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A Targeted Review of Safety Culture Interventions: Tools and Insights for Aviation Regulators

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12. Abstract Promoting a positive safety culture is essential to managing safety risks in aviation organizations. However, many safety culture change efforts fail due to a lack of evidence-based strategies. This literature review synthesizes research from safety, psychological, and organizational sciences to identify effective approaches for safety culture improvement. Findings are organized among the 10 dimensions of the Harmonized Safety Culture Model developed by the International Atomic Energy Agency (2020). The Federal Aviation Administration has adopted the IAEA's model for assessing safety culture within the agency and for overseeing the safety culture of its regulated entities. Following a review of the literature, we offer practical recommendations for implementing safety culture interventions within the aviation industry, as well as limitations and implications for future research.		
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List of Abbreviations

Acronym	Abbreviation Explained
ACSAA	Aircraft Certification, Safety, and Accountability Act
AVS	Aviation Safety
BBS	Behavior-Based Safety
CEO	Chief Executive Officers
CSA	Clear Signal for Action
DOD	Department of Defense
FAA	Federal Aviation Administration
FRA	Federal Railroad Administration
FSL	Foundations for Safety Leadership
HSCM	Harmonized Safety Culture Model
HSE	Health, Safety, and Environment
IAEA	International Atomic Energy Agency
NASA	National Aeronautics and Space Administration
NRC	U.S. Nuclear Regulatory Commission
OR	Operating Room
OSHA	Occupational Safety and Health Administration
PAR	Participatory Action Research
PPE	Personal Protective Equipment
SPC	Safety Planning and Control
SSTL	Safety Specific Transformational Leadership
STAR	Support Transform Achieve Results
TRB	Transportation Review Board
UP	Union Pacific Railroad

1. Introduction

The landscape of transportation is facing significant change over the coming years, with emerging entrants, advancing remotely operated vehicles, and expanding safety management requirements. Given these planned changes, consideration is warranted about how safety culture can be assessed, monitored, and continually improved *at scale*, as safety culture is a critical enabler of effective safety management (International Civil Aviation Organization [ICAO], 2016; ICAO, 2018). The Federal Aviation Administration (FAA) defines safety culture as "…the shared values, actions, and behaviors that demonstrate a commitment to safety over competing goals and demands (Morrow and Coplen, 2017).

The need for safety culture improvement is also apparent in National Academies of Science evaluations of FAA oversight of emerging safety hazards -

> "AVS must consider the safety culture of the entities it oversees, including new entrants. This requires AVS to carefully consider their role and methods for monitoring safety culture, including how an organization's structure, policies and processes, and safety assurance methods, support continuous learning in support of safety. This also includes considering the culture appropriate for AVS to have within itself" (TRB, 2024, p. 27).

Attention to safety culture is in demand due to increased public interest, media reporting, and Congressional legislation (Aircraft Certification, Safety, and Accountability Act [ACSAA], Sections 108 and 132, 2020). The ACSAA, published in response to B737 MAX 8 accidents and ensuing concerns about safety culture across the aviation industry, requires the FAA to monitor safety culture within the agency and across regulated entities. Previous FAA-funded research has established mechanisms for assessing and monitoring safety culture of regulated entities (Worthington et al., 2023) and those providing regulatory oversight (Worthington et al., 2024). For example, researchers developed a novel way for inspectors to document safety culture concerns observed during routine surveillance and oversight activities (Worthington et al., 2023). Consequently, there is also a need for a framework and guidance on how to respond to identified safety culture concerns - in particular, to guide the regulatory workforce and regulated entities to implement and monitor scalable interventions aimed at improving upon any identified deficiencies.

One such framework is the *Harmonized Safety Culture Model* (HSCM) developed by the International Atomic Energy Agency (IAEA; 2020). Worthington et al. (2024) leveraged the HSCM as the backbone of their safety culture survey, which has now been successfully deployed year-over-year to benchmark and trend safety culture perceptions within the FAA workforce. The HSCM is composed of ten core traits, which have been identified as foundational dimensions of a positive safety culture and have a long-standing history within the nuclear industry (IAEA, 1991; Keefe et al., 2014). The traits have also been chosen by the Department of Transportation Safety Council for use in other modes of transportation (e.g., railroads; Morrow & Coplen, 2017).

Having identified HSCM as the foundation for safety culture assessment, the FAA must now implement a long-term strategy for sustaining cultural strengths and meaningfully improving upon areas of opportunity as they relate to the model. Thus, there is a need to identify and

evaluate the effectiveness of safety culture interventions for each core trait. This report aims to fill that gap, especially as it relates to safety culture interventions undertaken within regulated environments, such as the aviation industry, as well as within the regulatory bodies that provide oversight.

1.1. Purpose

The purpose of this report is to inform the FAA about evidence-based interventions to promote a positive safety culture. This report aims to operationalize safety culture promotion by summarizing effective interventions, ultimately empowering a long-term, data-driven strategy for safety culture improvement across regulators and the regulated entities they oversee. The report contains a summary of publicly available, peer-reviewed literature from 2001 to 2025. First, we provide an overview of safety culture efforts taken within regulated environments. Subsequently, we synthesize the safety culture interventions relating to the 10 traits of a positive safety culture per the HSCM (IAEA, 2020) and highlight factors that contribute to successful safety culture change. Table 1 includes a description of each trait. In instances where interventions were unsuccessful, we identify and share barriers to success as cautionary messages about what to avoid when embarking on safety culture change efforts. In addition to our synthesis, the report contains a brief list of effective safety culture interventions by safety culture trait (See Tables 2 and 3). The literature review draws on peer-reviewed research from interdisciplinary domains, including the safety, psychology, and management sciences. Finally, we present key lessons from the literature and offer recommendations for future efforts. This report should be referred to when considering appropriate interventions as they relate to each trait.

Table 1
IAEA Harmonized Safety Culture Model Traits and Definitions

Trait	Definition
Leadership Responsibility	Leaders demonstrate a commitment to safety via their decisions and behaviors. Leaders are seen as the role models for safety.
Individual Responsibility	Individuals at all levels are personally accountable for safety.
Communication	Communications support a focus on safety.
Questioning Attitude	Individuals remain vigilant regarding assumptions, anomalies, conditions, behaviors, and activities that can adversely impact safety.
Raising Concerns	Personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination.

Trait	Definition
Respectful Work Environment	Trust and respect are held throughout the organization.
Decision Making	Decisions are made systematically and are characterized by rigor, thoroughness, and prudency.
Continuous Learning	Learning is considered highly valuable.
Problem Identification and Resolution	Issues with the potential to impact safety are systematically identified, fully evaluated, and promptly resolved according to their level of risk.
Work Planning	Safety is maintained throughout the planning and controlling of work activities.

2. Method

We identified articles through two methods: 1) subject matter experts provided a subset of relevant articles, and 2) the lead author conducted a targeted Google Scholar search between December 2024 and January 2025 using combinations of the 10 IAEA dimensions and the following search terms: safety culture, safety culture intervention, safety culture change, safety management. We included articles for review when an article 1) was peer-reviewed, 2) was publicly available (i.e., open-access, available via authorized database), and 3) featured an organizational intervention intended to alter safety-specific outcomes aligned with one or more of the 10 IAEA dimensions. Next, the lead author organized each article and intervention by dimension and subsequently conferred with the second author until full agreement was reached regarding their categorization. Notably, we were unable to identify interventions relating to two of the IAEA dimensions: Questioning Attitude and Decision Making. We present a synthesis of our findings in the following sections.

3. Synthesis of Key Findings

The following sections begin with an overview of safety culture interventions implemented within regulatory environments, followed by a synthesis of the safety culture intervention literature as it relates to each HSCM trait.

3.1. Safety Culture Change in Regulated Environments

While sustainable safety culture improvements are challenging, they are worthy of long-term investment. Several government agencies, including the National Aeronautics and Space Administration (NASA), the Federal Railroad Administration (FRA), and notably the U.S. Nuclear

Regulatory Commission (NRC), have robust safety culture programs. The interventions are summarized in Table 2.

Table 2
Example Interventions in Regulated Environments

Example Interventions in Regulated Environments
• Awards and recognition for safe behavior (NASA, 2025) • Worker education and engagement (NASA, 2025) • Leadership development (Zuschlag et al., 2016) • Peer-to-peer feedback on unsafe behaviors (Zuschlag et al., 2016) • Analysis and resolution of safety issues (Zuschlag et al., 2016)

The NRC began investing significant effort to improve safety culture across the nuclear energy industry following the 1980 disaster at Chernobyl, where investigators suggested a “lack of safety culture” largely contributed to the event. As a result, key advances have been made – including the development of a common model of safety culture, harmonization with international regulators, and the publication of guidance material for both self- and inspector-led safety culture assessment (Cole et al., 2013; Keefe et al., 2014; IAEA, 2020).

Similarly, disasters such as the Columbia space shuttle’s disintegration motivated NASA to pursue safety culture improvements. Consequently, they established a sweeping safety culture program composed of regular safety culture assessments, awards and recognition for safe behavior, workforce education and engagement, and published guidance materials such as checklists, flyers, brochures, assessment guides, and more (NASA, 2025). Their program, now in its 16th year of implementation, offers hope that safety culture change is possible for both regulators and their regulated entities.

There is also evident interest in culture change within the Department of Defense (DOD). Gallagher (2022) examined the impact of leader behavior on culture and innovation in the DOD. The author conducted a secondary analysis of employee opinion data (i.e., Federal Employee Viewpoint Survey results) and held virtual focus groups with self-identified public leaders employed by the U.S. government. Findings suggested the DOD experienced significant cultural challenges resulting from leadership, including leadership turnover, shifting priorities, a general lack of accountability, personal agendas overriding the mission of the agency, a strict chain of command, and underlying competitiveness and mistrust. These leadership behaviors affected innovation, employee well-being, productivity, morale, engagement, and fueled an overall organizational resistance to change. To mitigate these challenges, focus group participants recommended raising awareness of organizational culture, ensuring leaders explain the reasoning behind their decisions, and improving communication flow throughout the organization. They also emphasized the importance of education and knowledge management,

leadership development strategies such as reverse mentoring, and the need to protect resources for strategic priorities. Other key recommendations included embracing diversity, encouraging humility and reducing ego-driven leadership, ensuring accountability and transparency to both internal and external stakeholders, and conducting a continuous skills inventory to address future staffing needs. A key is that leadership plays a critical role in shaping organizational culture and achieving strategic outcomes. The multifaceted nature of the recommendations illustrates that the leadership responsibility trait of safety culture aligns with others in the IAEA model. This suggests that a broad, multi-faceted approach to intervention and culture change is likely to be more effective than single-faceted efforts.

Looking beyond culture change internal to regulated environments, there is also evidence that regulatory actions can impact safety outcomes in regulated entities. Recently, regulators in the DOT have undertaken efforts to define, assess, and improve safety culture across the transportation sector (Morrow & Coplen, 2017; Kidda & Howarth, 2019). In the railroad industry, a regulator-sponsored intervention helped transform the organization's culture from one defined by punishment and reactivity to one embodying blame-free information exchange (Zuschlag et al., 2016). This intervention was multi-faceted, consisting of peer-to-peer feedback on unsafe behaviors, analysis and resolution of safety issues, and leadership development. Post-intervention analyses found an 80% reduction in at-risk behaviors and an 81% reduction in derailments and incidents following the intervention. The intervention also improved labor-management relations (i.e., perceptions of trust between leaders and workers). These promising results showcase how well-executed interventions conducted and sponsored by regulatory bodies can improve safety-related outcomes and safety culture perceptions.

Other research has sought to examine the role of the regulator in shaping the safety culture within regulated entities. A recent analysis of safety data from 70 countries revealed that airlines in countries with well-developed aviation infrastructure, stricter regulations, and legal enforcement exhibit better safety records (Khadivar et al., 2025). Studies across the nuclear and healthcare sectors have emphasized that effective regulatory relationships are marked by professionalism, transparency, and a balance between formal enforcement and informal interactions (Willis et al., 2023; Weenick et al., 2022; Barbour & Gill, 2017). Positive regulatory influence on organizational and safety culture requires balancing enforcement with fostering a learning environment (Weenick et al., 2022) and balancing questioning attitude with maintaining trust (Barbour & Gill, 2017). Together, these findings underscore that regulators play a pivotal role in shaping safety culture, not only through enforcement but by cultivating trust-based, learning-oriented relationships with the organizations they oversee.

3.2. Safety Culture Change in Industry

As with safety culture change in regulated environments, sustainable change has proven to be challenging but worthwhile across safety-critical industries. A list of effective intervention practices by trait is provided in Table 3. Appendix A further summarizes the interventions, including details on the interventions themselves, participant characteristics, industry context, outcomes, and limitations. Each intervention is described further in the section that follows.

Table 3

Interventions in Industry, Organized by Safety Culture Trait

Trait	Intervention
Leadership Responsibility	• Safety Specific Transformational Leadership (SSTL) training (Mullen & Kelloway, 2009) • Senior-management safety rounds (Bronkhorst et al., 2018) • Foundations of Safety Leadership OSHA module (Schwatka et al., 2019) • Leader-led goal setting and behavior modification (von Thiele Schwarz et al., 2016)
Individual Responsibility	• STAR Intervention: 1) Supervisor supportive practices training, 2) Behavioral tracking (Hammer et al., 2016) • Peer-to-peer safety observations (Pecillo, 2012) • Safety poster competitions (Williams, 2008) • Charity-based safety observation programs (Williams, 2008) • New employee mentoring (e.g., “buddy for a week”) (Williams, 2008) • Weekly safety topics (Nielsen et al., 2015) • Including safety as a standalone topic in staff meetings (Nielsen et al., 2015) • Employee safety project groups (Rasmussen et al., 2006) • Participatory action research integration (Rasmussen et al., 2006)
Communication	• Supervisor safety-based communication training (Kines et al., 2010; Zohar & Polachek, 2014) • Safety-specific messaging from executive leadership (Vecchio-Sadus, 2007) • Safety communication campaigns (i.e., (Dietl et al., 2023; Vecchio-Sadus, 2007) Team-based discussions to solicit employee input (Vecchio-Sadus, 2007)
Questioning Attitude	• No interventions identified.
Raising Concerns	• Video messaging from senior leadership expressing support for speaking up about safety (O'Donovan & McAuliffe, 2020)
Respectful Work Environment	• Conflict resolution training (Costello et al., 2011)
Decision Making	• No interventions identified.
Continuous Learning	• Data-based continuous improvement programs (Zuschlag et al., 2016) • Proactive safety leadership training (Zuschlag et al., 2016)
Problem Identification and Resolution	• Analyses and communication of accident patterns to workforce (Nielsen et al., 2006) • Obligatory minor incident and near-miss reporting. (Nielsen et al., 2006)
Work Planning	• Specific criteria for safety when planning new work (Saurin et al., 2004)

3.3. Leadership Responsibility

"Leaders demonstrate a commitment to safety via their decisions and behaviors. Leaders are seen as the role model for safety." (IAEA, 2020)

Taken together, leadership interventions that aim to modify specific behaviors are a powerful tool for improving organizational safety climate. Across the studies we reviewed, results demonstrate leadership responsibility for safety is not just a matter of policy; it is enacted through visible, consistent behaviors that shape how safety is prioritized, communicated, and reinforced throughout the organization.

3.3.1. Safety Specific Transformational Leadership (SSTL) Training

We found strong evidence that leadership responsibility, especially transformational leadership focused on safety, plays a critical role in shaping safety climate, employee behavior, and injury outcomes across industries. Multiple intervention studies show that training supervisors in safety-specific transformational leadership (SSTL) can improve safety participation, perceptions of management commitment, and safety climate.

In an oft-cited example, Mullen and Kelloway (2009) found that SSTL improved managers' safety attitudes and their intent to promote safety, with downstream effects on employee perceptions of leadership and safety climate. In their quasi-experimental study, healthcare organizations and their managers were assigned to one of three training interventions: 1) SSTL training, 2) general transformational leadership training, or 3) no training. In both training conditions, managers attended a half-day group-based training workshop. Both trainings included lectures, discussions, and goal-setting activities meant to increase management understanding of how to incorporate transformational leadership behaviors into their daily work. The primary difference between the training conditions was the type of transformational leadership (i.e., safety-specific versus general), and the type of goals managers were to set. For example, goals in the SSTL training condition included strategies such as providing feedback on safety performance and responding quickly to safety concerns. Following the intervention, managers who received the SSTL training displayed significantly higher safety attitudes, intentions to promote safety, and feelings of self-efficacy. Notably, employees reporting to managers receiving the SSTL training reported significantly higher safety climate ratings than those whose managers received no training, but not significantly higher than those who received general training. Taken together, these results suggest that SSTL training is an effective intervention for influencing leaders' safety attitudes. However, simply providing transformational leadership training to management may serve as a mechanism for indirectly influencing employee safety perceptions through their leaders.

In another study, Bronkhorst et al. (2018) implemented a six-month, quasi-experimental, and multi-level intervention within a healthcare organization. The intervention was divided into three thematic rounds (e.g., Physical Health and Safety, Psychological Health and Safety, and Organizational Conditions for Employee Health and Safety). Each round lasted two months and included 1) safety rounds performed by senior management, 2) SSTL training for supervisors, and 3) the use of an online discussion platform for employees to provide input on health and safety issues, followed by recurring team meetings to discuss the online results. Overall, the intervention group showed improved perceptions of safety climate and safety participation,

particularly when supervisors demonstrated visible support, reinforcing the role of frontline leadership in implementation success. However, given the multi-level nature of the intervention, the impacts of SSTL could not be isolated in this study.

Among twenty construction companies, Schwatka et al. (2019) evaluated a 2.5-hour Foundations for Safety Leadership (FSL) training program. The FSL training included materials on the direct and indirect costs of poor safety leadership, the benefits of proper leadership, and how to incorporate five safety leadership skills on the jobsite. Modeled after SSTL, the five FSL skills included leading by example, engaging and empowering team members, providing development for team members via coaching and feedback, active listening and communication, and providing recognition for safety performance. Following the intervention, supervisors from companies that received the training reported a greater understanding of safety leadership skills and increased intended use of safety practices at both 2 and 4 weeks post-intervention. However, these gains did not translate into measurable changes in worker outcomes. Additionally, considering the study did not measure supervisors' actual behavior, these results may only be interpreted as they relate to improvements in leaders' understanding and intent.

3.3.2. Safety Governance

Other studies reinforce the role of leadership at the highest level of the organization. Tucker et al. (2016) found that chief executive officers (CEOs) can indirectly influence frontline injuries through a cascade of safety climate perceptions, from top management to supervisors to employees. While no intervention was conducted, the researchers collected safety climate perceptions from 54 organizations. Analyses showed that when top management teams (e.g., chief officers) demonstrate a strong priority for safety, supervisors within the organization also demonstrate a higher level of support for safety. Consequently, employees in those organizations report significantly fewer work-related injuries. With this study, the authors provide evidence for a new perspective that suggests CEOs indirectly influence frontline safety by cultivating a safety climate within the top management team, which then cascades through the organization and relies on collective engagement and action across different organizational levels.

Likewise, Khadivar et al. (2025) examined the critical role of corporate governance and leadership in aviation safety, emphasizing how board and CEO characteristics influence airline accident rates. Using data from 70 countries between 1990 and 2016, the research analyzed how factors such as board qualifications, CEO tenure, and director workload impact an airline's safety performance. In addition, the study explored how national regulatory environments and air transport infrastructure investments contribute to overall aviation safety. The study found a strong relationship between corporate leadership and airline safety. Airlines with more qualified board members had fewer accidents, while airlines with overburdened directors and frequent leadership changes experienced higher accident rates. CEO tenure was a particularly strong predictor of safety performance, with longer-serving CEOs associated with fewer accidents. Additionally, airlines based in countries with strong legal enforcement, stringent regulations, and well-developed aviation infrastructure exhibited better safety records. These findings highlight the importance of experienced and stable leadership in airline safety management.

3.3.3. Behavior-Based Leadership Interventions

We found additional evidence supporting the use of interventions that target supervisory feedback behavior, especially rewarding workers' safety performance. Zohar (2002) presents a quasi-experimental study evaluating a leadership-based intervention designed to modify supervisory monitoring and recognition behaviors. Per the intervention, researchers provided experimental-group supervisors with feedback related to the percentage of safety-related versus general interaction with subordinates they engaged in throughout the work week. In addition, section managers continuously communicated a high prioritization of safety to the supervisors. Following the 8-week intervention, supervisors demonstrated significantly more safety-based interactions with their subordinates, increasing from a 9% baseline to a new plateauing average of 58%, which remained up to 5 months after the intervention. Notably, there was an increase in employee safety performance as demonstrated via a sharp increase in earplug usage from an initial 25% to a plateau average of 73%, which remained 5 months after the intervention. The experimental group also demonstrated a significant increase in safety climate perceptions and a significant decrease in occupational injuries post-intervention. No changes in safety climate were noted in the control group, and there was a significant increase in occupational injuries in the control group post-intervention. Overall, Zohar (2002) shows that weekly feedback regarding supervisors' safety-oriented interactions can significantly increase safety behavior, decrease accidents and injuries, and improve safety climate.

Likewise, von Thiele Schwarz et al. (2016) found that combining leadership training with applied behavior analysis can enhance safety climate and productivity, particularly when managers select safety as a focus area for their leadership development. The authors deployed a multi-method intervention among managers within a forest industry company in Sweden. All managers were invited to participate. Measures were taken pre- and post-intervention to include employee ratings of safety climate and productivity, and manager self-ratings of leadership behavior, self-efficacy, and intervention effectiveness. The intervention began with a 360-degree evaluation of each participating manager's respective leadership behaviors and included associated feedback. Following the evaluation, participating managers engaged in a 14-day lecture-based course providing a summary of applied behavioral analyses and various leadership theories, including transformational leadership. During the final phase of the intervention, participating managers engaged in applied behavior analysis by identifying improvement areas and were to subsequently apply knowledge gained from the course to generate improvements in their chosen area. For example, one manager chose to focus on improving information-sharing and safety-reporting systems within their work unit. This phase of the intervention also included six full-day sessions in which participating managers received feedback and practical support on their chosen improvement project, as well as internal follow-up meetings to track progress.

Following the intervention, analyses revealed significant improvement in employee perceptions of safety climate actions and expectations, suggesting employees observed increased manager safety behavior and, in turn, increased expectation for safe behavior (von Thiele Schwarz et al., 2016). Additionally, participating managers' self-ratings of transformational leadership behaviors increased significantly post-intervention, with a greater likelihood of rewarding safe behavior and stopping others when observing unsafe actions. Notably, 32% of employees and 79% of

managers reported that safety improvements were due to the intervention. Moreover, 14% of employees and 59% of managers reported that the leadership training intervention increased productivity.

3.3.4. Leader Visibility

Among the other articles we reviewed, some studies demonstrate the importance of interventions that target leadership visibility. For example, Morello et al. (2013) conducted a systematic review of strategies to enhance patient safety culture in hospitals, identifying six key interventions. Those with the strongest evidence included leadership walk-arounds and unit-based programs, though their success depended on context, organizational support, and implementation structure. While high staff turnover and visibility challenges may limit the practicality of leadership walk-arounds, unit-based programs may be more adaptable. Given the cost of these interventions, organizations must validate strategies within their specific settings to ensure effectiveness and sustainability.

3.4. Individual Responsibility

"Individuals at all levels are personally accountable for safety." (IAEA, 2020)

We discovered consistent evidence that workplace interventions can promote individual responsibility for safety. Across controlled trials and case studies, interventions that empower employees to monitor behavior, identify hazards, and engage in corrective actions demonstrated positive outcomes in both safety performance and cultural indicators (Hammer et al., 2016; Nielsen, 2014; Pecillo, 2012; Reader et al., 2017; Williams, 2008).

3.4.1. Support for Employee Non-Work Life

The STAR (Support Transform Achieve Results) intervention was used to train supervisors to support employees' work-life balance while maintaining performance expectations (Hammer et al., 2016). The goal of their study was to examine the effect of an intervention that sought to reduce work-family conflict (i.e., stress resulting from incompatible demands between work and family roles) on safety compliance among nursing home employees. The intervention consisted of supervisor training on strategies for supporting personnel and their families while maintaining work performance. Results showed that the intervention resulted in a significant increase in safety compliance at 6 months, but not at 12 months, when compared to baseline. This study demonstrates that organizational interventions targeting employee work-life support and job control can contribute to an environment that is conducive to improved safety compliance and employee helping behaviors.

Correlational findings also reinforce the connection between perceived organizational support and employee-driven safety behaviors. In the oil and gas sector, Reader et al. (2017) found that company investment in organizational health activities was linked to improved employee perceptions related to health support. Perceived organizational support was also correlated with support for personal health, stress, and healthy eating. Additionally, perceptions of organizational commitment were tied to greater support, safety citizenship, and employee health. Like Hammer and colleagues (2016), these results demonstrate that providing support for employees' personal lives can lead to improved safety and employee helping behaviors.

3.4.2. Integrating Employees in Intervention Efforts

Among several case studies, we found sufficient evidence to suggest that directly involving employees in identifying and correcting unsafe behavior can build personal accountability.

In a well-cited example, Rasmussen and colleagues (2006) took a participatory action research (PAR) approach to generating safety culture change in two Danish plants. PAR approaches typically integrate employees at each stage of the change process. Rasmussen's team believed that greater employee integration in important organizational matters was a foundational component to improving safety culture and climate. In their quasi-experimental study, they coordinated twelve working groups, each of which took responsibility for designing and implementing safety projects that directly aligned with the plants' priorities and available resources. Project topics included personal protective equipment (PPE) procurement, recording safety videos, conducting safety rounds, and streamlining accident and injury registration systems, among others. Each group included two workers, two supervisors, and at least one researcher. The researchers' roles included conducting observations of the work environment and coaching managers and workers throughout the change process. Each group's project underwent a feasibility assessment prior to plant-wide implementation in collaboration with the company's safety committees and environmental departments.

The researchers assessed change outcomes via in-depth interviews and focus groups that included personnel from all levels of the company (Rasmussen et al., 2006). These efforts were performed throughout the entirety of the intervention to evaluate change perceptions over time. In addition, they conducted surveys pre- and post-intervention with participants from the project groups, and post-intervention surveys with all other personnel. Generally, these efforts demonstrated significant positive changes in safety culture perceptions post intervention, and support Rasmussen and colleagues' assumption that greater worker involvement would lead to improved safety culture change. Of equal importance is the collaboration between the plant personnel and researchers with expertise in safety culture change. This component corresponds with the notion that meaningful safety culture improvements are unlikely without the use of evidence-based change management practices.

In Nielsen and colleagues (2015), a Danish industrial plant implementing a multi-method safety intervention saw wide-scale improvements in worker safety participation. Prior to implementation, the organization collected workforce feedback via surveys and employee interviews. Taking employee input into consideration, the intervention was designed to increase the quality and quantity of safety interactions within the company via a series of pre-planned and feedback-informed activities. Pre-planned activities primarily focused on the design and function of the HSO, while the feedback-informed activities directly targeted workforce information sharing and participation. Examples of the feedback-informed activities included a) weekly safety topics, b) safety-specific bulletin boards, c) inclusion of safety information at council meetings, d) safety-specific messaging from senior leadership, e) including safety in staff meetings, and f) a column on safety within the staff magazine. Following the intervention, the organization collected a second round of workforce perceptions via survey. Survey results indicated significant improvements in perceptions of worker involvement in safety and in safety interactions between workers and their supervisors post-intervention. Notably, an analysis of

safety performance data showed a decrease in lost-time injury rates following the intervention, though the difference was not statistically significant.

In another case study, Pecillo (2012) found that behavioral observation programs led by workers in Polish companies, paired with regular meetings to develop preventive and corrective measures, improved both safety practices and employee well-being. Specifically, workers and supervisors were trained on how to conduct behavioral observations to identify unsafe behaviors, and subsequently, both groups performed observations within their work site. Following the observations, meetings were held between workers and their supervisors where they worked together to identify various causes of the unsafe behaviors observed and form proposals for corrective actions. Post-intervention improvements in both workforce perceptions of safety culture and employee quality of life, as well as a reduction in cases of unsafe behavior, suggest that including the workforce in the behavioral intervention helped to reinforce individual accountability for safety.

Within the context of aviation, peer-to-peer observations such as Line Observation Safety Audits (LOSA) have been deployed with great success (Klinect et al., 1999; Ma et al., 2011; ICAO, 2002. In LOSA programs, observations conducted by well-trained workers provide an unparalleled way for organizations to collect data about operations – both what is working well and what is not. Observers document and provide corrective feedback when a threat, error, or procedural deviation is observed. Exemplary behavior is also documented, which can be used for subsequent training and development. That, combined with the anonymous, nonpunitive nature of the observations and feedback, lends to the success of LOSA programs.

Finally, Williams (2008) discussed recommended practices for increasing employee engagement in safety programs, including behavior-based safety (BBS). Williams emphasized hiring conscientious employees, providing effective training, and encouraging corrective feedback. Williams also provided examples of applied practices that had been shown to effectively increase safety participation, such as safety poster contests, charity-linked peer-to-peer observation programs, and wellness initiatives. Other effective practices include a focus on mentoring new employees, such as a “buddy for a week” program, which has been shown to increase job-specific knowledge sharing, and hands-on training opportunities for new employees. Williams highlighted the importance of mentorship in preventing workplace injuries, especially among new employees. Finally, the author briefly outlined effective feedback practice and suggested that praise for safe behavior is critical to improving safety culture and reinforcing future safe practices.

When giving corrective feedback, Williams suggests:

- “Deliver it one-on-one and right away.”
- “Focus on the specific behavior observed and avoid making it personal.”
- “Rather than lecture, ask questions to facilitate the discussion.”
- “Show genuine concern for the other person’s feelings and well-being.”
- “Work together to find better solutions.”
- “Thank the person for listening.”

When receiving feedback, he notes:

- “Listen actively.”
- “Be objective, not defensive. Remain open and receptive.”
- “Accept feedback without resentment.”
- “Clarify the future desired behavior with the speaker.”
- “Express commitment to conduct the desired behavior in the future.”
- “Thank the person for providing feedback.”

Taken together, Williams’ commentary and the reviewed case studies provide compelling evidence that interventions emphasizing worker participation, personal control, and reciprocal organizational support help build a culture where individual responsibility for safety is the norm. However, as some authors note, tailoring interventions to the industry context and reinforcing behavior over time is essential for sustained change.

3.5. Communication

“Communications support a focus on safety.” (IAEA, 2020)

When it comes to safety-communication, we found successful interventions to be those that targeted supervisory and management safety-based communication, peer-to-peer feedback, behavioral observations, and organizational-wide approaches to safety culture improvement.

3.5.1. Supervisor Safety-Based Communication Training

There is clear evidence in the literature that training supervisors to improve safety-specific communication is an effective intervention. In Kines and colleagues’ (2010) study, construction foremen were coached by members of the research team on including safety issues in their daily verbal exchanges with front-line workers. Foremen were given biweekly feedback related to the percentage of their safety-related communications with subordinates as compared to all other communications. Additionally, the research team performed weekly walkarounds at the supervisors' worksites to observe working conditions and behaviors, and collected worker perceptions via a safety climate survey. Post-intervention results indicated significant increases in the amount of safety-related content discussed by supervisors who received the training as compared to a control group. Increases of up to 56% in safety-related discussions from baseline to follow-up were observed among supervisors receiving the intervention. Notably, improvements in safety-based discussions did not negatively impact communications about production. The intervention also resulted in significant increases in safety performance and physical safety measures. Survey results also indicated improvements in perceptions of worker attention to safety among the intervention group. These results highlight a critical phenomenon wherein safety can be prioritized in workforce communications without sacrificing productivity.

In a similar study within a metal fabrication plant, Zohar and Polachek (2014) implemented a 12-week quasi-experimental intervention meant to modify supervisors’ daily communication behaviors. Supervisors in the experimental group attended two feedback sessions provided 6 weeks apart, where they received feedback data that had been anonymously collected from the workforce related to three topics: 1) safety and reliability, 2) speed and efficiency, and 3) team communication. Facilitators of these feedback sessions helped supervisors interpret the feedback data and set informal goals for future communication exchanges. Correspondingly,

pre- and post-intervention questionnaires were given to the workforce to evaluate worker perceptions of safety climate, safety behavior, workload, teamwork, and corrective leadership. Safety audits were also performed pre- and post-intervention by two external safety consultants. Following the intervention, results revealed significant improvements in worker perceptions of safety climate, safety behavior, workload, and teamwork, as well as externally conducted safety audit scores. Except for perceptions of safety behavior, these results were observed only in the experimental group and thus provide direct evidence that efforts to modify supervisory communication behaviors based on worker feedback can positively impact workforce safety perceptions and behavior.

The authors note that while their intervention covered a wide span of feedback topics, future interventions should be tailored to the respective industry or the organization, especially as it relates to specific work demands, familiar terminology, and communication styles. Also note that in each of these studies (Kines et al., 2010; Zohar & Polachek, 2014), the intervention periods were lengthy, at 12-16 weeks, suggesting it may take time for interventions to successfully change behavior. Kines et al. cautioned that “long-term behavioral change maintenance is a constant challenge” (p. 404) as safety climate culture change takes time. More recently, Zohar and Polachek (2014) added that “changes in the content of (received) supervisory messages or role expectations must remain stable and consistent, offering sufficient opportunities for group members to experience and validate it as a real (rather than espoused) change in supervisory role expectations” (p. 115). We interpret these statements as critical reminders that safety culture change requires consistency and time, especially when attempting to change deeply rooted norms surrounding communication.

3.5.2. Safety Communication Campaign

In the case studies reviewed, we found limited evidence supporting the effectiveness of communication campaigns and interpersonal communication interventions. In one case study, after an interpersonal communication intervention among interdisciplinary health care teams, participants perceived significantly lower patient safety risks but did not perceive changes in communication, psychological safety, or team performance (Dietl et al., 2023). However, teams that had higher baseline levels of psychological safety indicated improved communication post-intervention. These results suggest the intervention used in their study may be best suited for well-integrated teams.

Another case study employed a communication campaign targeting management and front-line employees (Vecchio-Sadus, 2007). The intervention involved a multi-method approach which included 1) a video message placed on the organization’s intranet from the chief executive reinforcing the message that “safety always comes first”, 2) communication training for management and supervisors, 3) team-based discussions with all employees and their managers on topics related to working safely, asking for help, providing feedback, and working in teams, 4) development of campaign posters with messages gathered from the team-based discussions, and 5) integration of employee input from the team-based discussions into the organizations health, safety, and environment (HSE) management system. Post-campaign, the organization noted improvements in injury statistics, including fewer lost-time injuries and fewer compensation claims, and increased participation in safety programs. Workers also reported improved safety satisfaction on the company’s insight poll.

This case study demonstrates the value of involving personnel at all levels in safety interventions. Additionally, the author (Vecchio-Sadus, 2007) recommends improving safety communication in the workplace by (a) defining goals clearly in writing, (b) identifying appropriate lines of communication with managers and employees, (c) responding to instruction or enquiries promptly and appropriately, (d) developing effective questioning and speaking skills to gather and convey information, (e) speaking in the language of the person with whom you are communicating, (f) increasing listening skills, and (g) giving feedback. These recommendations should be considered when designing interventions targeting safety communication.

Lastly, there is an important limitation to note across both case studies. In both cases, the intervention was conducted as part of a larger improvement effort, which confounds the results and makes it impossible to discern whether the communication interventions were the real driver of improvements. However, we present these efforts in text and in Table 2 because they align with best practices in change management (Rousseau & ten Have, 2022).

3.6. Questioning Attitude

"Individuals remain vigilant regarding assumptions, anomalies, conditions, behaviors, and activities that can adversely impact safety." (IAEA, 2020)

We did not identify interventions specifically related to the core trait of Questioning Attitude. However, Hardy (2012) summarized 8 accidents and incidents related to cybersecurity system safety to illustrate the importance of ensuring management asks critical questions throughout the system safety process. The author suggested management should have a questioning attitude regarding the software element of system safety to include: (a) avoiding oversimplifying potential hazard causes; (b) not downplaying uncertainties, especially with likelihoods; (c) paying attention to not self-censor, especially with respect to hazard controls; (d) providing alternatives, but discussing the risk-tradeoffs; (e) discussing the limitations of testing and verification efforts; (f) being clear about the effects of failures and changes during development and the potential for increased risk; and (g) using accidents and incidents to provide support for safety conclusions.

3.7. Raising Concerns

"Personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination." (IAEA, 2020)

We found qualitative and experimental evidence in support of interventions that promote environments where employees feel safe raising concerns. However, studies of applied interventions are less prevalent. The literature that does exist suggests the effectiveness of interventions in this domain is likely to vary by approach, context, and the presence of leadership behaviors that support psychological safety and reduce fear of blame.

A systematic review by O'Donovan and McAuliffe (2020) found mixed results across 14 intervention studies aimed at improving psychological safety and speaking up in healthcare teams. Educational strategies alone often failed to change behavior, whereas those including leader participation showed more promise. The authors noted, "Educational interventions identified challenges related to changing deeply rooted speaking up behaviours and questioned

whether education alone is sufficient. Implementation science literature suggests that education alone is insufficient for changing behaviour and that it is necessary to have a context which is receptive to change and appropriate facilitation" (O'Donovan and McAuliffe, 2020, p. 6). Notably, interventions that used video messages from senior staff expressing support led to improved attitudes and behavior around speaking up, suggesting leadership modeling is a critical factor.

In another example, Leroy et al. (2012) explored the link between leadership integrity, psychologically safe work environments, team safety values, and willingness to speak up about errors in hospital nursing teams. Although no intervention was tested, this team-level analysis revealed that leader behavioral integrity for safety (e.g., practicing what one preaches) was significantly associated with increased team-level psychological safety and a stronger team-wide prioritization of safety. These factors, in turn, predicted lower treatment error rates. The effect of psychological safety on error reporting was complex. Specifically, teams that were more psychologically safe were more likely to report treatment errors and thus reflected a higher number of treatment errors overall. However, when teams were both high in psychological safety and prioritization of safety, there was a sharp decrease in the number of treatment errors reported, suggesting that the prioritization of safety led to fewer errors within the team. Conversely, teams low in psychological safety reported the same number of errors regardless of team-wide prioritization of safety. Ultimately, this study reflects the importance of leaders' behavioral integrity in establishing strong levels of team psychological safety and error reporting, as well as in reducing error rates among their teams. The study underscores how consistent, value-driven leadership behavior can shape respectful team dynamics, reduce fear, and improve communication around mistakes.

Together, these findings show that effective environments for raising concerns rely on reducing fear of blame, clarifying accountability, and encouraging leader behaviors that actively support open dialogue. Interventions should go beyond training to embed speaking up as a shared, supported, and expected part of organizational culture.

3.7.1. Regulatory Influence on Worker Voice

Although fostering an environment for raising concerns within organizational boundaries is essential, other environmental factors are worth noting – national culture, political factors, and regulatory standards. For example, Khadivar et al. (2025)'s analysis of safety data from 70 countries revealed that airlines in countries with well-developed aviation infrastructure exhibit better safety records.

Likewise, other studies have examined perceptions of the influence that individual members of regulatory bodies (e.g., inspectors) can have in shaping the culture of regulated entities. Though these studies did not test interventions, they do illustrate the role of the regulator on regulated entities' culture. For example, Barbour and Gill (2017) examined the role of questioning as a regulatory work practice within nuclear power plant oversight, highlighting how inspectors use questions to maintain safety and reliability. Through interviews (N=29) and shadowing at six nuclear power plants and a regional office of the U.S. Nuclear Regulatory Commission, the authors identified three primary questioning practices: a) interrogating an issue, b) coordinating interactions, and c) tracking regulatory concerns. The authors suggest questioning is a central mechanism for information gathering, coordination, and decision-making, but can also present

challenges, such as the risk of redundancy, undermining trust, or overwhelming the process with excessive inquiry.

In another study, Weenink et al. (2022) explored the role of regulators in enabling a just culture within healthcare organizations, such as mental health services and hospital care. Through a combination of interviews, focus groups, and observations across five organizations and the Dutch Health and Youth Care Inspectorate, the authors found that while regulators can act as catalysts for learning and improvement, their presence often creates fear and hesitancy among healthcare professionals due to concerns over accountability and potential sanctions. Their study concludes with three primary recommendations for regulators: a) recognize the influence of regulation, stakeholders, and policies on just culture, b) adopt procedures that support reflection and learning rather than punitive measures, and c) consistently reflect on the dual roles of coaching and policing strategies as inspectors.

Finally, Willis et al. (2023) explored how regulatory authorities influence safety culture in high-risk industries via a case study in the nuclear sector. Through interviews with inspectors from a nuclear regulator, employees from regulated nuclear organizations, and analysis of regulatory documents, the study found that regulators operate in three key roles: a) as enforcers ensuring compliance, b) as partners fostering collaboration beyond minimum standards, and c) as advisors providing guidance. Their qualitative study highlights that regulators facilitate self-development among regulated organizations and can exert implicit influence by modeling strong safety cultures themselves.

This research highlights that a just culture is relational and layered, requiring mutual trust between regulators and healthcare organizations. Inspectors struggle with balancing enforcement and fostering a learning environment, as well as managing the external pressures of media scrutiny and legal accountability. Effective regulatory relationships are marked by professionalism, transparency, and a balance between formal enforcement and informal interactions.

3.8. Respectful Work Environment

"Trust and respect are held throughout the organization." (IAEA, 2020)

We found evidence that respectful workplace interventions, particularly those that target leadership behavior, structured team processes, and shared norms, can improve psychological safety and team functioning in high-stress environments like health care and construction. However, findings are mixed, and successful implementation appears to depend heavily on leadership engagement, employee participation, and organizational context.

Costello et al. (2011) describe a multi-year initiative to improve respect in hospital operating rooms (OR) following low staff survey scores across two ORs. The deployed intervention was constructed based on supplementary employee input via a tailored respect survey. The intervention included 1) development and implementation of an OR charter which set standards for communication, teamwork, and supporting a respectful environment, 2) a full-day conflict resolution training for management including activities such as self-assessment, role play, and coaching simulations, 3) creation of a resolution process defining both team member and leader responsibilities and a step-by-step guide for resolving interpersonal conflicts, and 4) a full-day

course for staff members focusing on effective communication under pressure including topics such as self-management and approaches for resolving conflict. Evaluation of pre- and post-intervention staff survey scores showed improvements of 20% or more in the areas of respect, teamwork, and communication. In one of the two ORs, scores in each area increased by more than 40%. This study demonstrates that long-term improvements in respectful behavior can be achieved through simultaneous cultural, procedural, and educational interventions. However, because the authors relied on the hospital's annual general opinion survey to assess improvement post-intervention, it is difficult to attribute these improvements to any single element of the intervention.

Collectively, these findings suggest that promoting a respectful work environment depends not just on policies or training, but on visible, consistent leadership behaviors and team-level trust. While structured interventions may improve clarity and reduce friction, sustainable change requires alignment across leadership, process, and cultural expectations.

3.9. Decision Making

"Decisions are made systematically, and are characterized by rigor, thoroughness, and prudency." (IAEA, 2020)

While we did not identify any safety culture interventions specific to decision-making, some literature provides insights into the conditions necessary for effective decision-making. For example, McCall and Pruchnicki (2017) examined how blurred lines of accountability (e.g., hierarchical, legal, professional, and political) can impact decision-making in high-consequence environments. Their case study of Swissair Flight 111 highlighted how a rigid, punitive culture discouraged deviation from procedures, even when professional judgment suggested a faster emergency landing could be achieved by deviating. The authors argue that a just culture requires allowing employees to explain decisions and contribute to future risk mitigation, which helps shift from blame to learning.

3.10. Continuous Learning

"Learning is considered highly valuable." (IAEA, 2020)

Current research indicates that fostering continuous learning in safety-critical environments may be best attained when interventions include system-wide feedback mechanisms and contextualized training. When organizations create space for peer learning, adaptive feedback, and leader accountability, safety outcomes and safety culture tend to improve.

3.10.1. System-Wide Methods for Continuous Improvement

Zuschlag et al. (2016) detail the implementation and evaluation of a multi-year pilot demonstration of a Clear Signal for Action (CSA) program within a transportation department of the Union Pacific Railroad (UP). Prior to the intervention, the safety culture of the rail industry could be characterized by a strict chain of command, reactive tendencies, and punishment for accidents and injuries. Thus, a key aim of the intervention was to create an environment where blame-free information exchange could occur.

The CSA intervention integrates three components 1) peer-to-peer feedback where workers take turns performing work observations and exchange feedback on the safety of their behaviors using checklists of safe and at-risk work behaviors, 2) continuous improvement, in which workers and managers gather and analyze data to identify system-wide causes of at-risk behaviors and conditions and collaboratively implement corrective actions to address them, and 3) safety-leadership development where managers are trained to promote safety practices via non-disciplinary techniques and safety-related activities.

To implement the intervention, local managers and workers, as well as their unions, were required to work together. Two full-time facilitators were selected from among union personnel. Additionally, a steering committee of eight additional workers was assigned to meet approximately once a month and serve as co-facilitators. One service-unit manager was recruited part-time to act as chief liaison between the steering committee and UP management. Notably, the intervention was customized to fit within the local context and regulatory environment. Both qualitative and quantitative approaches were used to measure intervention outcomes, including open-ended interviews with workers and managers, peer-to-peer feedback session data, corporate safety data provided by UP, and closed-ended attitude and behavior surveys of workers and managers.

Overall, data from the feedback sessions and questionnaires indicated improvement in worker safety practices following the CSA intervention. Data from the peer-to-peer feedback sessions also showed drastic improvement with an 80% decrease in at-risk behaviors. Notably, post-intervention corporate safety data indicated an 81% reduction in derailments and incidents. Finally, the survey results indicated a significant improvement in perceptions of trust between workers and their leaders.

This program's success highlights how structured feedback loops and frontline engagement foster learning and performance improvements. It is notable that the CSA program was initiated after a series of high-profile safety events, but within an industry with an already strong safety record. The authors note that high levels of safety may be considered a prerequisite for implementing programs like CSA to further improve safety.

It is important to note that a similar intervention deployed at an Amtrak railroad location was unsuccessful in generating safety culture change. In this case, a major barrier to effective change was that the company's supervisors and managers were intentionally excluded from the intervention steering committee. Lacking appropriate insight from their managers, employees experienced ambiguity about who was leading the program and whom to contact regarding safety issues. Other prominent issues included low overall participation by the steering committee. Further complicating matters, the intervention lacked measurable performance goals, struggled to engage employees, lacked accountability structures for unsafe behaviors, did not set targets for tracking progress, and offered employees no reasonable incentive to participate in the intervention (Nævestad et al., 2018). The sweeping nature of these challenges demonstrates the complexity of culture change and the myriad factors that can help or hinder success.

3.10.2. Context Driven Training and Development

In Harvey and colleagues' (2001) study in the nuclear regulatory setting, training was found to be ineffective at changing safety attitudes when employees were not involved in the development of training themes or content. The authors evaluated the effects of a workshop-based intervention within a nuclear processing plant. Employees at all levels attended a one-day training workshop with their immediate workgroup. The purpose of the workshop was to raise awareness of safety issues and safety behaviors and provide an opportunity to solicit feedback on what was going "right or wrong" within their work unit. Following the workshop, teams were provided a summary of the feedback and recommendations for improvement, and the same central body monitored progress against each issue. Ultimately, the training was only effective in changing safety attitudes among leadership and higher-pay-grade employees. The authors speculated these results were due to differences in perceived ownership: the training was initiated by management (with considerable cost involved), and the trainers were appointed by management. Additionally, the solutions chosen for each workgroup's concerns were not collaboratively developed. The authors state, "Training to change attitudes and safety culture must be carefully designed to take into account the complex nature of risk and perception of risk, the need to involve the employees and reduce the possibility of 'latent' failures" (Harvey et al., 2001, p. 622). Similarly, interviews with experienced safety trainers reveal that training initiated by workers, rather than imposed by management, is more practically relevant and likely to be applied (Pilbeam & Karanikas, 2023). Learning thrives in systems that recognize the value of employee insight and cultivate opportunities to reflect, adapt, and improve (Edwards, 2017).

3.11. Problem Identification and Resolution

"Issues with the potential to impact safety are systematically identified, fully evaluated, and promptly resolved according to their level of risk." (IAEA, 2020)

We found growing evidence that structured problem identification and resolution processes, when supported by leadership and employee involvement, can improve safety outcomes and organizational leadership.

Nielsen et al. (2006) evaluated a new incident reporting scheme at two industrial plants. The reporting scheme was structured such that employees were obligated not only to report lost-time incidents, but also near misses and minor incidents. In addition, modifications were made to the reporting system such that incident reports were continuously analyzed and information about accident patterns was shared with workers by their supervisors on a recurring basis. These accident patterns were also used by the plant safety committee to develop preventative measures. Following the introduction of the new reporting scheme in both plants, only the plant with strong leadership commitment demonstrated improvement. Within this plant, there was an overall increase in the number of minor incidents and near misses reported, suggesting that highlighting the importance of these reports via obligation rather than suggestion was effective in increasing reporting behavior. There was also an overall decrease in the number of lost-time injury reports, indicating that supervisor communication of accident patterns and subsequent preventative measures were influential in reducing the prevalence of serious accidents among the plants. These findings underscore the importance of top management commitment to safety,

the use of clearly defined incident reporting, and the integration of accident patterns within preventative measures to prevent occupational incidents.

In a multi-case study, Nielsen et al. (2015) found mixed results when introducing a 26-week intervention that included workshops on identifying and solving safety issues, worker-supervisor problem-solving for baseline safety issues, and safety management and leadership, followed by individual coaching sessions for supervisors to drive culture change. One site showed great improvements in leadership, safety behaviors, and problem-solving outcomes, while another saw no change. The key difference appeared to be implementation quality, with the site that showed the most improvement having better participation, supervisor involvement, and follow-through on actions. Thus, sustainable culture improvements require both structured processes and leadership buy-in.

Altogether, these studies demonstrate that identifying and resolving safety problems requires more than collecting data; it also depends on leadership engagement, structured analysis, and mechanisms that motivate participation and follow-through. When these elements align, organizations are better positioned to turn safety events into learning opportunities.

3.12. Work Planning

"Safety is maintained throughout the planning and controlling of work activities." (IAEA, 2020)

We found evidence that integrating safety into work planning processes can improve safety outcomes, though effects depend on how planning is executed and perceived by the workforce.

Saurin et al. (2004) reported positive outcomes from a safety planning and control (SPC) model that integrated safety into production planning in Brazilian construction projects. Weekly and daily planning meetings included safety constraints, and worker feedback informed hazard controls and process improvements. This research defined a work package as a unit of work that meets specific quality criteria (definition, soundness, sequence, size, and learning) before being assigned, ensuring that safety and production plans are properly evaluated and executed. Results showed increasing reliability in both production and safety planning over time, with safe work packages exceeding 80%. No clear correlation was found between safety and production outcomes, indicating that both must be managed distinctly, even when integrated procedurally. An extension of this model by Saurin et al. (2005) across five sites further emphasized management's role in planning failures that led to unsafe conditions. Most safety failures were due to violations, often stemming from a lack of safeguards or PPE. A targeted near-miss intervention at one site increased reporting and awareness. However, the SPC model was less effective in addressing violations, likely because it focused on managerial planning rather than worker behavior or individual risk perception.

Pousette and Törner (2016) evaluated a training-based intervention to implement structured work preparation meetings on Swedish construction sites. Three of six worksites received a four-hour education in planning structured work preparation meetings for workers at various worksites. Contrary to expectations, safety climate and perceived influence at work *decreased* at worksites that received the intervention, while comparison sites saw improvement. The authors suggest that workers may have interpreted the meetings as management efforts to improve efficiency, not as a genuine concern for safety. It is important to note that two of the

three intervention sites reported recent worker layoffs and management changes. Thus, these results align with the broader body of literature and highlight that work planning interventions must be backed by visible, credible leadership commitment to safety and by a work environment conducive to intervention, not just by procedural changes.

Taken collectively, these studies suggest that integrating safety into planning processes holds promise but must be implemented with attention to worker perceptions, organizational priorities, and the balance between managerial control and frontline engagement. Without clear signals that safety is prioritized over efficiency, planning efforts may be viewed with skepticism or fail to influence behavior.

4. Discussion

Safety culture improvement requires deliberate effort at all levels of an organization. For this reason, many improvement efforts are unsuccessful – often facing barriers such as competing organizational priorities, limited leadership commitment, and employee resistance to change (Blackburn et al., 2011). To address these challenges, there is a need for an evidence-based approach to safety culture change that is both practical and intentional. Key components should include a foundational assessment of organizational conditions followed by the development and integration of tailored interventions and continuous measures to track and maintain change efforts (Key et al., 2023). In doing so, aviation practitioners must exercise caution and ensure intervention methods are shaped by well-established, evidence-based practices.

We conducted this literature review in direct response to these needs. Our review examined the safety, psychological, and organizational sciences to identify effective safety culture interventions that the aviation industry can use to improve safety culture. In the following section, we provide and discuss recommendations for applied interventions within the aviation industry.

4.1. Implications for Practice

Among the articles reviewed, interventions that simultaneously addressed multiple dimensions of safety culture, integrated employees within intervention efforts, ensured sustained and visible leadership commitment, and appropriately addressed organizational context within the design of the intervention were most commonly effective in fostering measurable safety culture improvements.

4.1.1. Combine Multiple Intervention Strategies

Safety culture is multi-dimensional and, as such, requires multiple approaches for improvement. In our review, successful interventions often leveraged multiple strategies, including leadership development, feedback sessions, behavioral observations, and data-driven improvement efforts. By combining strategies, organizations can simultaneously address different dimensions of safety culture in need of improvement. For instance, Worthington et al. (2024) demonstrate how intervention action planning can assist practitioners in identifying and targeting multiple cultural dimensions for intervention. However, for each dimension of safety culture targeted for improvement, practitioners must be sure to systematically measure and evaluate indicators

reflective of the individual dimensions of interest. For example, if choosing to implement leadership training and peer observation sessions within the same intervention, practitioners should identify different outcome measures to assess the effectiveness of each method, rather than relying on a single indicator such as an overall safety culture score.

Notably, recent research has begun to address this important methodological consideration. Fleming & Cairns (2024) specified operational indicators within the transportation industry that may be linked to different dimensions of safety culture. Practitioners can begin to use these insights when identifying relevant indicators within the aviation context.

4.1.2. Actively Engage Employees

Integrating employees throughout the intervention process is critical for generating meaningful safety culture change. By including employees in the design and implementation of an intervention, organizations are more likely to empower employees' ownership of safety and successfully improve their safety culture. When employees lack ownership during an intervention, they may be more likely to perceive the intervention as irrelevant or unlikely to improve issues they care about. In turn, employees will be more likely to passively participate or resist the change efforts completely (Erwin & Garman, 2010; Furst & Cable, 2008).

This is a common challenge in aviation (McDonald et al., 2002), where regulatory constraints may pose barriers for incorporating employees system-wide. However, there remain many opportunities to involve employees in decisions and process designs that shape their day-to-day work. As an example, some interventions reviewed empowered small groups of employees to lead safety projects while others incorporated feedback from focus groups and surveys when considering areas to target for intervention (Rasumussen et al., 2006; Neilsen, 2014). These practices can be scaled to more appropriately fit the size and structure of organizational branches or units. However, when soliciting employee feedback via these methods, practitioners must follow up and act upon the insights obtained (Heubner & Zacher, 2021). Any failure to acknowledge or respond to employees will result in diminished trust and a reversal of progress in safety culture improvement.

McDonald et al. (2022) discuss other ways for engaging employees and reducing resistance to change. The authors suggest managing resistance by providing transparent communications about the intervention to the workforce and helping employees to understand and feel confident in the process. Further, Key et al.(2023) recommend designating representatives for each stakeholder group to be included in the planning and implementation of safety culture change initiatives.

4.1.3. Ensure Visible Leadership Commitment

Leaders must role model a visible commitment to safety if they expect employees to readily and willingly pursue safety culture change. In our review, successful intervention efforts demonstrated that leadership visibility, communication, and role modeling around safety from senior leaders, managers, and supervisors are critical behaviors for improving safety culture (Bronkhorst et al., 2018; Mullen & Kelloway, 2009). For example, leadership listening tours, in which senior leaders visit work units and engage with employees to better understand the conditions they deem necessary for safety culture change, can help maximize the impact of

intervention efforts. Smaller-scale efforts, such as within-group safety meetings, can also help foster more frequent and high-quality safety communication between managers, supervisors, and employees.

Finally, organizations should ensure a central point of accountability when implementing safety culture interventions. This individual should be considered as a safety champion or a guiding coalition responsible for the planning, design, and implementation of the change effort (Patankar et al., 2012). Commonly, this safety champion is a leader from the organization's safety division. This individual will play a critical role in the intervention effort and should be seen as responsible for obtaining leadership buy-in and encouraging participation across the organization.

4.1.4. Tailor Interventions to Meet the Organizational Context

Effective safety culture interventions are uncommonly one-size-fits-all endeavors. Practitioners must tailor their interventions to meet the organizational context. Interventions should be adjusted to reflect the realities of the work environment, the composition of the workforce, and the norms and common language used to communicate across the organization. In doing so, practitioners can maximize employee buy-in and reduce the likelihood of resistance to change. Practitioners should take caution to not pursue get-safe-quick schemes, which may overlook important organizational factors such as the regulatory environment or organizational size and structure. In aviation, this will require practitioners to understand the operational environment as well as the structure of operational systems. For instance, some methods for safety culture improvement position reporting systems as a foundational component of continuous improvement, highlighting near misses as an opportunity to learn about and mitigate risks in the operational environment. In aviation, however, the term "near miss" takes on numerous operational definitions depending on the occupation of interest, such as the difference in lessons to be learned from a near miss occurring in air traffic versus maintenance. Considering this case, off-the-shelf reporting interventions are unlikely to be effective. Instead, an intervention is likely to be more effective when it is both evidence-based and aligned with the realities of the organization.

4.2. Limitations and Future Directions

This review was constrained by several factors. First, we were limited to studies explicitly identified as safety culture research, which may have excluded relevant findings from adjacent fields. This constraint could result in a narrower perspective on safety-related attitudes and behaviors. There are likely insights from the broader organizational psychology literature related to organizational development, change management, leadership, training and development, organizational culture, and high-reliability organizations, among others, that could be translated to generate effective safety culture interventions. Second, our findings were subject to publication bias, as studies with significant results are more likely to be published than those with null or negative findings. This bias may have skewed the overall conclusions of the review, potentially overrepresenting positive associations between safety climate and various outcomes. Additionally, the scope of our review was influenced by the databases searched, the search terms used, and the inclusion/exclusion criteria, which may have inadvertently omitted relevant

studies. The findings may also be contextually limited, as research conducted in specific industries, regions, or time periods may not generalize broadly.

There were also limitations among the methods used in the articles we reviewed. Many intervention studies lacked objective outcome measures and experimental designs that compared effects across intervention groups and a control group. A potential reason for these limitations is that organizations conducting interventions may only collect metrics to inform business decisions of whether to continue or expand the intervention throughout the organization. Further complicating this, data about intervention success may be proprietary and not shared with researchers and/or consultants, thereby limiting the ability to identify patterns of success across organizational change efforts. Other methodological concerns include non-random assignment of participants into intervention and control groups, paucity of longitudinal designs (to determine whether the intervention had long-term impacts on safety culture perceptions and/or behaviors), small sample sizes, and participant dropout during the studies (Lee et al., 2019; Morello et al., 2013). This "demonstrates the need for further high-quality experimental research in the area of workplace safety culture interventions" (Aburumman et al., 2019, p. 389).

5. Conclusion

This review highlights the growing body of evidence supporting the effectiveness of safety culture interventions, especially when they are intentional, multi-faceted, and grounded in both leadership commitment and employee engagement. Across industries and regulatory contexts, successful interventions shared several key features: they combined multiple strategies (e.g., training, feedback, behavioral observation), were tailored to the specific organizational setting, and meaningfully involved personnel at all levels.

Importantly, the most impactful interventions were not simply about implementing isolated practices but about cultivating a systemic shift in how safety is prioritized, communicated, and reinforced. Leadership visibility, behavioral integrity, and responsiveness to employee concerns emerged as essential drivers of change. Equally, when employees were empowered to participate in problem identification, solution generation, and peer learning, organizations experienced improvements not only in safety attitudes, but also in tangible outcomes such as injury rates and operational performance.

However, the literature also makes clear that safety culture interventions are not one-size-fits-all. Their success depends on careful planning, contextual awareness, and sustained organizational commitment. Without these, even well-intentioned efforts may falter—or, worse, be perceived as disingenuous, eroding trust and undermining safety goals.

By organizing this review around the Harmonized Safety Culture Model (HSCM) traits and drawing on evidence from across regulated sectors, this report aims to support practitioners and policymakers in making informed, strategic decisions about safety culture improvement. The recommendations outlined here should serve as both a roadmap and a caution: culture change is achievable, but only with deliberate design, authentic leadership, and active collaboration across the workforce.

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Appendix A

Intervention Information by Author, Intervention Methods, Participants, Industry, Outcomes, and Major Limitations

Authors	Intervention(s)	Participants	Industry	Outcomes	Major Limitations
Kines et al. (2010)*	Supervisor safety-based communication training	Supervisors	Construction	Increased safety communication; increased safety performance and physical safety, increased worker attention to safety	N/A
Zohar & Polachek (2014)*	Supervisor safety-based communication training	Supervisors	Metal Fabrication	Improved perceptions of safety climate, reported safety behaviors, workload; Improved safety audit scores	N/A
Zohar (2002)*	Weekly structured feedback on safety monitoring and recognition behaviors	Supervisors	Equipment Maintenance	Increased safety communication; Increased safety performance and safety climate perceptions; Decreased count of occupational injuries	N/A
Hammer et al. (2016)	STAR Intervention	Supervisors	Healthcare	Increase in safety compliance at 6-months; Plateau in safety compliance at 12-months	N/A
Mullen & Kelloway (2009)	Safety Specifical Transformational Leadership Training	Managers	Healthcare	Improved safety attitudes; Increased intentions to promote safety; Increased perceived self-efficacy; Increased safety climate ratings	N/A
Schwatka et al. (2019)	Foundations of Safety Leadership OSHA Module	Supervisors	Construction	Greater perceived knowledge of safety leadership skills; Increased intentions to promote safety 2- and 4-months post-intervention; No change in workforce outcomes	Measured attitudes rather than behaviors.

Authors	Intervention(s)	Participants	Industry	Outcomes	Major Limitations
Von Thiele Schwarz et al. (2016)	Leader-led safety goal setting and behavioral modification	Managers	Forest Industry	Improved safety climate perceptions; Increased self-reports of transformational leadership behaviors; Increased productivity perceptions	N/A
Saurin et al. (2003)	Safety criteria within work planning processes	Managers, Staff, Safety Personnel, Sub-contractors	Construction	Higher proportion of work packages completed meeting safety criteria; No impact on production	N/A
Nielsen et al. (2006)	Obligatory near-miss and minor incident reporting; Continuous analysis and reporting of accident patterns to workforce	Supervisors, Staff	Industrial	Mixed results across participating plants; Increased reporting; Decreased lost-time injury reports	Mixed implementation quality and leadership involvement across plants.
Nielsen et al. (2015)	Weekly safety topics; Safety as agenda item in staff meetings	Supervisors, Staff	Metal / Wood Processing	Mixed results across participating plants; Improved perceptions of leadership and safety behaviors; Increased problem-solving outcomes	Mixed implementation quality and leadership involvement across plants.
Pecillo (2012)	Peer-to-peer safety observations	Supervisors, Staff	Production Plants	Reduced cases of unsafe behavior; Improved perceptions of safety culture and employee quality-of-life	
Costello et al. (2011)	Conflict resolution training; Policy implementation; Training	Management, Staff	Healthcare	Improved survey reports of respect, teamwork, and communication	Same outcome measures used to measure effectiveness of multiple intervention methods.

Authors	Intervention(s)	Participants	Industry	Outcomes	Major Limitations
Zuschlag et al. (2016)	Data-based continuous improvement program; Safety leadership training and development; Peer-to-peer safety observations and feedback	Management, Staff, Labor Union	Railroad	Increased worker safety behaviors; Reduced cases of derailments and incidents; Improved leadership-worker trust perceptions	Same outcome measures used to measure effectiveness of multiple intervention methods.
Bronkhorst et al. (2018)	Senior-management safety rounds; Online platform for safety feedback; Safety leadership training and development	Management, Staff	Healthcare	Improved safety climate and safety participation perceptions	Same outcome measures used to measure effectiveness of multiple intervention methods.
Rasmussen et al. (2006)	Participatory action research integration; Employee safety project groups	Supervisors, Staff	Industrial Plant	Improved safety culture perceptions	N/A
Dietl et al. (2023)	Safety communication campaign	Interdisciplinary Teams	Healthcare	Improved (i.e., reduced) perceptions of patient safety risk; No change in communication, psychological safety; or team performance	Results suggest intervention best-suited for well-integrated teams.
Vecchio-Sadus (2007)	Safety-specific messaging from executive leadership; Safety communication campaign; Team-based discussions to solicit employee input	Management, Staff	Research and Development	Reduction in lost-time injuries and compensation claims; Increased safety program participation; Greater survey ratings of safety satisfaction	Same outcome measures used to measure effectiveness of multiple intervention methods.