine the appropriate method of eliminating or controlling the new or evolving hazards are an essential component of an OHS management system. Lastly, communication was a concern as there was evidence of OHS concerns failing to be disseminated throughout the organizations, resulting in high-potential incidents not being reported. In the change management literature, it is evident that communication is a foundational aspect of organizational transformation. The process in which change is introduced sets the tone for recipients with respect to acceptance or rejection [65]. Therefore, if an organization fails to willingly and effectively communicate OHS concerns, latent organizational issues will challenge the system and lead to potential accidents.

#### 4.3. Limitations and future studies

Although the study encompasses 50 years, five countries, and 10 reports, it is not without limitations. As there is no commonly accepted definition of safety culture, the study dictionary was developed through a review of the literature, and therefore there may have been additional terms throughout the evolution of the concept that were missed in the development of the dictionary. However, during the computer-assisted data analysis, in addition to the seeded terms, any related automatically identified terms were extracted during the generate thesaurus phase through an iterative process [41], therefore, decreasing the risk of missing any contextually relevant discussion. Secondly, although the sample itself was large in scope, there could have been a more diverse number of reports included from different countries. Having incorporated additional countries may have provided a more diverse discussion due to the variation in legislation, safety standards, and cultural norms, along with investigative techniques. Lastly, commissioned reports, or investigation reports, have the potential to be influenced by the authoring body. This study is limited to the interpretation of what was published. For example, there may have been conversations throughout the investigation process that further discussed safety culture that were not captured in the published public reports.

As this study has been a retrospective analysis, future research should focus on proactive measures of organizational culture to

analyze potential differences in how recommendations from commissioned reports are implemented in the mining industry. The results of this research could assist OHS personnel in identifying how safety culture may influence the disconnect between the delivery of the safety recommendations and the implementation of the recommendation. This would allow future implementation of recommendations to result in greater compliance and improved safety-related outcomes. Furthermore, although the contexts of various work environments can be different, there is an opportunity to learn from occupational accident investigations and recommended practices from other countries, industries, or variations within the same sector (i.e., metalliferous and coal mining) [2,66,67]. This research has further identified a new methodology for big data analysis that can assist in identifying trends over time and prove useful in other industries across the broader OHS landscape.

## 5. Conclusion

This historical analysis of the emergence and presence of safety culture in this sample of OHS commissioned reports in mining, reveals how the industry has progressed and adapted to advancements in organizational safety science. This research provides a positive outlook on the broadening inclusion of safety culture in understanding accidents in the mining industry and makes clear that identifying and altering cultural drivers may impact the likelihood of an accidents reoccurrence. In addition, this study has further identified a new methodology for continued research in this area, using big data analysis techniques to learn from lessons of the past, without having to endure another industry accident.

## Conflicts of interest

All authors have no conflicts of interest to declare.

## References

- [1] ILO. Economic and social sectors: energy and mining. International Labour Organization. 2020. Available from: [www.ilo.org](http://www.ilo.org).
- [2] Turner BA. Man-made disasters. London, United Kingdom: Wykeham Publications; 1978.
- [3] Braithwaite J. To punish or persuade: enforcement of coal mine safety. Albany, USA: State University of New York Press; 1985.
- [4] Hopkins A. A culture of denial: sociological similarities between the Moura and Gretley mine disasters. *J Occup Health Saf* 2000;16(1):29–36.
- [5] Quinlan M. Ten pathways to death and disaster: learning from fatal incidents in mines and other high hazard workplaces. Sydney, Australia: The Federation Press; 2014.
- [6] Dekker SWA. The psychology of accident investigation: epistemological, preventive, moral and existential meaning-making. *Theor Issues Ergon Sci* 2015;16:202–13.
- [7] HSC HaSC. ACSNI study group on human factors. London, UK: Organizing for Safety; 1993.
- [8] Cooper MD. Towards a model of safety culture. *J Saf Sci* 2000;36:111–36.
- [9] Abdelhamid TS, Everett JG. Identifying root causes of construction accidents. *J Construct Eng Manag* 2000;126(1):52–60.
- [10] ILO. Chernobyl 20 years after: from disaster, breeding a new safety culture. International Labour Organization. 2016. Available from: [www.ilo.org](http://www.ilo.org).
- [11] Cullen WD. The public inquiry into the piper Alpha disaster. London, UK: H.M.S.O.; 1990.
- [12] Baker JA, Erwin G, Priest S, Tebo PV, Rosenthal I, Bowman FL, et al. The report of the B.P. US refineries independent safety review panel. The B.P. US Refineries Independent Safety Review Panel; 2007.
- [13] Magnus R, The CI, Lau JM. Report of the committee of inquiry into the incident at the MRT circle line worksite that led to the collapse of the nicoll highway on 20 April 2004. Singapore: Subordinate Courts; 2005.
- [14] Sheen J. MV herald of free enterprise: report of court No. 8074 formal investigation. London, UK: Department of Transport; 1987.
- [15] Goh YM, Bornw H, Spickett J. Applying systems thinking concepts in the analysis of major incidents and safety culture. *J Saf Sci* 2010;48:302–9.

- [16] Dejoy DM, Murphy LR, Gershon RRM. The influence of employee, job/task, and organizational factors on adherence to universal precautions among nurses. *Int J Ind Ergon* 1995;16:43–55.
- [17] Griffin MA, Neal A. Perceptions of safety at work: a framework for linking safety climate to safety performance, knowledge, and motivation. *J Occup Health Psychol* 2000;3:347–58.
- [18] Mattila M, Hyttinen M, Rantanen E. Effective supervisory behaviour and safety at the building site. *Int J Ind Ergon* 1994;13:85–93.
- [19] Cheyne A, Cox S, Oliver A, Tomas JM. Modelling safety climate in the prediction of levels of safety activity. *J Work Stress* 1998;12(3):255–71.
- [20] Zohar D. Safety climate in industrial organizations: theoretical and applied implications. *J Appl Psychol* 1980;65:96–102.
- [21] Dedobbeleer N, Beland F. A safety climate measure for construction sites. *J Saf Res* 1991;22:97–103.
- [22] Gillen M, Baltz D, Gassel M, Kirsch L, Vaccaro D. Perceived safety climate, job demands, and coworker support among union and nonunion injured construction workers. *J Saf Res* 2002;33(1):33–51.
- [23] Tetzlaff E, Pegoraro A, Pakalnis V, Eger T. Thematic analysis of key recommendations from commissioned Occupational Health and Safety Reports in mining, Sudbury, Ontario: Laurentian University; 2017.
- [24] Shirali GA, Shekari M, Angali KA. Qualitative assessment of resilience safety culture using principal components analysis and numerical taxonomy: a case study in a petrochemical plant. *J Loss Prev Process Ind* 2016;40:277–84.
- [25] Vaughan D. The challenger launch decision: risky technology, culture and deviance at NASA. Chicago: University of Chicago Press; 1996.
- [26] Antonsen S. Safety culture and the issue of power. *J Saf Sci* 2009;47:183–91.
- [27] NTSB. National transportation safety board. Washington, DC: National Transportation Safety Board; 2013.
- [28] Strauch B. Can we examine safety culture in accident investigations, or should we? *J Saf Sci* 2015;77:102–11.
- [29] Tetzlaff E, Pegoraro A, Dorman S, Pakalnis V, Eger T. Analysis of recommendations from mining incident investigative reports: a 50-year review. *Safety* 2019;6(3):15.
- [30] Prasser S. Royal Commissions in Australia: when should governments appoint them? *Aust J Public Adm* 2006;65(3):28–47.
- [31] Davies SHE. Report of the tribunal appointed to inquire into the disaster at Aberfan on October 21st 1966. 1 ed. London, United Kingdom: Her Majesty's Stationary Office; 1967.
- [32] Ham JM. Royal commission on the health and safety of workers in mines. Toronto, Canada: Ministry of the Attorney General; 1976.
- [33] Burkett KM, Riggan RP, Rothney KE. Towards safe production: joint federal-provincial inquiry commission into safety in mines and mining plants in Ontario. Ontario, Canada: Government of Canada; 1981.
- [34] Stevenson T, Campbell B, Curtis P, Briggs R, Guillet S, Bharti S, et al. Improving ground stability and mine rescue: the report of the provincial inquiry into ground control and emergency preparedness in Ontario mines. Ontario, CAN: Ontario Government Bookstore; 1986.
- [35] Windridge FW, Parkin RJ, Neilson PJ, Roxborough FF, Ellicott CW. Report on an accident at Moura No. 2 underground mine on Sunday, 7 August 1994. Moura District, Australia: Australian Government; 1996.
- [36] Richard KP. The Westray story: a predictable Path to disaster: report of the Westray mine public inquiry. Nova Scotia, CAN: Lieutenant Governor in Council; 1997.
- [37] Roberts CE, Kane DJ. The Sago mine disaster. West Virginia, USA: United Mine Workers of America; 2006.
- [38] Beall K, Beck JA, McGinley PC, Monforton C, Roberts DC, Spence B, et al. Upper big branch: the April 5, 2010 explosion: a failure of basic coal mine safety practices: report to the governor of West Virginia. Charleston, USA: Diane Publishing; 2011. 122 p.
- [39] Panckhurst G, Bell S, Henry D. The royal commission on the pike river coal mine tragedy. Wellington, New Zealand: Governor General of New Zealand; 2012.
- [40] Government O. Mining health, safety and prevention review. Ontario, Canada: Ministry of Labour; 2015.
- [41] Leximancer. Leximancer manual (version 4). 4.0 ed; 2014.
- [42] Yin RK. Case study research design and methods. Sage; 2009.
- [43] Entman R. Framing: toward clarification of a fractured paradigm. *J Commun* 1993;43(4):51–8.
- [44] Goffman E. Frame analysis: an essay on the organization of experience. Boston, USA: Northeastern University Press; 1974.
- [45] Saldana J. The coding manual for qualitative researchers. Thousand Oaks, CA: Sage; 2009.
- [46] Guldenmund FW. The nature of safety culture: a review of theory and research. *J Saf Sci* 2000;34:215–57.
- [47] Atkinson PE. Creating culture change: the key to successful total quality management. USA: Kempston; 1990.
- [48] Seddon J. A passion for quality. *The TQM Magazine* 1989:153–7.
- [49] Davies GF, Powell WW. Organization – environment relations. In: Dunnette MD, Hough LM, editors. *Handbook of industrial and organizational psychology* 1992. p. 315–75.
- [50] Clarke SC. The relationship between safety climate and safety performance: a meta-analytic review. *J Occup Health Psychol* 2006;11:315–27.
- [51] Marsick VJ, Watkins KE. Demonstrating the value of an organization's learning culture: the dimensions of the learning organization questionnaire. *J Adv Dev Hum Resour* 2003;5(2):132–51.
- [52] Organizations HfLi. Strategic organizational learning: how innovative companies use learning to address business challenges (Report to participating companies). New York: Teachers College, Columbia University; 2002.
- [53] Hemingway MA, Smith CS. Organizational climate and occupational stressors as predictors of withdrawal behaviours and injuries in nurses. *J Occup Org Psychol* 1999;72:285–99.
- [54] Goldenhar LM, Williams LJ, Swanson NG. Modelling relationships between job stressors and injury and near-miss outcomes for construction labourers. *J Work Stress* 2003;17(3):218–40.
- [55] Neal A, Griffin MA. Safety climate and safety behaviour. *Aust J Manage* 2002;(Special Issue):67–75.
- [56] Dejoy D. Behaviour change versus culture change: divergent approaches to management workplace safety. *J Saf Sci* 2005;43(2):105–29.
- [57] Flin R, Mearns K, O'Connor P, Bryden R. Measuring safety climate: identifying the common features. *J Saf Sci* 2000;34:177–92.
- [58] Mohamed S. Scorecard approach to benchmarking organizational safety culture in construction. *J Construct Eng Manage* 2003;129(1):80–8.
- [59] Choudhry R, Fang D, Mohamed S. The nature of safety culture: a survey of the state-of-the-art. *J Saf Sci* 2007;45(10):993–1012.
- [60] Mearns K, Flin R, Gordon R, Fleming M. Human and organizational factors in offshore safety. *J Work Stress* 2001;15:144–60.
- [61] Hopkins A. Safety culture, mindfulness and safe behaviour: converging ideas?; 2002.
- [62] Neal A, Griffin MA. A study of the lagged relationships among safety climate, safety motivation, and accidents at the individual and group levels. *J Appl Psychol* 2006;91:946–53.
- [63] Pidgeon NF. The limits to safety? Culture, politics, learning and man-made disasters. *J Contingencies and Crisis Manag* 1997;5:1–14.
- [64] Kim Y, Park J, Park M. Creating a culture of prevention in occupational safety and health practice. *J Saf Health Work* 2016;7:89–96.
- [65] Mento A, Jones R, Dirndorfer W. A change management process: grounded in both theory and practice. *J Change Manag* 2002;3(1):45–59.
- [66] Vuorio A, Rantonen J, Johnson C, Ollila T, Salminen S, et al. What fatal occupational accident investigators can learn from fatal aircraft accident investigations. *J Saf Sci* 2013;62:366–9.
- [67] Lind S, Kivistö-Rahnasto J. Utilization of external accident information in companies' safety promotion – case: Finnish metal and transportation industry. *J Saf Sci* 2008;46:802–14.