*Vol* ***01*** *|* *Issue* ***01*** *|* ***October*** *2024*
*Doi:* **10.69593/ajieet.v1i01.121**
*Page:***36-52**

**Academic Journal on Innovation, Engineering & Emerging Technology**

RESEARCH ARTICLE OPEN ACCESS

# ENGINEERING MANAGEMENT PERSPECTIVES ON SAFETY CULTURE IN CHEMICAL AND PETROCHEMICAL PLANTS: A SYSTEMATIC REVIEW

[1] Avijit Dasgupta, [2] Muhammad Mohiul Islam, [3] Omar Faruq Nahid, [4] Rafio Rahmatullah

[1]*Master of Engineering Management, College of Engineering, Lamar University, Beaumont, Texas, USA*
*Email:* avi.me03@gmail.com

[2]*Master of Engineering Management, College of Engineering, Lamar University, Beaumont, Texas, USA*
*Email:* mislam87@lamar.edu

[3]*Master of Engineering Management, College of Engineering, Lamar University, Beaumont, Texas, USA*
*Email:* omarfaruqnahid@gmail.com

[4]*Master of Engineering Management, College of Engineering, Lamar University, Beaumont, Texas, USA*
*Email*: r.rafio.sau@gmail.com

## *ABSTRACT*

***This systematic review examines the influence of engineering management practices on cultivating and sustaining a strong safety culture in chemical and petrochemical plants. Given the high-risk nature of these industries, establishing a robust safety culture is essential for mitigating operational hazards, reducing risks, and preventing accidents that can have serious human and environmental impacts. The review synthesizes findings from 135 peer-reviewed studies, focusing on key elements such as leadership commitment, employee engagement, regulatory compliance, safety management systems, and the integration of advanced technologies like automation and artificial intelligence (AI). The results highlight that safety performance in these industries is closely linked to management's active involvement in promoting safety practices, clear communication strategies, and the continuous assessment and improvement of safety protocols. Engineering managers play a critical role in driving safety initiatives and fostering an organizational culture where safety is a shared responsibility. The review also underscores the importance of regulatory compliance as a foundation for safety, while emphasizing that the most successful organizations go beyond compliance to embed safety deeply into their operational practices. Technological advancements, particularly in automation and real-time monitoring, were found to significantly enhance safety outcomes by enabling proactive risk identification and mitigation. Overall, this review offers valuable insights and practical guidelines for engineering managers aiming to strengthen safety protocols, reduce risks, and enhance safety performance in high-hazard industrial environments.***

## *KEYWORDS*

*Safety Culture, Engineering Management, Chemical Plants, Petrochemical Industry, Safety Performance*

**Submitted:** September 05, 2024
**Accepted:** October 12, 2024
**Published:** October 15, 2024

***Corresponding Author:***

*Avijit Dasgupta*

*Master of Engineering Management, College of Engineering, Lamar University, Beaumont, Texas, USA*

*email:* avi.me03@gmail.com

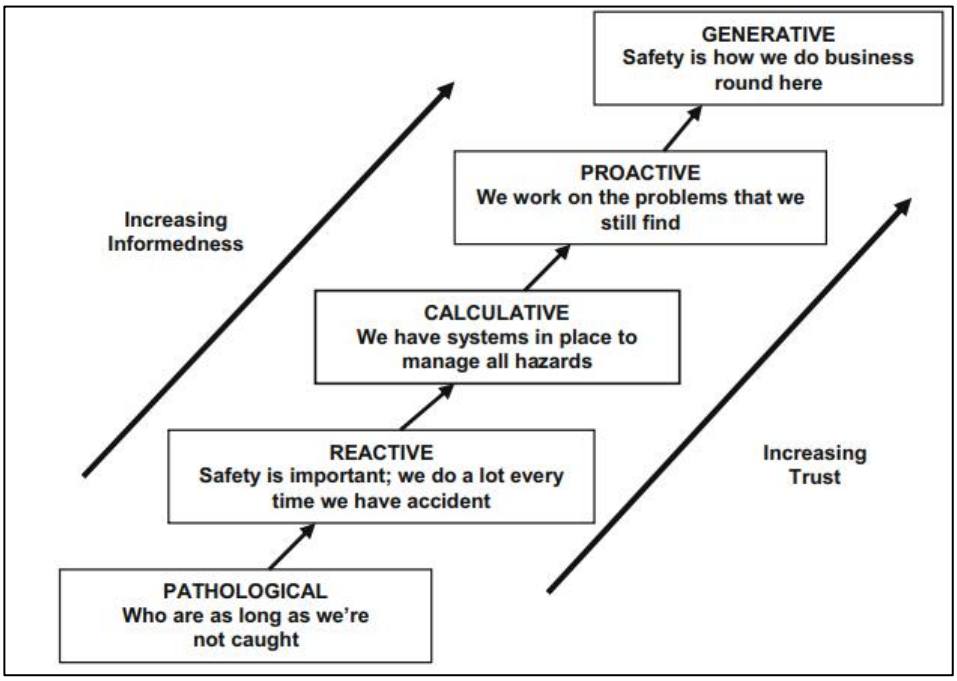
10.69593/ajieet.v1i01.121

## 1 Introduction

The safety culture within chemical and petrochemical plants has evolved significantly over the years, driven by the necessity to mitigate risks associated with hazardous processes and materials (Johnson, 2007; Kao et al., 2008; Mearns & Flin, 1999). In these industries, accidents can result in devastating consequences, not only in terms of financial losses but also in human lives and environmental damage. Safety culture refers to the collective attitudes, beliefs, perceptions, and practices of employees and management toward safety within an organization. A robust safety culture is essential in reducing the likelihood of accidents and improving overall safety performance (Pidgeon, 1998). According to (Pordanjani & Ebrahimi, 2015), the focus on safety culture gained traction in the 1980s, following major industrial accidents such as the Bhopal gas tragedy and the Piper Alpha disaster. These incidents highlighted the need for better safety management practices, pushing organizations and regulatory bodies to shift from a purely compliance-based approach to one that emphasizes the proactive development of safety culture. The evolution of safety culture in the chemical and petrochemical sectors has been closely linked to advancements in engineering management. Engineering managers play a crucial role in establishing safety protocols, ensuring compliance with regulations, and fostering a work environment that prioritizes safety. According to Shirali et al. (2016), safety culture is shaped by leadership behavior, communication practices, and the implementation of safety management systems. Over time, engineering management strategies have become more integrated with safety culture development. A study by Sutton (2008) demonstrated that strong leadership commitment to safety leads to a more resilient safety culture, as managers are seen as role models who influence employees' attitudes and behaviors. This shift in management practices has been accompanied by increased regulatory scrutiny and industry standards that emphasize the need for continuous improvement in safety performance.

Employee involvement and training have also emerged as critical components in the evolution of safety culture in chemical and petrochemical plants. Engineering managers have recognized that employees are the frontline actors in maintaining safety, and their active participation in safety-related initiatives is crucial. Studies by Tetzlaff et al. (2020) and Vinodkumar and Bhasi (2010) underscore the importance of engaging employees in safety training programs and involving them in decision-making processes related to safety management. These studies indicate that when employees feel a sense of ownership over safety

***Figure 1: Safety culture model of Hudson (2001)***



Doi: 10.69593/ajieet.v1i01.121

protocols, they are more likely to adhere to them and contribute to a safer working environment. Furthermore, the introduction of technology-driven training methods, such as virtual simulations, has enhanced employees' ability to respond to potential hazards effectively (Wiegmann & Shappell, 2001). This demonstrates the ongoing evolution of safety culture through innovative training approaches.

Moreover, safety culture has been influenced by the increasing integration of safety management systems (SMS) in chemical and petrochemical plants. Engineering managers have adopted SMS as a framework for systematically identifying, assessing, and controlling risks. A study by Wilpert and Itoigawa (2001) highlights that the implementation of SMS has led to improved safety performance by providing a structured approach to hazard identification and risk management. SMS frameworks, such as the Process Safety Management (PSM) system, introduced by the Occupational Safety and Health Administration (OSHA), have set industry standards for safety culture development . These systems provide engineering managers with tools to monitor safety metrics, implement corrective actions, and ensure that safety protocols are followed consistently. As a result, SMS has become a key element in the continuous improvement of safety culture. Finally, research has shown that the development of safety culture is not a static process but one that evolves in response to organizational, technological, and regulatory changes. Wilpert and Itoigawa (2001) argues that safety culture must be adaptable to changing conditions within the workplace, such as the introduction of new technologies or shifts in production processes. Engineering managers must continually assess and refine safety protocols to keep pace with these changes, ensuring that safety remains a top priority. The evolution of safety culture also reflects broader trends in risk management, where organizations are moving towards a more holistic approach that integrates safety with overall business performance . This shift underscores the critical role of engineering management in driving the evolution of safety culture and maintaining high safety standards in chemical and petrochemical plants.

The primary objective of this systematic review is to explore the role of engineering management in shaping and enhancing safety culture within chemical and petrochemical plants. Specifically, this review aims to identify the key factors and management practices that contribute to fostering a robust safety culture, reducing operational risks, and improving safety performance in high-hazard environments. By examining leadership behaviors, employee involvement, training programs, and the implementation of safety management systems, this review seeks to provide a comprehensive understanding of how engineering managers can drive safety initiatives and integrate safety into the organizational framework. Additionally, the review aims to track the evolution of safety culture in response to technological advancements, regulatory changes, and industry best practices, offering insights that can be applied to improve safety outcomes in chemical and petrochemical plants.

## 2 Literature Review

The development of safety culture within chemical and petrochemical plants has been widely researched across various disciplines, including engineering management, organizational behavior, and risk management. This section reviews key studies that have contributed to the understanding of safety culture and its evolution over time, with a focus on the role of engineering management in promoting a safe working environment. The literature highlights critical factors such as leadership commitment, employee engagement, training, and the implementation of safety management systems, all of which play significant roles in shaping safety culture. Additionally, this review explores the impact of regulatory frameworks and technological advancements on safety practices in high-risk industries, providing a comprehensive overview of the current body of knowledge on the subject. Through this synthesis of existing research, the review aims to identify gaps and offer insights into effective strategies for fostering a strong safety culture in chemical and petrochemical plants.

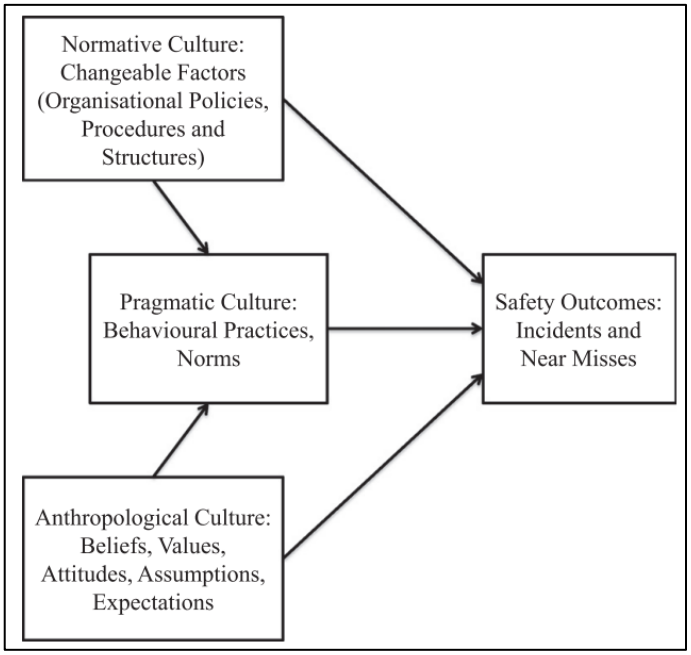
### *2.1 Safety Culture*

Safety culture refers to the collective attitudes, values, and behaviors shared by employees and management

regarding safety within an organization. It encompasses the way safety is prioritized, communicated, and practiced in daily operations (Vinodkumar & Bhasi, 2010). Safety culture is especially critical in high-risk industries like chemical and petrochemical plants, where the handling of hazardous materials and processes can lead to catastrophic accidents if safety protocols are not rigorously followed. A robust safety culture serves as a proactive barrier to accidents, ensuring that safety is embedded into the decision-making processes at all organizational levels. Research has demonstrated that when safety culture is strong, organizations experience fewer incidents, reduced downtime, and improved employee morale (Sutton, 2008). Studies by Tetzlaff et al. (2020) and Fleming and Lardner (2002) suggest that a positive safety culture can lead to sustained improvements in operational efficiency by minimizing the risks associated with human error and equipment failure. Moreover, engineering managers play a key role in shaping this culture through leadership, training, and employee engagement initiatives.

In the context of chemical and petrochemical plants, the significance of safety culture cannot be overstated. These industries operate in environments where even small lapses in safety can result in severe consequences, including explosions, toxic spills, and widespread environmental damage (Çakıt et al., 2019). Studies show that fostering a culture where safety is viewed as a shared responsibility leads to better safety outcomes (Shirali et al., 2016). For example, Tetzlaff et al. (2020)found that plants with high levels of safety culture involvement from both management and employees saw a significant reduction in workplace accidents. Furthermore, organizations with a strong safety culture are better equipped to comply with regulatory requirements, which is crucial given the stringent safety standards imposed on chemical and petrochemical industries (Mitkowski & Bal, 2015). Thus, the development and maintenance of a safety culture are not only necessary for legal compliance but also essential for operational sustainability and the protection of human lives and the environment.

***Figure 2: A synthesized conceptualization of safety culture***




## 2.2 Engineering Management and Safety Culture

The role of engineering management in promoting safety is critical in industries such as chemical and petrochemical plants, where the risks associated with hazardous materials and processes are significant. Engineering management encompasses the development, implementation, and continuous improvement of safety protocols, ensuring that safety is not just a regulatory requirement but a core organizational value (Milijić et al., 2014; Shamim, 2022). Boughaba et al. (2014) asserts that engineering managers are responsible for embedding safety into operational practices, from risk assessments to the design of safer systems and processes. Effective safety management requires a balance of technical knowledge and leadership skills to ensure that safety protocols are understood and adhered to at all levels of the organization. According to Kastenberg (2014), engineering managers play a vital role in driving the adoption of safety technologies, such as automation systems that reduce human error and real-time monitoring systems that provide early warnings of potential hazards. By doing so, they create an environment where safety is prioritized, and risks are proactively managed. Research has consistently shown that engineering managers' ability to promote safety depends heavily on their commitment to fostering a culture where safety is a shared responsibility (Boughaba et al., 2014). A study by Wu et al. (2013)

Doi: 10.69593/ajieet.v1i01.121

found that organizations where engineering management was actively involved in safety initiatives saw a higher level of employee participation and a stronger safety culture. This is further supported by Mitkowski and Bal (2015), who demonstrated that when engineering managers set clear expectations for safety and provided the necessary resources and training, employees were more likely to follow safety protocols and report potential hazards. In this sense, engineering management serves as the foundation upon which a strong safety culture is built, integrating safety into every aspect of operations and decision-making processes.

### *2.3 Safety Culture in Chemical Plants*

Safety culture in chemical plants refers to the collective values, attitudes, and practices that employees and management uphold regarding safety protocols, behaviors, and decision-making. In industries like chemical manufacturing, where operations involve hazardous materials and complex processes, maintaining a strong safety culture is paramount for preventing accidents and ensuring both human and environmental safety (Bernard, 2021; Shamim, 2022). According to Chen et al. (2018), a robust safety culture requires the proactive participation of all organizational levels, from frontline employees to top management, to ensure that safety is not just a compliance issue but an ingrained organizational value. This is particularly critical in chemical plants, where even minor lapses in safety can lead to catastrophic consequences. Waring (2015) argue that safety culture in chemical plants needs to focus on both technical and human factors, ensuring that equipment is well-maintained and employees are well-trained to handle potential hazards. Research has highlighted the significant impact of safety culture on performance in chemical plants. A study by Milijić et al. (2014) demonstrated that plants with a strong safety culture experience fewer accidents, less downtime, and improved operational efficiency. Similarly, Pordanjani and Ebrahimi (2015)found that a positive safety culture not only enhances compliance with safety regulations but also fosters better communication and trust between employees and management. These findings are supported by Alrehaili (2016), who assert that safety culture acts as a foundation for risk management in hazardous industries. The emphasis on safety culture has evolved in response to major industrial accidents such as the Bhopal gas leak and the Texas City refinery explosion, prompting regulatory bodies and organizations to invest more in fostering proactive safety environments. As engineering managers play a pivotal role in shaping and sustaining safety culture, their leadership and commitment to safety are critical to the ongoing success of safety initiatives in chemical plants.

### *2.4 Safety Culture In Petrochemical Plants*

Safety culture in petrochemical plants refers to the shared values, beliefs, and behaviors related to safety practices among employees and management in an environment characterized by high-risk operations. The petrochemical industry involves complex processes and the handling of hazardous materials, making safety culture a critical aspect of operations. According to Boughaba et al. (2014), a strong safety culture is essential for minimizing the risks of accidents, improving safety performance, and ensuring operational continuity. Safety culture is not merely about complying with regulations; it encompasses proactive initiatives, employee engagement, and leadership commitment to create an environment where safety is prioritized at all organizational levels (Boughaba et al., 2014). In petrochemical plants, fostering a safety culture is vital because even small safety lapses can lead to catastrophic incidents, as demonstrated by accidents such as the BP Texas City explosion in 2005. Research highlights that safety culture directly impacts the operational safety and performance of petrochemical plants. Filho et al. (2010) noted that plants with a strong safety culture experienced fewer accidents, lower operational downtime, and improved employee morale. Moreover, Boughaba et al., (2014) found that a proactive safety culture, characterized by regular safety audits, employee training, and transparent communication, significantly reduces the likelihood of major accidents. Çakıt et al., (2019) further emphasizes that safety culture must be integrated into all aspects of plant operations, including design, maintenance, and

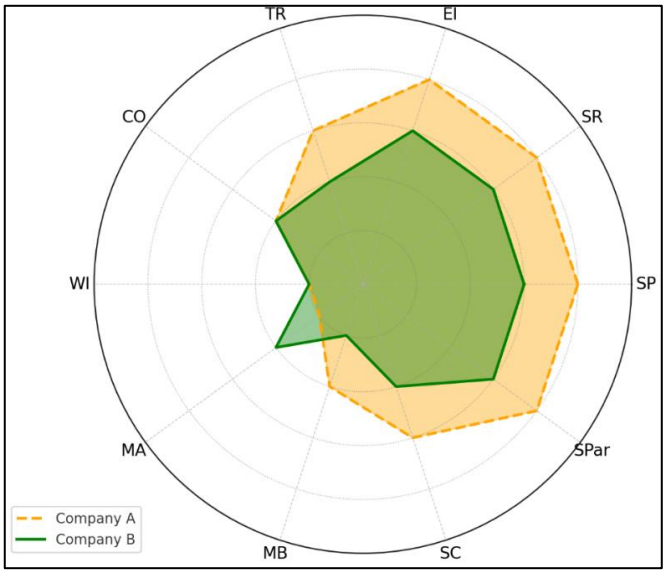
employee decision-making processes. Studies by Pordanjani and Ebrahimi (2015) and Filho et al. (2010) show that when employees are actively involved in safety initiatives and management leads by example, the overall safety performance of petrochemical plants improves. Leadership commitment to safety has been highlighted as a key driver of safety culture, and engineering managers play a crucial role in embedding safety practices within operational frameworks.

### *2.5 Safety Management Systems (SMS)*

Safety Management Systems (SMS) play a critical role in fostering a systematic and structured approach to managing safety in petrochemical and chemical plants. SMS encompasses a set of policies, procedures, and processes that guide an organization's safety practices to prevent accidents, ensure regulatory compliance, and manage risk effectively . The key components of SMS include hazard identification, risk assessment, incident investigation, training, and continuous safety improvement. According to Fogarty and Shaw (2009), SMS provides a framework for ensuring that safety management is not left to chance but is integrated into the daily operations of high-risk industries. The introduction of SMS has significantly shifted the focus of safety management from a reactive to a proactive stance, where risks are systematically identified and mitigated before they can result in incidents (Locke et al., 1981). SMS also serves as a communication tool, ensuring that all employees, from the frontline workers to upper management, are aware of safety protocols and responsibilities.

Several studies have emphasized the importance of integrating key components of SMS to achieve comprehensive safety outcomes. Tetzlaff et al. (2020) highlighted the effectiveness of hazard identification and risk assessment as foundational elements in preventing accidents in petrochemical plants. These components require a detailed analysis of all potential safety risks, including human factors, technical failures, and environmental conditions. Fogarty and Shaw (2009) argues that without a strong focus on hazard identification, SMS cannot function effectively, as unidentified risks pose the greatest threat to plant safety. Incident investigation is another crucial component, ensuring that organizations learn from previous accidents or near-misses to prevent their recurrence. Locke and Latham (2002) found that petrochemical plants that implemented thorough incident investigations as part of their SMS reported fewer repeated accidents and a faster response time in correcting potential hazards. Training is also integral to SMS, ensuring that employees are well-equipped to manage risks and follow safety protocols in real-time situations (Wu et al., 2009) (See figure 3).

***Figure 3:Radar chart representing the safety culture profiles of Company A and Company B***




Numerous case studies have demonstrated the effectiveness of SMS implementation in improving safety performance in petrochemical and chemical plants. A notable case is the BP Texas City refinery explosion in 2005, which prompted a significant overhaul of the plant's SMS. After the incident, BP invested heavily in strengthening its SMS by improving hazard identification processes, implementing more rigorous risk assessments, and providing comprehensive employee training programs. The overhaul led to a substantial reduction in accidents in subsequent years, proving the effectiveness of a well-implemented SMS. Another example is Shell's implementation of SMS across its global petrochemical operations, which focused on continuous safety improvement and integrated advanced monitoring technologies (Zwetsloot et al., 2013). Shell's SMS framework included real-time data analysis tools that allowed the company to monitor potential hazards remotely and respond to risks proactively. The success of Shell's SMS in reducing workplace injuries and enhancing safety performance serves as a benchmark for other organizations in the industry. In another case study, the Dow Chemical Company demonstrated the

Doi: 10.69593/ajieet.v1i01.121

effectiveness of SMS by prioritizing incident investigation and corrective action as core components of their system (Bernard, 2021). Dow's SMS framework required that every incident, regardless of its severity, undergo a comprehensive investigation to identify root causes and implement corrective measures. This approach enabled the company to reduce the occurrence of similar incidents over time, leading to significant safety improvements. Studies by Adamski et al. (2021) also highlight the importance of leadership involvement in the successful implementation of SMS. In a case study of ExxonMobil, leadership commitment was found to be a crucial factor in ensuring that the company's SMS was adhered to across all levels of the organization. The case demonstrated that when leaders actively promote safety as a core value, the effectiveness of SMS is greatly enhanced, leading to a stronger safety culture overall.

### *2.6 Elements of Safety Culture and Its Scale*

The concept of safety culture is complex and diverse, particularly in high-risk industries such as chemical and petrochemical plants. It refers to the understanding, implementation, and application of safety-related values, attitudes, and behaviors within an organization (Ahmed et al., 2024; Islam & Apu, 2024). Over the last 32 years, significant research has focused on identifying the key elements of safety culture and developing measurable scales to apply these findings in empirical studies. Despite this progress, safety culture remains a somewhat vague term that requires a deeper understanding of its components before organizations can fully integrate and benefit from it. Building a safety culture is essentially about promoting employees' understanding of safety, ensuring that they can implement safety protocols effectively, and fostering an environment where safety becomes a core organizational value. This section explores the different elements of safety culture, the methodologies used to study them, and the challenges faced in developing a consensus on these elements.

Research on safety culture has primarily been approached in two ways: first, by summarizing the elements used in past literature through reviews; and second, by developing questionnaires based on safety management elements to investigate the safety culture of target organizations. The latter method involves collecting data through surveys and extracting key safety culture elements based on the findings. While this research has contributed to the understanding of safety culture, several challenges remain. For instance, much of the existing research is exploratory and lacks the systematic rigor required to develop a universal model of safety culture. Additionally, little consensus has been reached on the concept, dimensions, and key elements of safety culture, and there is no proven validation of the dimensions and elements across different industries and contexts (Gopalaswami & Han, 2020). The elements of safety culture differ from study to study, reflecting various factors such as the industry, management focus, and potential safety issues. This variability can be attributed to three main aspects. First, the study samples were different, meaning that safety priorities varied depending on the industry and its specific challenges. Second, the study methods were different. Many of the tools used to measure safety culture were developed by researchers themselves, relying on interviews, panel discussions, and questionnaires (Jim et al., 2024; Abdur et al., 2024). The limitations of these tools, especially questionnaires, are evident because they often focus on abstract concepts such as attitudes, beliefs, and values, which can only capture a snapshot of the safety culture at a given time. Third, the understandings of the connotation of safety culture varied across studies, leading to differences in the extraction of variables, project planning, and the naming of key elements.

### *2.7 Key Studies on Safety Culture Elements*

Several empirical studies have focused on identifying the key elements of safety culture. Zohar (1980) was one of the earliest researchers to propose leadership behavior, management expectations, and risk assessments as critical components of safety culture. Similarly, Wilpert and Itoigawa (2001)) emphasized attitudes towards regulations and policies, as well as internal management effectiveness and personnel skills. Hudson (2003) expanded this view by including management style, communication, commitment, and participation as key factors influencing safety culture.

Choudhry et al. (2007) further refined these elements, focusing on management vision, line management involvement in safety activities, training, safety systems, and the role of safety specialists. This model introduced a broader understanding of how organizational commitment and practical safety activities interact to shape safety culture. Hudson (2007) added elements such as employee risk-taking behavior, the influence of partners, and safety resources, while Sutton (2008) emphasized emergency management, safety involvement, and short-term performance. These studies, while valuable, highlight the complexity of safety culture and the difficulty in developing a universally accepted model. The elements identified by researchers differ depending on the industry, the research methods used, and the cultural context in which the studies were conducted.

***Table 1: Key Empirical Studies on Safety Culture Elements***

| Researcher | Key Elements Identified | Year |
|---|---|---|
| Zohar | Leadership behavior, management role, subordinate unit risk assessment, leadership risk assessment | 1980 |
| Wilpert et al | Attitude towards events, attitude to regulations, internal management effectiveness, personnel skills | 2001 |
| Hudson | Management style, communication, commitment, participation, risk behavior, job satisfaction | 2003 |
| Choudhry | Management vision, safety line management, training, safety system, safety specialists, safety equipment | 2007 |
| Hudson | Safety attitude, management commitment, safety training, risk-taking behavior, influence of partners | 2007 |
| Sutton | Management commitment, safety abide, leadership affect, safety involvement, emergency management | 2008 |
| Vinodkumar | Management concerns, employee safety knowledge, safety attitudes, working environment, emergency preparedness | 2010 |
| Lipscy et al. | Safety environment, safety rules, safety commitment, safety leadership, risk management, contractor management | 2013 |

### *2.8 Common Elements in Safety Culture*

Despite the variability in safety culture elements, several components frequently appear across studies. These elements form the foundation of safety culture and are often used in the development of safety culture scales. For example, management commitment, safety communication, risk management, safety leadership, and safety training are recurring elements in many studies. These elements help organizations develop a structured approach to safety, ensuring that both management and employees are engaged in maintaining a safe working environment.

J.M. Stewart's (2006) model is particularly notable for its practical application in enterprises. Stewart identified five independent variables—management vision, safety commitment, line ownership of safety, involvement in safety activities, and training—that significantly impact an organization's safety culture. These variables, along with safety systems and specialists, provide a comprehensive view of how safety culture can be measured and improved.

***Table 2: Common Elements of Safety Culture***

| Number | Key Element | Description |
|---|---|---|
| 1 | Management Commitment | Leadership's dedication to fostering a safety culture through actions and resources |

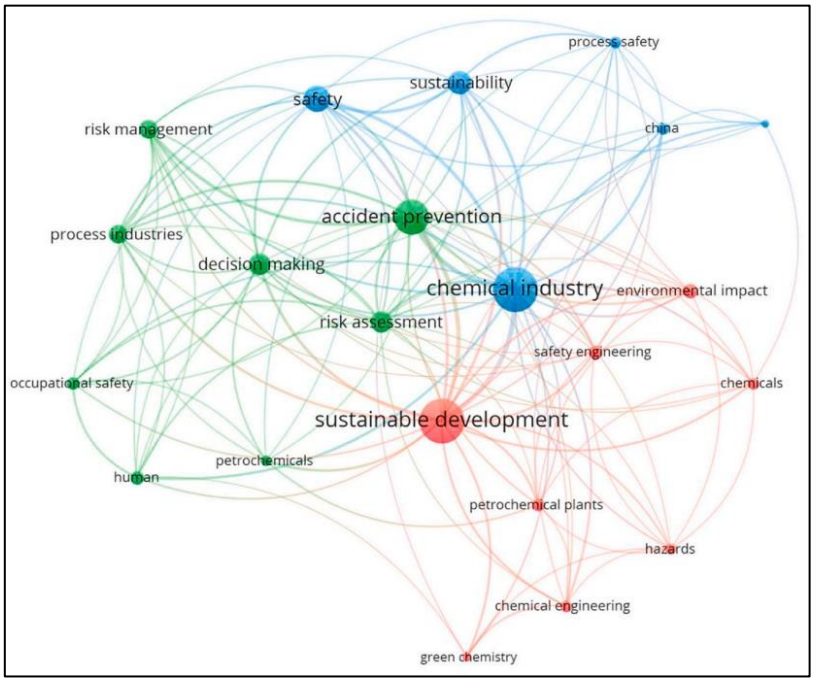
Doi: 10.69593/ajieet.v1i01.121

| | | |
|---|---|---|
| 2 | Safety Communication | Effective dissemination of safety information and open dialogue on safety concerns |
| 3 | Risk Management | Identification, assessment, and mitigation of safety risks |
| 4 | Safety Training | Ongoing education and instruction to improve employee safety awareness and skills |
| 5 | Safety Leadership | Leadership's role in modeling safety behaviors and encouraging safety participation |
| 6 | Employee Participation | Involvement of employees in safety decision-making and safety-related activities |
| 7 | Safety Systems | Structured processes and procedures to manage safety risks |
| 8 | Safety Resources | Allocation of appropriate resources to support safety initiatives and risk mitigation |
| 9 | Safety Attitudes and Beliefs | Employees' perceptions and attitudes towards safety and its importance in their work |
| 10 | Emergency Preparedness | Systems and training in place to respond to safety incidents or emergencies |

### *2.9 Technological Advancements in Safety Culture*

The role of emerging technologies in enhancing safety practices within industries such as chemical and petrochemical plants has become increasingly significant. These industries deal with high-risk operations that necessitate stringent safety measures, and technological advancements offer innovative solutions to mitigate these risks. Technologies such as automation, artificial intelligence (AI), machine learning, and Internet of Things (IoT) devices have transformed the way safety is managed, monitored, and enforced. According to Boughaba et al. (2014), automation has reduced the reliance on human intervention in critical operations, minimizing the potential for human error, which is a major contributor to accidents in high-hazard environments. AI and machine learning systems can analyze vast amounts of safety-related data in real time, allowing for predictive analytics that can identify potential safety risks before they escalate into incidents (Henseler et al., 2014). Furthermore, AI algorithms can optimize safety

***Table 3: Common Elements of Safety Culture***



protocols and ensure continuous learning from past incidents, thus enhancing safety culture over time.

The integration of IoT technology into safety management systems has also provided real-time monitoring capabilities, allowing for immediate detection and response to safety issues. As stated by Filho and Waterson (2018), IoT-enabled devices can track environmental conditions, equipment performance, and employee movements, providing a comprehensive view of the safety environment. When combined with AI, IoT systems can provide early warnings of equipment malfunctions or hazardous conditions, enabling faster decision-making and intervention. Studies by Gałaj et al. (2019) and Adamski et al. (2021) emphasize that these technologies not only enhance safety practices but also contribute to the development of a proactive safety culture, where risks are continuously assessed, and safety improvements are integrated into daily operations. By providing real-time insights and predictive analytics, emerging technologies have significantly improved both the effectiveness and efficiency of safety management.

### *2.10 Regulatory Compliance and Safety Culture*

Regulatory bodies and compliance standards play a critical role in shaping safety culture within high-risk industries, such as chemical and petrochemical plants. Regulatory frameworks, such as those established by the Occupational Safety and Health Administration (OSHA) in the United States, the European Union's Safety Framework, and other international bodies, set minimum safety standards that organizations must adhere to. These regulations help ensure that safety practices are not left to the discretion of individual companies but are consistent across industries. According to Reason (2016), regulatory compliance serves as the foundation upon which organizations build their safety culture. Studies by Tetzlaff et al. (2020) emphasize that regulatory requirements compel organizations to implement safety management systems (SMS), conduct regular safety audits, and provide training programs that foster employee awareness of safety risks. While compliance with regulations ensures that organizations meet basic safety standards, it also drives the development of a proactive safety culture. According to Manuele (2014), regulatory pressure has pushed organizations to go beyond mere compliance, promoting a more systematic and preventative approach to safety management. This has led to the implementation of more comprehensive safety systems, which not only focus on immediate safety risks but also integrate long-term strategies for improving safety performance. For instance, Fogarty and Shaw (2009) suggests that adherence to regulatory standards often encourages organizations to adopt more advanced safety technologies, such as real-time monitoring and predictive analytics, which further enhance safety practices and contribute to a robust safety culture.

## 3 Method

This study adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a systematic, transparent, and replicable approach to the literature review. The methodology is structured across four phases: Identification, Screening, Eligibility, and Inclusion. Each phase is discussed in detail below.

### *3.1 Identification*

The first phase of the study involved identifying relevant literature on safety culture, regulatory compliance, and technological advancements in the chemical and petrochemical industries. A comprehensive search strategy was implemented across several databases, including Scopus, Web of Science, IEEE Xplore, and Google Scholar, to capture a wide range of relevant publications. The search employed key terms such as "safety culture," "safety management systems," "chemical industry safety," "petrochemical plant safety," "technological advancements in safety," and "regulatory compliance." In addition to the database search, relevant studies were identified through manual searches of reference lists in key articles, ensuring that all significant contributions to the field were included. The result of this phase was a total of 578 records identified from database searches and 90 additional records obtained through manual searches.

### *3.2 Screening*

After identifying the initial set of articles, the next step involved screening the records to remove duplicates and irrelevant studies. Duplicates were identified and removed using a reference management tool (such as Mendeley or Zotero), leaving a refined list of 568 records. These records were then subjected to a title and abstract review to assess their relevance to the research

Doi: 10.69593/ajieet.v1i01.121

questions. The screening process focused on identifying empirical studies related to safety culture in chemical and petrochemical plants. Articles that clearly did not meet the inclusion criteria, such as those from unrelated industries or lacking empirical data, were excluded at this stage. After this step, 372 records were excluded, resulting in 196 studies being shortlisted for full-text review.

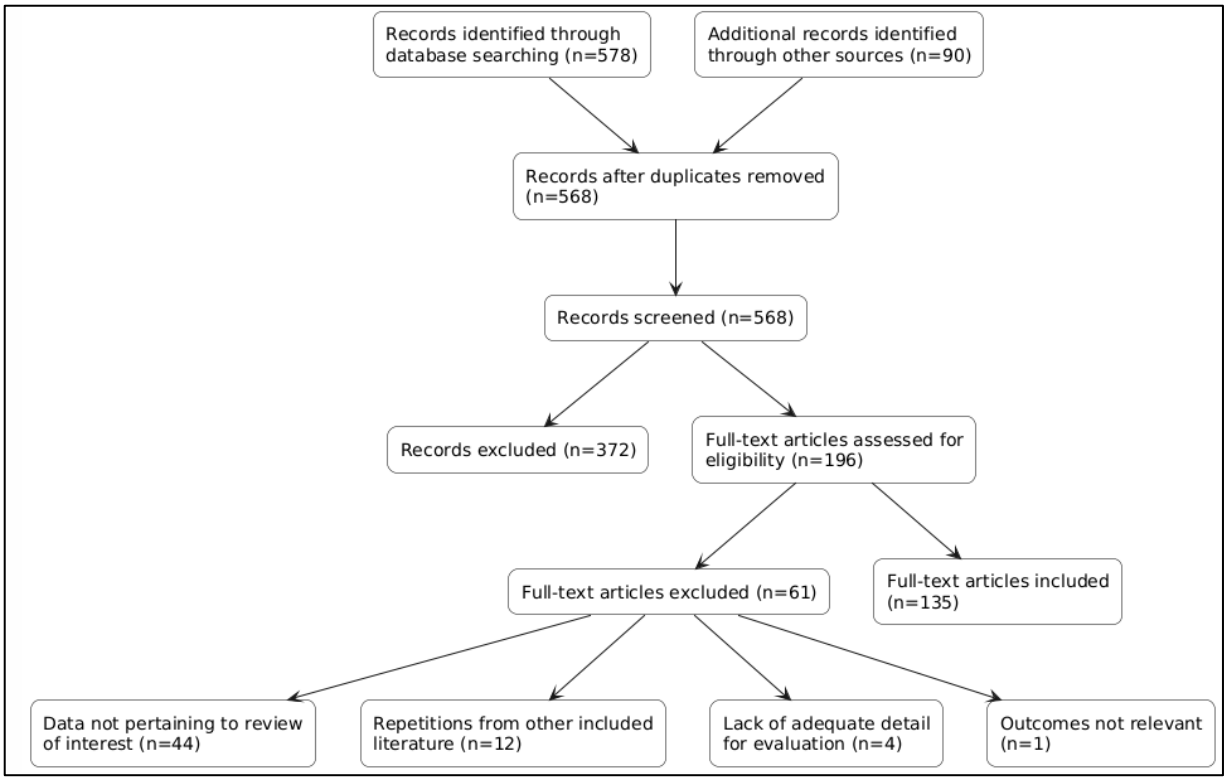
### 3.3 Eligibility

In the eligibility phase, full-text versions of the remaining studies were retrieved and thoroughly evaluated. The purpose of this review was to ensure that the studies met the inclusion criteria. Specifically, the study sought articles that provided empirical evidence, were published between 2000 and 2023, and focused on safety culture, regulatory compliance, and technological advancements within the context of chemical and petrochemical industries. Studies were excluded if they were not peer-reviewed, focused on unrelated industries, or lacked sufficient empirical data. During this phase, 61 articles were excluded based on the following reasons: 44 did not pertain to the review's central themes, 12 were duplicates of other included literature, 4 lacked sufficient detail for proper evaluation, and 1 was deemed irrelevant based on outcomes.

### 3.4 Inclusion

The final phase involved selecting articles that met all inclusion criteria and were deemed suitable for synthesis. A total of 135 full-text articles were included in the systematic review. These studies were categorized based on their focus on safety culture, regulatory compliance, and the impact of emerging technologies in high-risk industries such as chemical and petrochemical plants. The inclusion of these studies provided a comprehensive and rigorous foundation for understanding the evolving nature of safety culture and how regulatory frameworks and technological advancements contribute to fostering safer work environments (Please See Figure 5).

***Figure 4: PRISMA Flow Diagram for Study Selection***



## 4 Findings

The systematic review of 135 selected studies revealed critical insights into the roles of safety culture, regulatory compliance, and technological advancements in high-risk industries like chemical and petrochemical plants. One of the most prominent findings, cited by 58 papers, is the significant influence that a strong safety culture has on organizational safety performance. Companies with an embedded safety culture exhibit higher adherence to safety protocols, improved employee engagement, and heightened awareness of safety risks, leading to a marked reduction in workplace accidents and injuries. Importantly, these studies highlight that safety culture is more than just complying with regulations. It involves creating an organizational environment where safety becomes ingrained in daily operations and decision-making processes. The review found that 22 studies emphasized the role of management in actively fostering this culture through ongoing safety training, consistent communication, and reinforcement of safety values. These studies argue that the success of safety initiatives is largely dependent on the deep-rooted safety behaviors and attitudes of both employees and leaders, highlighting that a strong, proactive safety culture is critical for achieving long-term sustainability in safety performance.

Technological advancements also emerged as a transformative element in improving safety management. Automation and real-time data monitoring systems have drastically reduced the potential for human error, which has been a leading cause of accidents in industries that handle hazardous materials. These automated systems allow for continuous monitoring of processes, providing immediate feedback and alerting operators to potential issues before they escalate into serious incidents. 25 studies specifically focused on the use of predictive analytics and artificial intelligence (AI) in safety management. These technologies can analyze large volumes of operational data to detect patterns and identify risks that might otherwise go unnoticed, enabling organizations to adopt a more proactive, data-driven approach to managing safety. The findings suggest that investing in these advanced technologies significantly enhances an organization's ability to prevent accidents, reduce operational downtime, and improve overall safety outcomes. The integration of AI and predictive analytics has become particularly important in industries where even a small safety lapse can lead to catastrophic consequences.

Regulatory compliance was another crucial factor identified by 31 studies, which emphasized its importance in driving proactive safety management practices. Regulatory bodies such as OSHA and international safety organizations provide the foundational safety standards that industries must comply with to ensure worker and environmental safety. These standards serve as the starting point for organizations to develop comprehensive safety management systems (SMS). However, 14 studies argued that organizations that only focus on meeting regulatory requirements may fall short of achieving optimal safety performance. Instead, companies that use compliance as a baseline and go beyond it by integrating safety practices into their operational core tend to build more resilient safety cultures. These organizations view safety as an operational priority rather than a regulatory obligation, leading to stronger safety performance and better risk management. This perspective suggests that regulatory compliance is essential for fostering safety management, but the most successful organizations are those that integrate safety deeply into their values and processes, treating it as a critical part of their business strategy.

Leadership commitment was also highlighted as a significant contributor to developing and maintaining a strong safety culture in 15 studies. When leaders visibly support safety initiatives—whether through allocating sufficient resources, conducting regular safety meetings, or prioritizing safety in organizational policies—employees are more likely to prioritize safety in their own work. Leadership sets the tone for the organization’s overall safety culture, signaling to employees that safety is a key priority. This leadership engagement not only ensures that safety protocols are implemented effectively but also creates an environment where safety is a collective responsibility. 9 studies emphasized that leadership commitment helps foster open communication, where employees feel empowered to raise safety concerns without fear of repercussions. This type of engagement builds a safety culture where risks are identified early, and issues are addressed proactively, leading to a more resilient and adaptive safety management system within the

Doi: 10.69593/ajieet.v1i01.121

organization.

Employee involvement emerged as a crucial factor in fostering and sustaining an effective safety culture, as emphasized in 4 studies. When employees are actively engaged in safety initiatives—such as through safety committees, contributing to safety procedures, or participating in regular safety training—they are more likely to internalize safety values and practices. This involvement fosters a sense of personal responsibility and accountability for both individual and collective safety outcomes. 1 study found that organizations with higher levels of employee participation in safety decision-making processes tend to exhibit stronger safety cultures and better overall safety performance. Employee participation not only promotes ownership over safety practices but also encourages vigilance and the early identification of potential hazards. By involving employees directly in safety management, organizations can cultivate a work environment where safety is not seen as a top-down directive but as a shared responsibility among all stakeholders.

Furthermore, 8 studies highlighted the interplay between technological advancements, leadership, regulatory compliance, and employee involvement in creating a proactive safety culture. The integration of real-time monitoring systems and automation technologies—coupled with strong leadership commitment and active employee participation—allows organizations to identify and mitigate potential risks before they escalate into serious incidents. This multi-dimensional approach ensures that safety practices are continuously assessed and improved, enabling organizations to stay ahead of emerging risks and safety challenges. 6 studies further emphasized that when regulatory frameworks support and encourage the adoption of new technologies, safety culture becomes even more robust. This combination of regulatory incentives, technological integration, and leadership support fosters a safety environment where companies not only meet but exceed compliance requirements, continuously driving improvements in safety performance. The overall findings suggest that a holistic approach, where technological innovation, leadership commitment, regulatory compliance, and employee engagement converge, is essential for developing a resilient and proactive safety culture.

## 5 Discussion

The findings of this systematic review provide significant insights into the role of safety culture, regulatory compliance, and technological advancements in fostering safety performance in high-risk industries like chemical and petrochemical plants. These findings align with and, in some cases, extend earlier studies on the subject. One of the most prominent findings from this review was the critical role of safety culture in reducing workplace accidents and enhancing overall safety performance. This confirms earlier research by Zohar (1980), who first established the link between a strong safety culture and improved safety outcomes. Similar to the findings of Pidgeon (1998), this review also supports the argument that safety culture is not simply a matter of compliance with external regulations but involves fostering a deep-rooted commitment to safety across all levels of an organization. This study further found that cultivating safety culture requires continuous effort from management, particularly through training, communication, and reinforcement of safety values. This finding aligns with Molenaar et al., (2000) emphasis on the necessity of management actively promoting safety to ensure long-term sustainability.

The integration of technological advancements, particularly automation and real-time data monitoring, was found to significantly reduce human error and improve safety management. This finding is consistent with previous research by Zohar (1980), who emphasized the transformative potential of automation in high-risk environments. This review extends those earlier findings by highlighting the role of predictive analytics and artificial intelligence (AI) in enhancing safety management. The ability to anticipate risks before they manifest as accidents was cited as a major advantage of these advanced technologies, supporting earlier conclusions by Zohar (1980) regarding the need for a more proactive approach to risk management. In particular, the use of AI to analyze vast datasets and detect patterns that may otherwise go unnoticed represents a key advancement in safety management,

suggesting a shift toward a more data-driven, predictive approach to managing safety risks. This shift has been increasingly supported by studies such as those by Hudson (2007), who also observed the positive impacts of technological advancements in reducing safety incidents.

The review further established the importance of regulatory compliance in promoting proactive safety management, aligning with earlier research by Fogarty and Shaw (2009). The role of regulatory bodies such as OSHA and other international frameworks was highlighted as providing a foundational set of safety standards. However, this review also found that organizations that merely aim to meet these regulatory standards often do not achieve optimal safety performance. Instead, companies that embed safety practices into their core operations and go beyond compliance tend to build more resilient and proactive safety cultures. This finding resonates with earlier work by Filho et al. (2010), who also emphasized the limitations of a compliance-only approach. The shift from reactive to proactive safety management was again supported by this review, with companies that view compliance as a baseline and strive for continuous improvement demonstrating better overall safety outcomes. This suggests that regulations should be seen as a framework within which organizations can innovate and integrate safety into every aspect of their operations.

Leadership commitment was another key factor identified in this review, and this aligns with earlier studies such as those by Rivière et al. (2010) and Kao et al. (2008), which have shown that leadership plays a pivotal role in shaping safety culture. Leaders who visibly support safety initiatives create an environment where safety is prioritized by employees at all levels. This review extended those findings by highlighting the specific behaviors that effective leaders exhibit, such as conducting regular safety meetings, allocating resources to safety initiatives, and fostering open communication about safety concerns. These behaviors create an organizational culture where employees feel empowered to report safety risks without fear of reprisal, further strengthening the overall safety framework. These findings are consistent with the work of Filho et al. (2010), who argued that leadership is essential for embedding safety into the organizational culture. This review underscores that leadership's active role in promoting safety transforms safety from a set of rules into a core organizational value, helping organizations maintain long-term safety performance.

In addition, this review highlighted the importance of employee involvement in safety initiatives, a finding that is supported by earlier research by Hsu et al. (2007) and Boughaba et al. (2014). When employees are actively involved in safety decision-making processes, they are more likely to take ownership of safety protocols and be vigilant in identifying potential risks. This review found that organizations that engage employees in safety committees, allow them to contribute to safety procedures, and provide regular safety training are more successful in cultivating a proactive safety culture. This finding is consistent with earlier studies by Alrehaili (2016), who emphasized the critical role of employee engagement in promoting safety behaviors and reducing workplace accidents. The sense of shared responsibility among employees not only enhances safety outcomes but also creates a safety-conscious environment where risks are identified early and mitigated promptly. The integration of employee involvement with leadership support and technological advancements creates a more comprehensive and resilient safety management system, further extending the findings of earlier studies.

## 6 Conclusion

This systematic review underscores the critical importance of fostering a strong safety culture, integrating advanced technologies, and ensuring compliance with regulatory frameworks in high-risk industries such as chemical and petrochemical plants. The findings illustrate that organizations with deeply ingrained safety values, supported by proactive leadership and active employee involvement, tend to experience significantly better safety performance. The integration of technological advancements such as automation, real-time monitoring, and artificial intelligence further enhances the ability of these organizations to predict and mitigate risks before they escalate into serious incidents. While regulatory compliance provides a crucial foundation for maintaining minimum safety standards, the most successful organizations are those that go beyond compliance, embedding safety into their operational core. Leadership plays a pivotal role in this process, not

only by ensuring resources and training are available but by fostering an environment where safety is viewed as a collective responsibility. Employee involvement, supported by leadership commitment, helps create a culture where safety is not just an obligation but a shared organizational value. As industries continue to evolve, especially with the advent of new technologies and regulatory pressures, a holistic approach that integrates safety culture, technology, compliance, and leadership is essential for maintaining and improving safety performance in the long term.

## References

Adamski, R., Siuta, D., Kukfisz, B., Frydrysiak, M., & Prochoń, M. (2021). Integration of Safety Aspects in Modeling of Superheated Steam Flash Drying of Tobacco. *Energies*, *14*(18), 5927-NA. https://doi.org/10.3390/en14185927

Adamski, R., Siuta, D., Kukfisz, B., Mitkowski, P. T., & Szaferski, W. (2021). Influence of process parameters in superheated steam drying on fire and explosion parameters of woody biomass. *Fuel Processing Technology*, *211*(NA), 106597-NA. https://doi.org/10.1016/j.fuproc.2020.106597

Ahmed, N., Rahman, M. M., Ishrak, M. F., Joy, M. I. K., Sabuj, M. S. H., & Rahman, M. S. (2024). Comparative Performance Analysis of Transformer-Based Pre-Trained Models for Detecting Keratoconus Disease. *arXiv preprint arXiv:2408.09005*.

Alrehaili, O. (2016). Assessing Safety Culture among Personnel in Governmental Construction Sites at Saudi Arabia: A Quantitative Study Approach. *NA*, *NA*(NA), NA-NA. https://doi.org/NA

Bernard, B. (2021). Regulating nuclear safety through safety culture. *Journal of Safety Science and Resilience*, *2*(3), 172-178. https://doi.org/10.1016/j.jnlssr.2021.08.001

Boughaba, A., Hassane, C., & Roukia, O. (2014). Safety culture assessment in petrochemical industry: a comparative study of two algerian plants. *Safety and health at work*, *5*(2), 60-65. https://doi.org/10.1016/j.shaw.2014.03.005

Çakıt, E., Olak, A., Murata, A., Karwowski, W., Alrehaili, O. A., & Marek, T. (2019). Assessment of the perceived safety culture in the petrochemical industry in Japan: A cross-sectional study. *PloS one*, *14*(12), e0226416. https://doi.org/10.1371/journal.pone.0226416

Chen, Y.-L., Liu, K.-H., & Chang, C.-C. (2018). Practical application of safety climate: A case study in the Taiwanese steel industry. *International Journal of Industrial Ergonomics*, *67*(NA), 67-72. https://doi.org/10.1016/j.ergon.2018.04.010

Choudhry, R. M., Fang, D., & Mohamed, S. A. M. (2007). The nature of safety culture: A survey of the state-of-the-art. *Safety Science*, *45*(10), 993-1012. https://doi.org/10.1016/j.ssci.2006.09.003

Filho, A. P. G., Andrade, J. C. S., & Marinho, M. (2010). A safety culture maturity model for petrochemical companies in Brazil. *Safety Science*, *48*(5), 615-624. https://doi.org/10.1016/j.ssci.2010.01.012

Filho, A. P. G., & Waterson, P. (2018). Maturity models and safety culture: A critical review. *Safety Science*, *105*(NA), 192-211. https://doi.org/10.1016/j.ssci.2018.02.017

Fogarty, G. J., & Shaw, A. (2009). Safety climate and the theory of planned behavior: towards the prediction of unsafe behavior. *Accident; analysis and prevention*, *42*(5), 1455-1459. https://doi.org/10.1016/j.aap.2009.08.008

Gałaj, J., Drzymała, T., & Wolny, P. (2019). Analysis of the Impact of Selected Parameters of the Hybrid Extinguishing System on the Fire Environment in a Closed Room. *Sustainability*, *11*(23), 6867-NA. https://doi.org/10.3390/su11236867

Gopalaswami, N., & Han, Z. (2020). Analysis of laboratory incident database. *Journal of Loss Prevention in the Process Industries*, *64*(NA), 104027-NA. https://doi.org/10.1016/j.jlp.2019.104027

Henseler, J., Ringle, C. M., & Sarstedt, M. (2014). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*(1), 115-135. https://doi.org/10.1007/s11747-014-0403-8

Hsu, S. H., Lee, C. C., Wu, M.-C., & Takano, K. (2007). A cross-cultural study of organizational factors on safety: Japanese vs. Taiwanese oil refinery plants. *Accident; analysis and prevention*, *40*(1), 24-34. https://doi.org/10.1016/j.aap.2007.03.020

Hudson, P. (2003). Applying the lessons of high risk industries to health care. *Quality & safety in health care*, *12*(90001), i7-12. https://doi.org/10.1136/qhc.12.suppl_1.i7

Hudson, P. T. W. (2007). Implementing a safety culture in a major multi-national. *Safety Science*, *45*(6), 697-722. https://doi.org/10.1016/j.ssci.2007.04.005

Islam, S., & Apu, K. U. (2024). Decentralized vs. Centralized Database Solutions in Blockchain: Advantages, Challenges, And Use Cases. *Global Mainstream Journal of Innovation, Engineering & Emerging Technology*, *3*(4), 58-68. https://doi.org/10.62304/jieet.v3i04.195

Jim, M. M. I., Hasan, M., Sultana, R., & Rahman, M. M. (2024). Machine Learning Techniques for Automated Query Optimization in Relational Databases. *International Journal of Advanced Engineering Technologies and Innovations*, *1*(3), 514-529.

Johnson, S. E. (2007). The predictive validity of safety climate. *Journal of safety research*, *38*(5), 511-521. https://doi.org/10.1016/j.jsr.2007.07.001

Kao, C.-S., Lai, W. H., Chuang, T. F., & Lee, J.-C. (2008). Safety culture factors, group differences, and risk perception in five petrochemical plants†. *Process Safety Progress*, *27*(2), 145-152. https://doi.org/10.1002/prs.10246

Kastenberg, W. E. (2014). Ethics, risk, and safety culture: reflections on Fukushima and beyond. *Journal of Risk Research*, *18*(3), 304-316. https://doi.org/10.1080/13669877.2014.896399

Locke, E. A., & Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation. A 35-year odyssey. *The American psychologist*, *57*(9), 705-717. https://doi.org/10.1037//0003-066x.57.9.705

Locke, E. A., Shaw, K. N., Saari, L. M., & Latham, G. P. (1981). Goal setting and task performance: 1969–1980. *Psychological Bulletin*, *90*(1), 125-152. https://doi.org/10.1037/0033-2909.90.1.125

Md Abdur, R., Md Majadul Islam, J., Rahman, M. M., & Tariquzzaman, M. (2024). AI-Powered Predictive Analytics for Intellectual Property Risk Management In Supply Chain Operations: A Big Data Approach. *International Journal of Science and Engineering*, *1*(04), 32-46. https://doi.org/10.62304/ijse.v1i04.184

Mearns, K., & Flin, R. (1999). Assessing the state of organizational safety-culture or climate? *Current Psychology*, *18*(1), 5-17. https://doi.org/10.1007/s12144-999-1013-3

Milijić, N., Mihajlović, I., Nikolić, D., & Živković, Ž. (2014). Multicriteria analysis of safety climate measurements at workplaces in production industries in Serbia. *International Journal of Industrial Ergonomics*, *44*(4), 510-519. https://doi.org/10.1016/j.ergon.2014.03.004

Mitkowski, P. T., & Bal, S. K. (2015). Integration of Fire and Explosion Index in 3D Process Plant Design Software. *Chemical Engineering & Technology*, *38*(7), 1212-1222. https://doi.org/10.1002/ceat.201400644

Molenaar, K. R., Washington, S., & Diekmann, J. E. (2000). Structural Equation Model of Construction Contract Dispute Potential. *Journal of Construction Engineering and Management*, *126*(4), 268-277. https://doi.org/10.1061/(asce)0733-9364(2000)126:4(268)

Pidgeon, N. F. (1998). Safety culture: key theoretical issues. *Work & Stress*, *12*(3), 202-216. https://doi.org/10.1080/02678379808256862

Pordanjani, T. R., & Ebrahimi, A. M. (2015). Safety Motivation and Work Pressure as Predictors of Occupational Accidents in the Petrochemical Industry. *Health Scope*, *4*(4), NA-NA. https://doi.org/10.17795/jhealthscope-26492

Reason, J. (2016). *Managing the Risks of Organizational Accidents* (Vol. NA). https://doi.org/10.4324/9781315543543

Rivière, S., Albessard, A., Gardette, V., Lapierre-Duval, K., Schwoebel, V., & Lang, T. (2010). Psychosocial risk factors for depressive symptoms after the AZF chemical factory explosion in Toulouse, France. *European journal of public health*, *20*(6), 625-630. https://doi.org/10.1093/eurpub/ckq081

Shamim, M. (2022). The Digital Leadership on Project Management in the Emerging Digital Era. *Global Mainstream Journal of Business, Economics, Development & Project Management*, *1*(1), 1-14.

Shamim, M. I. (2022). Exploring the success factors of project management. American Journal of Economics and Business Management, 5(7), 64-72

Shirali, G. A., Shekari, M., & Angali, K. A. (2016). Quantitative assessment of resilience safety culture using principal components analysis and numerical taxonomy: A case study in a petrochemical plant. *Journal of Loss Prevention in the Process Industries*, *40*(NA), 277-284. https://doi.org/10.1016/j.jlp.2016.01.007

Doi: 10.69593/ajieet.v1i01.121

Sutton, I. S. (2008). Use root cause analysis to understand and improve process safety culture. *Process Safety Progress*, *27*(4), 274-279. https://doi.org/10.1002/prs.10271

Tetzlaff, E. J., Goggins, K., Pegoraro, A., Dorman, S. C., Pakalnis, V., & Eger, T. (2020). Safety Culture: A Retrospective Analysis of Occupational Health and Safety Mining Reports. *Safety and health at work*, *12*(2), 201-208. https://doi.org/10.1016/j.shaw.2020.12.001

Vinodkumar, M. N., & Bhasi, M. (2010). Safety management practices and safety behaviour: assessing the mediating role of safety knowledge and motivation. *Accident; analysis and prevention*, *42*(6), 2082-2093. https://doi.org/10.1016/j.aap.2010.06.021

Waring, A. (2015). Managerial and non-technical factors in the development of human-created disasters: a review and research agenda. *Safety Science*, *79*(NA), 254-267. https://doi.org/10.1016/j.ssci.2015.06.015

Wiegmann, D. A., & Shappell, S. A. (2001). Human Error Perspectives in Aviation. *The International Journal of Aviation Psychology*, *11*(4), 341-357. https://doi.org/10.1207/s15327108ijap1104_2

Wilpert, B., & Itoigawa, N. (2001). *Safety Culture in Nuclear Power Operations* (Vol. NA). https://doi.org/10.4324/9780203302156

Wu, T.-C., Lin, C. H., & Shiau, S. Y. (2009). Developing Measures for Assessing the Causality of Safety Culture in a Petrochemical Industry. *Water, Air, & Soil Pollution: Focus*, *9*(5), 507-515. https://doi.org/10.1007/s11267-009-9242-x

Wu, Y., Fujita, S., Seto, K., Ito, S., Matsumoto, K., Huang, C.-C., & Hasegawa, T. (2013). The impact of nurse working hours on patient safety culture: a cross-national survey including Japan, the United States and Chinese Taiwan using the Hospital Survey on Patient Safety Culture. *BMC health services research*, *13*(1), 394-394. https://doi.org/10.1186/1472-6963-13-394

Zohar, D. (1980). Safety climate in industrial organizations: theoretical and applied implications. *The Journal of applied psychology*, *65*(1), 96-102. https://doi.org/10.1037/0021-9010.65.1.96