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SYSTEMATIC REVIEW

The Important Role of Safety Culture in the Management of Major Industrial Accidents

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ABSTRACT

Introduction: Major industrial accidents or disasters can have significant impacts on various aspects, including human health, the environment, societal well-being, and national economies. The concept of safety culture is increasingly receiving attention as a means of mitigating industrial mishaps. Nonetheless, a dearth of comprehensive systematic reviews exists that specifically examine the important role of safety culture in effectively mitigating severe industrial accidents across diverse industries on a global scale. Hence, the primary aim of this research is to examine the important role of safety culture in the effective management of industrial accidents across diverse sectors. **Method:** The systematic literature review (SLR) from the ScienceDirect database was established using the four basic procedures outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). A total of thirty-three scholarly publications were retrieved from the database, encompassing the years 2017 to 2021, which specifically address the important role of safety culture in the effective management of major industrial incidents. **Results:** The findings yielded two primary themes, namely, the significance of safety culture at both the managerial and employee levels. These topics were then categorised into ten subthemes. The findings indicate that safety culture exerts a significant influence at the managerial level in mitigating industrial accidents through the enhancement of safety training. **Conclusion:** In summary, a safety culture holds significant importance within the realm of management as it serves to effectively mitigate the occurrence of industrial accidents in the years to come.

Keywords: industrial accidents, preferred reporting items for systematic reviews and meta-analyses, safety culture, management level, employee level

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INTRODUCTION

Industrial accidents pose significant challenges for numerous businesses since they have profound implications for human health, environmental integrity, societal well-being, and national economies (Zhang *et al*., 2020). Various industries around the world acknowledge the safety culture as a means to mitigate the probability of significant accidents and incidents (Cooper, 2000). Back to history, the International Nuclear Safety Advisory Group (INSAG) introduced the concept of "safety culture" in their report on the Chernobyl event in 1986 (Cooper, 2000). Noraishah, Ramli, and Abdul (2021) mentioned the safety culture holds greater significance in enhancing safety performance compared to alternative approaches such as heightened supervision and diverse procedures. Moreover, they mentioned the establishment of a safety culture to mitigate accidents assumes heightened importance when an organisation's accident statistics reach a state of plateau.

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According to Jääskeläinen, Tappura, and Pirhonen (2022), there is currently a diminished need for additional hardware, such as technical controls, and software, such as administrative controls in the form of processes. Rather, members of the organisation's hearts and minds should be targeted (Parker, Lawrie, and Hudson, 2006). Safety culture encompasses several interpretations, such as information problems, violations, failure to recognise increasing dangers, role ambiguity, management complacency, poor communication, low prioritisation of safety, and other intangible and frequently ambiguous issues (Cox and Flin, 1998). Morrow, Kenneth Koves, and Barnes (2014) claim that safety culture is a distinct facet of organisational culture, encompassing common beliefs, values, and attitudes that collectively contribute to the promotion and maintenance of safe operations. (Zwetsloot *et al*., 2020) argue that a universally agreed-upon definition of safety culture or a standardised assessment approach is currently lacking. Furthermore, it is widely recognised that the establishment of a mature safety culture plays a crucial role in promoting optimal safety outcomes, specifically in the realm of accident reduction (Stemn *et al*., 2020; Stemn *et al*., 2019).

According to Jiang *et al*. (2020), prioritising the investigation of accident causes above symptoms leads to a more efficient method for preventing accidents. Up until now, various safety culture models have been proposed, including the Social Learning Theory (Bandura, 1991), Schein's Theory (Schein, 2016), Guldenmund's Three Layered Organisational Culture (Guldenmund, 2000), and the Reciprocal Safety Culture Model (Cooper, 2000). Despite the existence of various safety culture models, there is a lack of systematic literature review (SLR) studies to understand the importance of safety culture in the management of catastrophic industrial accidents.

The riskiest industries in the world, for instance, are those in the chemical (Zwetsloot *et al*., 2020), construction (Duryan *et al*., 2020), oil and gas (Kalteh *et al*., 2020), manufacturing (Ghahramani and Salminen, 2019), mining (Jiang *et al*., 2020), and nuclear industries (Murata, 2021). These industries also contribute to significant accidents and disasters worldwide. Hence, the primary objective of this SLR study is to examine the significance of safety culture in the effective management of industrial accidents across six major sectors, namely chemical, construction, oil and gas, manufacturing, mining, and nuclear.

METHODS

The systematic review was completed in May 2022. The Science Direct database was selected for this study. Peer-reviewed journal research is widely regarded as having a strong academic standing and serves as a representation of scholarly inquiry within a particular field of study. The PRISMA phases consist of (1) Identification, (2) Screening, (3) Eligibility, (4) Data abstraction and analysis. Figure 1 presents an overview of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology utilised for conducting SLR. For the identification phase, this strategy successfully retrieved articles from the Science Direct database for the year 2021, utilising the techniques of "keywords" and "search strings". THE TITLE-ABS-KEY ("safety culture" OR "industrial accidents" OR "industrial disaster" OR "industrial catastrophic"). The reviews were conducted using particular scholarly articles that directly tackled the research enquiries and goals of the investigation.

The second phase involves the screening procedure, wherein articles are either included or excluded based on criteria defined by the authors in collaboration with a specific database. The establishment of eligibility, inclusion, and exclusion criteria was undertaken during the screening phase in order to identify pertinent publications for incorporation into the systematic review. This information is presented in Table 1. After the completion of the identification process, a total of 2011 items were available for examination. After conducting a comprehensive screening process, a total of 343 publications were identified. These

Table 1. Criteria for a screening process

Criteria	Inclusion	Exclusion
Publication timeline	2017–2021`	2016 and before
Document type	Journal	Systematic review), review papers, conference proceedings, chapters in books, book series, books
Type of industry	Oil and gas, construction, mining, nuclear and chemical, manufacturing	Other industries
Language	English	Non-English
Availability	All subscribed journals	Exclude non-subscribed journal

publications were released throughout the period of 2017 to 2021 and were centred around six distinct industries, namely chemical, construction, oil and gas, manufacturing, mining, and nuclear power. All enterprises operating in the medical, airline, hotel, restaurant, and various other sectors were eliminated. The analysis did not include journals that published systematic reviews or review papers, conference papers, proceedings, book chapters, book series, and books. The objective is to focus on empirical investigation pertaining to the significance of safety culture in the effective management of accidents within the chemical, construction, oil and gas, manufacturing, mining, and nuclear sectors.

The third phase encompasses the eligibility assessment, wherein papers are evaluated for acceptance or rejection based on the criteria stipulated by the authors. The literature review process is comprehensively evaluated by employing criteria derived from prior screening approaches, namely inclusion and exclusion criteria.

The final phases of the process involve data abstraction and analysis. According to the data presented in Table 2, the remaining publications underwent a process of appraisal, inspection, and analysis. From this process, a total of 33 articles (studies) were selected for in-depth examination in this study. The similarities and differences among the 33 studies were recognised and classified using thematic analysis (Nowell *et al*., 2017), which

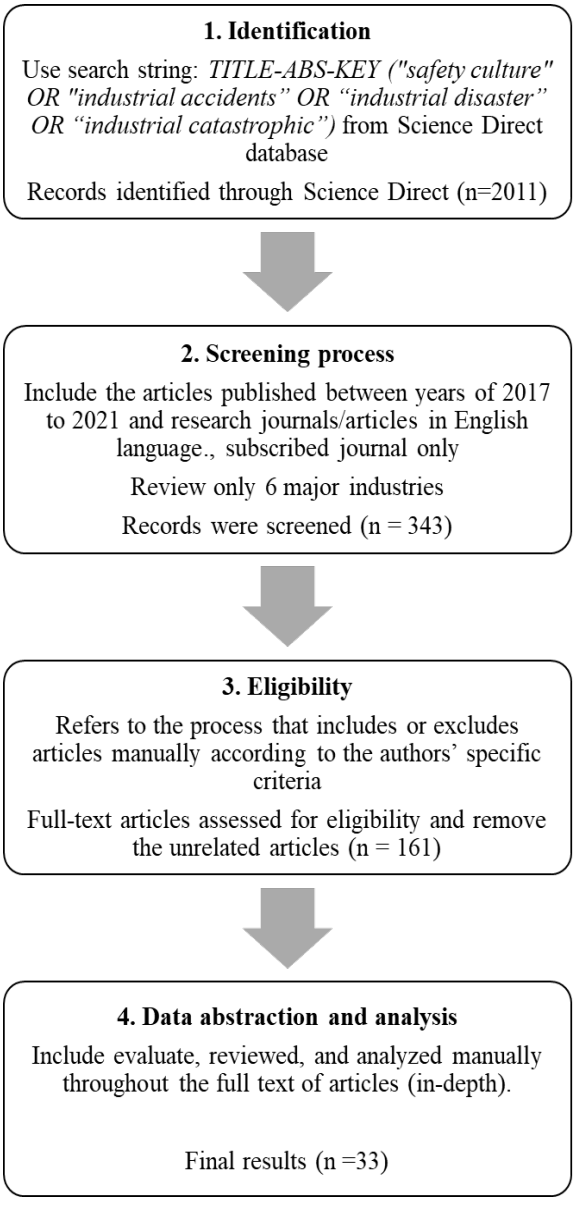

Figure 1. The PRISMA flowchart for SLR studies (Adapted and modified from Nowell *et al*., 2017)

Table 2. SLR Results based on the Type of Industries, Countries, and Number of Published Articles from 2017 to 2021

Type of industries	Countries and Number of Papers	(n)
Chemical	USA	(1)
	China	(1)
	Netherlands	(1)
	United Kingdom	(1)
Construction	China	(2)
	Oil and gas	(1)
	Mexico	(1)
	Norway	(1)
Oil and gas	Iran	(2)
	Canada	(2)
	China	(1)
	Sweden	(1)
Manufacturing	Iran	(1)
	South Korea	(1)
	China	(3)
Mining	Ghana	(1)
	Kenya	(1)
	Balkan	(1)
	South Korea	(3)
	Japan	(2)
Nuclear	Spain	(2)
	German	(1)
	Brazil	(1)
	Malaysia	(1)
Total		33 articles

was deemed suitable for the qualitative analysis conducted in the context of this SLR study.

RESULT

The SLR study included a total of 33 publications consists of 18 different countries. Table 2 presents the findings of the SLR conducted, focusing on the categorisation of industries, nations, and the number of published papers over the period from 2017 to 2021. Table 3 shows SLR results on the role of safety culture for six major industrial accidents from 2017 until 2021.

In terms of scholarly publications pertaining to the role of safety culture in six significant industrial catastrophes, China emerged as the foremost contributor with a total of seven articles. Following China, South Korea and Iran made notable contributions with five and three articles, respectively. The dataset consists of two articles dedicated to each of the countries Japan, Spain, and Canada, with the inclusion of one item each representing Ghana, Sweden, the Netherlands, Malaysia, Kenya, the Balkan region, Germany, Brazil, Mexico, Norway, the United Kingdom, and the United States of America (USA). The thematic analysis yielded the identification of two primary themes and ten sub-themes, which were derived from the review of 33 selected articles that emphasised the similarities in the significance of safety culture. Theme 1: The significance of safety culture within the managerial domain constitutes 80% of the comprehensive study on SLR, encompassing eight distinct subthemes. In contrast, Theme 2 constitutes a significant portion, accounting for 20% of the comprehensive SLR study. This theme encompasses two distinct subthemes.

DISCUSSION

The SLR pertaining to the significance of safety culture in the effective management of significant industrial accidents was effectively conducted through the use of the PRISMA methodology. One of the primary motivations for comprehending the significance of safety culture is its capacity to

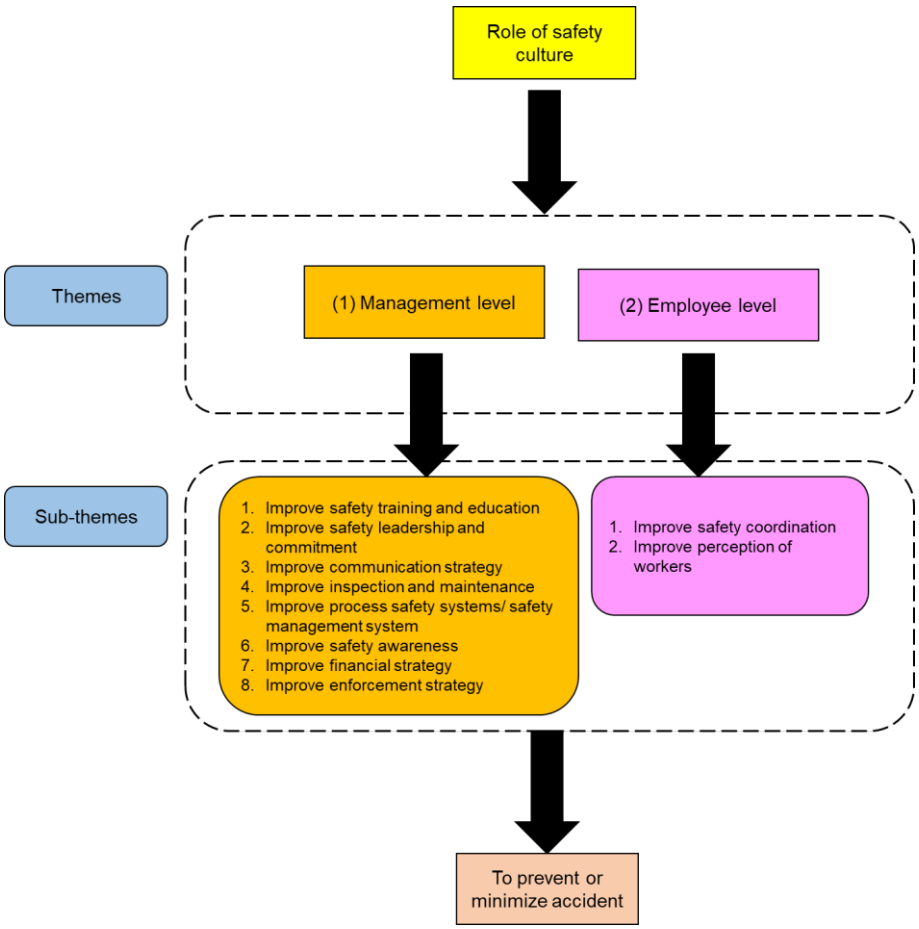

Figure 2. Summary of two themes 10 subthemes generated using thematic analysis

Table 3. SLR results for six major industrial accidents from 2017 until 2021

Authors	Type of industries	Country	*Role of safety culture at the management level by improving								*Role of Safety Culture at employee level by improving	
			ST	SL	CO	IM	PSM	SA	FS	EN	SC	IPW
(Jain *et al*., 2018)	Chemical	USA	/	/	/	/	/				/	/
(Chen, Wood and Zhao, 2019)	Chemical	China	/					/		/		/
(Zwetsloot *et al*., 2020)	Chemical	Netherlands	/	/	/		/			/	/	
(Nwankwo, Theophilus and Arewa, 2020)	Chemical	United Kingdom	/				/	/			/	/
(Wu, Li and Fang, 2017)	Construction	China		/							/	
(Duryan *et al*., 2020)	Construction	United Kingdom	/		/		/			/	/	
(Fang *et al*., 2020)	Construction	China		/								
(Amernic and Craig, 2017)	Oil and gas	Mexico		/	/		/		/		/	/
(Antonsen, Nilsen and Almklov, 2017)	Oil and gas	Norway	/				/			/	/	/
(Haghighi *et al*., 2017)	Oil and gas	Iran	/		/		/	/				/
(Behari, 2019)	Oil and gas	Canada	/			/	/	/				/
(Behari, 2019)	Oil and gas	Canada	/	/	/	/	/	/		/	/	/
(Gao *et al*., 2019)	Oil and gas	China	/		/	/	/			/	/	
(Kalteh *et al*., 2020)	Oil and gas	Iran	/	/			/	/				/
(Nordlöf *et al*., 2017)	Manufacturing	Sweden							/			
(Ghahramani and Salminen, 2019)	Manufacturing	Iran	/	/	/		/			/	/	/
(Kim, Lee and Kang, 2021)	Manufacturing	South Korea						/			/	
(Wang, Cao and Zhou, 2018)	Mining	China	/	/	/	/	/	/	/	/	/	/
(Stemn *et al*., 2019)	Mining	Ghana	/	/	/	/	/	/		/	/	/
(Fu *et al*., 2020)	Mining	China	/	/	/		/	/		/	/	/
(Zhang *et al*., 2020)	Mining	China	/	/	/	/	/	/		/	/	/
(Ajith, Ghosh and Jansz, 2021)	Mining	Kenya	/	/	/	/				/	/	/
(Moore *et al*., 2021)	Mining	Balkan	/		/						/	/
(Kim, Lee and Seong, 2017)	Nuclear	Korea	/	/	/	/	/	/	/	/	/	/
(Schöbel *et al*., 2017)	Nuclear	German	/	/	/		/					/
(do Nascimento, Andrade and de Mesquita, 2017)	Nuclear	Brazil	/	/	/	/	/	/	/	/	/	/
(de Castro *et al*., 2017)	Nuclear	Spain	/	/	/	/	/	/	/	/	/	/
(Kim *et al*., 2018)	Nuclear	Korea	/	/	/	/	/	/	/	/	/	/
(Han *et al*., 2018)	Nuclear	Korea	/	/	/	/	/	/	/	/	/	/
(Kasim *et al*., 2019)	Nuclear	Malaysia	/	/	/	/	/	/	/	/	/	/
(Berglund, 2020)	Nuclear	Japan	/	/	/	/	/	/	/	/	/	/
(Renecle *et al*., 2020)	Nuclear	Spain	/	/	/	/	/	/		/	/	/
(Murata, 2021)	Nuclear	Japan	/	/	/	/	/	/		/	/	/

*Role of safety culture at (1) management level by improving;

ST = Safety Training / Education
SL = Safety leadership and commitment
CO = Communication
IM = Inspection and maintenance
PSM = Process safety systems/ safety management system
SA = Safety awareness
FS = financial strategy
EN = Enforcement

*Role of safety culture at (2) employee level by improving;

SC = Safety coordination
IPW = Perception of workers on SC

mitigate the occurrence of significant industrial accidents. Moreover, the present study has found a total of 33 studies that have examined the influence of safety culture in the management of major industrial accidents for six major industries, which consist of chemical, construction, oil and gas, manufacturing, mining, and nuclear industries. Figure 2 provides a comprehensive summary of the themes and subthemes that were derived from the SLR study. All these findings regarding effective management, especially significant industrial accidents, have been analysed using thematic analysis (Nowell *et al*., 2017). Two themes, Role of Safety Culture at the Management Level (Theme 1) and Role of Safety Culture at the Management Level (Theme 2), were developed as shown in Figure 2.

The Role of Safety Culture at the Management Level (Theme 1) consists of safety training, safety leadership and commitment, communication, inspection and maintenance, process safety systems, safety awareness, financial strategy, and enforcement, which the six major industries need to improve to achieve a good safety culture in order to prevent the occurrences of industrial accidents. For Theme 2, at the employee level, two main factors need to be improved, which are the improvement of safety coordination and the perception of workers on the importance of safety culture to prevent or minimise industrial accidents.

Theme 1: Role of Safety Culture at the Management Level

Theme 1 has eight main subthemes consisting of the role of safety culture at (1) management level to improve safety training/education (28 articles), safety leadership and commitment (24 articles), communication (24 articles), inspection and maintenance (18 articles), improve process safety management systems (27 articles), improve safety awareness (20 articles), improve financial strategy (10 articles), and enforcement strategy (24 articles). A significant majority of 29 out of 33 studies have indicated that safety culture is a crucial factor in enhancing the effectiveness of present safety training programs. Furthermore, these studies have emphasised the necessity of implementing improvements to prevent the recurrence of industrial accidents. The analysis of past industrial incidents can serve as a valuable learning experience in enhancing the efficacy of current safety training programs for workers. This is because training is a proactive measure aimed at implementing and sustaining effective hazard management practices.

Out of 33 studies, 27 stated that process safety management systems might be enhanced by safety culture. Nwankwo *et al*. (2020) state that process safety issues such as a poor safety culture, a lack of communication, issues with asset integrity, a lack of managerial leadership, and human factors have been linked to the majority of process industry incidents. If a robust process safety management (PSM) system had been appropriately put in place, these accidents might have been prevented.

Furthermore, the establishment of a positive safety culture within the sector and a decreased number of accidents would lead to enhanced communication between managers and employees. Hence, there is potential for enhancing safety leadership and commitment. Leadership is commonly perceived as a critical factor in determining the success or failure of an organisation. Supervisors play a crucial role in motivating miners to approach their daily tasks with enthusiasm through various means such as providing encouragement, demonstrating care, and setting a positive example. Additionally, supervisors take the initiative in adhering to multiple safety protocols and regulations within coal mines, thereby fostering a favourable safety environment (Niu, Gao, and Zhao, 2015; Nwankwo, Theophilus, and Arewa, 2020). Moreover, the establishment of a solid framework to guarantee the enforcement of crucial laws and regulations, the effective functioning of equipment, and the enhancement of safety protection facilities can be regarded as a safety investment. Enhancing financial strategy through the establishment of a robust safety culture at the workplace necessitates prioritising investments in safety measures. According to Zhou *et al*. (2017), allocating sufficient resources to safety measures can facilitate the seamless integration of safety systems, enhance the stability of equipment operation, and optimise the expenses associated with inspection and maintenance.

Theme 2: Role of Safety Culture at Employee Level

Thematic analysis was employed to produce subthemes for Theme 2, specifically focusing on the enhancement of safety coordination (25 studies) and the perception of employees about safety culture (26 research). The significance of safety culture lies in its ability to effectively coordinate safety efforts among

employees, drawing upon the lessons learnt from past industrial catastrophes. Furthermore, there is a need to enhance the perspective of the significance of prioritising and implementing a safety culture within the workforce. Jiang *et al*. (2020) argue that establishing a strong workplace safety culture relies heavily on fostering mutual understanding between employers and employees. The role safety culture at the employee level can develop trust and assurance and make the safety coordination run smoothly. For example, a positive safety culture promotes trust among employees and management. When employees realise that their safety is a key priority, they gain trust in the organisation's dedication to their well-being. Trust and confidence between employer and employees could lead to better job satisfaction and safety results. This can also increase the perception of workers on the importance of safety at the workplace. For example, employees can report any dangers at their workplaces without fear to their employer. This transparency helps to identify and address safety issues, but it also increases the employers' opinions of the organisation's concern for safety. Moreover, safety communication is important for creating a safety culture at the workplace in which employees believe their concerns are acknowledged and addressed. Therefore, creating a good safety culture is critical for improving the relationships between employers and employees at their workplace. It increases trust and morale, promotes two-ways communication, inculcates a positive work environment, and improves the reputation of the organisation.

CONCLUSION

The present SLR study successfully investigated the important role of safety culture in the effective management of industrial accidents for six major industrial sectors. In conclusion, a safety culture is critical in management since it successfully reduces the occurrence of industrial accidents in the future.

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