

Safety Culture as a Pillar of Sustainability and Productivity in Modern Industry: A Mixed-Methods Investigation

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Workplace safety remains a critical determinant of operational reliability, particularly in industrial environments characterized by complex socio-technical systems. While formal safety management systems are essential, increasing evidence suggests that safety performance is strongly influenced by organizational and human factors, including employee engagement, communication, and risk perception. This study investigates safety culture perceptions among industrial workers, focusing on differences related to age, work experience, organizational role, and site characteristics. Data were collected through a structured questionnaire administered to 315 employees across multiple industrial sites and analyzed using analysis of variance (ANOVA). The results reveal statistically significant differences across demographic groups, particularly in participation in risk assessment ($p = 0.0007$), perceived safety ($p = 0.0017$), and risk awareness ($p = 0.0056$). These findings highlight the need for targeted and adaptive safety strategies that address demographic and organizational diversity. Younger and less experienced workers demonstrate higher levels of active engagement, procedural compliance, and comfort in reporting safety issues, while more experienced employees exhibit lower involvement in formal safety mechanisms, reflecting a potential risk of cultural stagnation. Differences across organizational roles indicate that supervisors and technical staff are more engaged in decision-making and risk evaluation than production-line employees, suggesting that participatory mechanisms are not uniformly applied. Strengthening safety culture through inclusive and adaptive practices can contribute simultaneously to improved safety performance, organizational sustainability, and industrial productivity.

Keywords: Safety Culture, Industrial Safety, Human Factors, Sustainability, Risk Assessment, ESREL 2026.

1. Introduction

Workplace safety is a fundamental prerequisite for sustainable industrial operations, employee well-being, and organizational resilience, particularly in complex socio-technical systems where technical, human, and organizational risks coexist. Accident prevention cannot rely solely on regulatory compliance and formal procedures. Traditional safety management systems, while indispensable, are often insufficient to address incidents arising from human behavior, communication failures, and organizational dynamics (Reason 1997; Hollnagel 2014).

The concept of safety culture emerged in response to major industrial accidents, such as the Chernobyl disaster, highlighting the role of shared

values, beliefs, and practices in shaping safety performance (IAEA 1991; Reason 1997). Safety culture encompasses the collective attitudes, perceptions, and behaviors through which employees and management engage with risk prevention in daily operations. Leadership commitment, employee participation, trust, and organizational learning mechanisms strongly influence safety outcomes (Guldenmund 2000; Cooper 2000; Clarke 2006).

Empirical evidence suggests that safety culture is dynamic, evolving across hierarchical levels, professional roles, and career stages. Differences in age, tenure, and role are associated with variations in engagement, reporting behavior, and participation in formal safety structures (Griffin and Neal 2000; Clarke 2006). In standardized

industrial settings, formal compliance may be uniform while the lived experience of safety differs significantly across workforce groups. Despite a growing body of literature, empirical evidence on how demographic characteristics influence safety perceptions in operational industrial contexts remains limited. This study addresses this gap by investigating variations in safety culture perceptions across age, tenure, organizational role, and site characteristics, using ANOVA to identify statistically significant differences that can guide adaptive safety management strategies.

1.1 Scope and contribution of the study

This study aims to examine how safety culture is experienced across different workforce groups within a complex industrial environment. While many organizations implement standardized safety management systems, employees' perceptions of safety practices may vary depending on organizational context, hierarchical position, and individual experience. Understanding these variations is essential for designing adaptive safety strategies capable of addressing the human and organizational dimensions of risk management.

The research contributes to the safety culture literature in three main ways. First, it provides empirical field-based evidence from operational industrial environments, addressing a common limitation of safety culture studies that rely primarily on perception surveys detached from real organizational contexts. By collecting data from multiple industrial sites and professional roles, the study captures the diversity of safety experiences across a complex workforce.

Second, the study simultaneously examines multiple demographic and organizational variables—including site characteristics, professional role, age, and work experience—allowing for a multidimensional assessment of safety culture. This approach enables the identification of patterns of convergence and divergence in safety perceptions across the workforce.

Third, the research connects statistical findings with practical safety management implications.

Rather than treating statistically significant differences solely as numerical outcomes, the study interprets them in terms of organizational dynamics and proposes targeted interventions aimed at strengthening employee engagement, preventing cultural stagnation, and promoting participatory safety practices.

1.2 Safety Culture and Industrial Sustainability

In recent years, safety culture has increasingly been examined not only as a mechanism for accident prevention but also as a key component of organizational sustainability. Industrial organizations operate in environments characterized by technological complexity, regulatory pressure, and the need to maintain stable production while minimizing operational risks. Within this context, safety culture plays a strategic role by shaping how employees perceive hazards, communicate risks, and participate in safety-related decision-making.

A strong safety culture contributes to sustainability in several ways. First, it reduces the likelihood of accidents and operational disruptions, thereby supporting production continuity and system reliability. Second, it encourages proactive identification of hazards and near misses, enabling organizations to learn from weak signals before incidents occur. Third, participatory safety practices foster trust between employees and management, strengthening workforce engagement and collective responsibility for safety outcomes.

From an organizational perspective, safety culture can therefore be considered an intangible asset that supports both operational efficiency and long-term resilience. Companies that invest in developing strong safety cultures often experience improved productivity, reduced incident costs, and enhanced organizational learning capacity.

2. Methodology

2.1 Study design and sample

The study was conducted across multiple industrial installations involving 315 employees representing a wide range of roles, departments,

age groups, and levels of professional experience. Participants included production-line workers, technical specialists, and supervisors. Participation was voluntary and anonymous to reduce response bias and encourage honest reporting of perceptions regarding safety practices and organizational culture.

2.2 Measurement instrument

Data were collected using a structured safety culture questionnaire designed to capture both individual attitudes and perceptions of organizational safety practices.

The questionnaire assessed several key dimensions commonly associated with safety culture:

- Procedural compliance
- Incident and near-miss reporting
- Risk awareness
- Participation in risk assessment
- Trust in safety leadership
- Participation in health and safety committees

Responses were recorded using a Likert-type scale, allowing participants to express varying levels of agreement with each statement.

Table 1. Sample Characteristics and Safety Culture Dimensions

Category	Description
Sample Size	N = 315, multiple industrial sites
Demographics	age groups, tenure (≤ 7 vs > 7 years), roles
Safety Culture Dimensions	Compliance, reporting, awareness, participation
Statistical Method	One-way ANOVA; $p < 0.05$

2.3 Statistical analysis

One-way analysis of variance (ANOVA) was used to examine differences in safety culture indicators across four grouping variables:

- Industrial site
- Organizational role
- Age group
- Work experience (tenure)

Statistical significance was evaluated at $p < 0.05$.

2.4 Reliability and validity

The questionnaire captured both behavioral and perceptual dimensions of safety culture. Ensuring anonymity helped reduce social desirability bias, while the use of ANOVA enabled transparent identification of differences across demographic groups.

3. Results

3.1 Site effects (“site paradox”)

While training, procedural knowledge, and reporting freedom were consistent across sites ($p > 0.10$), employees at the Middle risk installation reported significantly lower levels of:

- Perceived safety ($p = 0.0017$)
- Risk awareness ($p = 0.0056$)
- Participation in risk assessment ($p = 0.0007$)

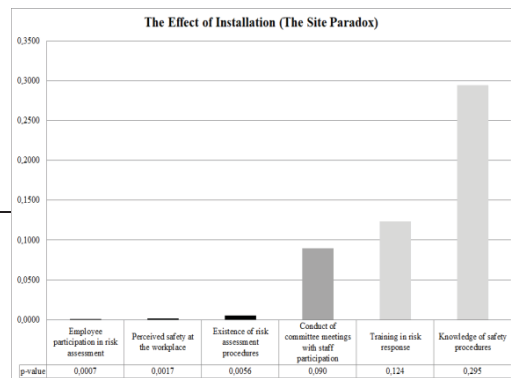


Figure 1 – Site differences: Perceived Safety, Risk Awareness, and Risk Assessment Participation

These results indicate that although formal safety structures were implemented uniformly, employees experienced safety practices differently depending on their operational environment.

3.2 Role effects

Supervisors and technical staff reported significantly higher engagement in risk assessment and safety decision-making compared with production-line employees. This finding indicates that safety management processes remain partially hierarchical, with frontline workers having fewer opportunities to participate actively in risk management.

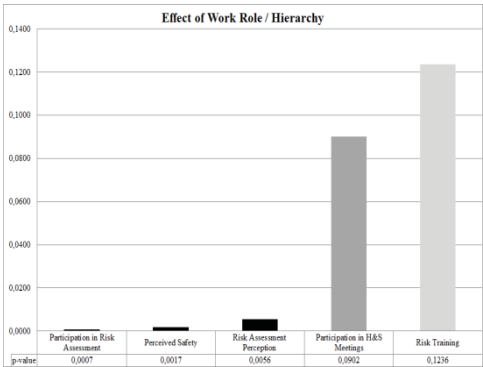


Figure 2 – Role differences in safety engagement

3.3 Tenure effects (“paradox of experience”)

Employees with seven or fewer years of experience (≤ 7 years) demonstrated higher engagement in safety committees, risk assessments, and reporting behavior. In contrast, employees with more than seven years of experience (> 7 years) complied with safety procedures but participated less frequently in institutional safety mechanisms.

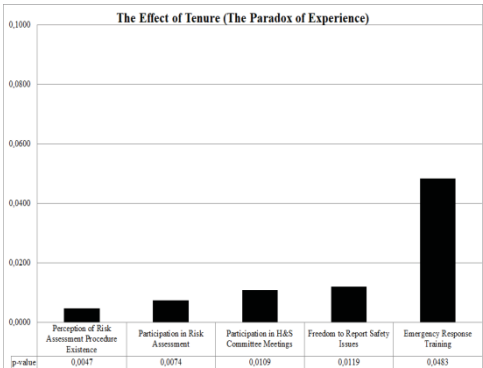


Figure 3 – Tenure effects on participation

3.4 Age effects

Younger employees showed stronger adherence to safety rules and greater willingness to report safety concerns. Older employees, while maintaining procedural compliance, participated less in formal safety activities.

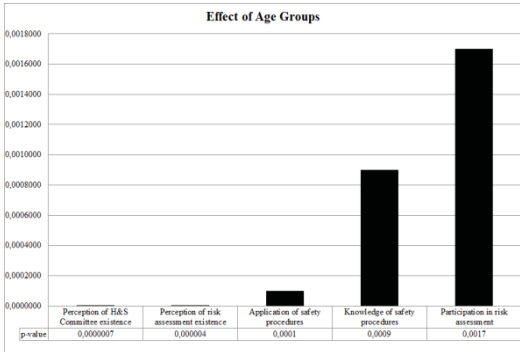


Figure 4 – Age effects on engagement and reporting

3.5 Synthesis of results

Across all demographic groups, formal compliance with safety procedures remained relatively consistent. However, significant variations were observed in:

- Participation in risk assessment
- Perceived safety
- Risk awareness

These findings suggest that safety culture extends beyond formal compliance and depends strongly on employee engagement and participation in safety processes.

3.6 Integrated interpretation of statistical patterns

A cross-comparison of the statistical findings reveals a consistent pattern across the examined variables. While formal safety procedures and training programs appear to be implemented uniformly across the organization, deeper aspects of safety culture—such as risk ownership, engagement in risk assessment, and perceived safety—vary significantly across demographic and organizational groups.

Participation in risk assessment activities emerged as the most sensitive indicator across the dataset. This result suggests that employee engagement in structured safety processes remains unevenly distributed. Workers occupying supervisory or technical roles tend to participate more actively in risk evaluation activities, whereas production-line employees are less frequently involved in formal decision-making processes.

Similarly, perceived safety and risk awareness appear to be influenced not only by formal training but also by everyday work experiences and communication dynamics within teams. This finding reinforces the view that safety culture emerges from the continuous interaction between organizational structures and human behavior, rather than being determined exclusively by formal procedures and compliance mechanisms.

4. Interpretation and implications

The results highlight the importance of considering organizational and demographic diversity when designing safety management strategies. Although standardized safety procedures ensure a consistent baseline of compliance, the depth of safety engagement varies across workforce groups.

Site-specific differences suggest that local operational contexts influence safety perceptions. Similarly, hierarchical differences indicate that frontline workers may have fewer opportunities to participate in safety decision-making processes. Encouraging participatory safety management practices can help bridge these gaps by involving employees directly in risk assessment and safety improvement initiatives.

Generational differences further demonstrate that safety culture evolves across career stages. Younger employees often demonstrate strong engagement with formal safety systems, while experienced workers rely more heavily on

personal experience and routine practices. Organizations can leverage these differences through cross-generational mentoring and targeted engagement initiatives that integrate experience with fresh perspectives on safety.

5. Practical implications for industrial safety management

The findings of this study highlight the importance of adopting adaptive and participatory approaches to safety management in industrial environments. While standardized safety management systems provide a necessary foundation for regulatory compliance, they may not fully capture the diversity of experiences and perceptions present within a heterogeneous workforce.

Industrial organizations should therefore complement procedural safety measures with initiatives that actively involve employees in risk management processes. Encouraging participation in safety committees, risk assessments, and improvement initiatives can strengthen employees' sense of ownership over safety outcomes. Additionally, targeted programs addressing demographic differences may enhance safety engagement. For example, mentoring initiatives that connect experienced employees with younger workers can facilitate knowledge transfer while maintaining engagement with formal safety processes.

By recognizing safety culture as a dynamic organizational capability rather than a static compliance requirement, companies can develop more resilient safety systems that support both operational reliability and sustainable industrial performance.

6. Limitations and future research

Despite providing valuable insights into safety culture dynamics, the study has several limitations. First, the research relies on self-

reported perceptions, which may not fully capture actual safety behaviors. Second, the cross-sectional design captures safety culture at a single point in time, while safety culture is inherently dynamic and may evolve over time.

Future research could adopt longitudinal designs to examine how safety perceptions change throughout employees' careers. Additionally, qualitative methods such as interviews and focus groups could provide deeper insight into the mechanisms shaping employee engagement in safety processes.

7. Conclusions and strategic roadmap

The findings indicate that the organization exhibits a generally mature but fragmented safety culture. While formal training and procedural knowledge are consistent across sites, differences in safety engagement emerge across demographic and organizational groups.

Younger employees and new hires demonstrate higher levels of engagement in safety processes, while experienced employees show greater reliance on procedural compliance. Supervisors and technical staff participate more actively in safety decision-making than production-line employees, creating potential hierarchical gaps in safety participation.

To address these issues, organizations should adopt targeted safety strategies, including site-specific engagement programs, role-based participation mechanisms, cross-generational mentoring, and continuous monitoring of safety culture indicators. By strengthening participatory safety practices, organizations can foster a resilient safety culture that supports both operational reliability and long-term sustainability.

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