Federal Aviation Administration

DOT/FAA/AM-23/13
Aviation Safety
Office of Aerospace Medicine
Washington, DC 20591

Safety Culture Assessment and Continuous Improvement in Aviation: A Literature Review

Kylie N. Key[1]

Peter T. Hu[2]

Inchul Choi[2]

David J. Schroeder[2]

[1]Civil Aerospace Medical Institute

Federal Aviation Administration

Oklahoma City, OK 73125

[2]Cherokee Nation 3S, LLC

Oklahoma City, OK 73125

May 2023

Report

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents thereof.

This publication and all Office of Aerospace Medicine technical reports are available in full-text from the Civil Aerospace Medical Institute's publications Website: www.faa.gov/go/oamtechreports

Technical Documentation Page

1. Report No. DOT/FAA/AM-23/13	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Safety Culture Assessment and Continuous Improvement in Aviation: A Literature Review		5. Report Date May 2023
		6. Performing Organization Code
7. Author(s) Key, K.[1], Hu, P.[2], Choi, I.[2], Schroeder, D.[2]		8. Performing Organization Report No.
9. Performing Organization Name and Address Federal Aviation Administration Civil Aerospace Medical Institute, AAM-500 Oklahoma City, OK 73169		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Office of Aerospace Medicine Federal Aviation Administration 800 Independence Ave., S.W. Washington, DC 20591		13. Type of Report and Period Covered
15. Supplementary Notes		

16. Abstract

The effectiveness of safety management depends on the organization having a positive safety culture, or the shared values, actions, and behaviors that demonstrate a commitment to safety over competing goals and demands. However, despite the recognized importance of safety culture, organizations may neither be equipped to establish the benefits of safety culture (e.g., clear linkages to safety outcomes), nor to develop assessment methods, nor to improve safety culture based information collected from the assessments. In support of Federal Aviation Administration (FAA) efforts to promote a positive safety culture, we reviewed the literature on safety culture assessment and promotion. The literature reveals the development of a deeper understanding of safety culture, identifies a wide range of individual and organizational outcomes to include in assessments, provides interpretive theoretical frameworks, and summarizes preliminary investigations of intervention strategies.

17. Key Words safety culture, organizational culture, assessment, human factors, aviation	18. Distribution Statement Unlimited		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 74	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Table of Contents

List of Tables

List of Abbreviations

Abbreviation	Definition
ASAP	Aviation Safety Action Program
ASRS	Aviation Safety Reporting System
CSAS	Command Safety Assessment Survey
DOT	Department of Transportation
ECAST	European Commercial Aviation Safety Team
FAA	Federal Aviation Administration
HSE	Health, Safety, and Environment
I-ASC	IATA Aviation Safety Culture
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
JD-R	Job Demands-Resources
KPI	Key Performance Indicator
LOSA	Line Operations Safety Assessments
MASCA	Managing System Change in Aviation
MCAS	Maintenance Climate Assessment Survey
NASEM	National Academies of Sciences, Engineering, and Medicine
NOSACQ-50	Nordic Safety Climate Questionnaire
NTSB	National Transportation Safety Board
OIG	Office of Inspector General
OTJ	On-the-job (training, performance)
SAQ	Safety Attitudes Questionnaire
SMBWA	Safety Management by Walking Around
SMICG	Safety Management International Collaboration Group
SMS	Safety Management System

Acknowledgements

This research was completed with funding from the Federal Aviation Administration (FAA) NextGen Human Factors Division (ANG-C1) in support of FAA Flight Standards Service (AFS) Aircraft Maintenance Division (AFS-300) and Aircraft Certification Service (AIR) Policy and Innovation Division (AIR-600). We would like to thank our FAA Program Manager Dr. Chuck Perala and technical sponsor Dr. Bill Johnson.

Abstract

The effectiveness of safety management depends on the organization having a positive safety culture, or the shared values, actions, and behaviors that demonstrate a commitment to safety over competing goals and demands. However, despite the recognized importance of safety culture, organizations may neither be equipped to establish the benefits of safety culture (e.g., clear linkages to safety outcomes), nor to develop assessment methods, nor to improve safety culture based information collected from the assessments. In support of Federal Aviation Administration (FAA) efforts to promote a positive safety culture, we reviewed the literature on safety culture assessment and promotion. The literature reveals the development of a deeper understanding of safety culture, identifies a wide range of individual and organizational outcomes to include in assessments, provides interpretive theoretical frameworks, and summarizes preliminary investigations of intervention strategies.

Keywords*:* safety culture, organizational culture, assessment, human factors, aviation

Introduction

> "Our focus must be less about human error, and more about behavioral choices. Less about blame, and more about learning…The question is can we design a system, a culture, a world where we can safely learn from our mistakes – or do we continue with the game of Whack-a-Mole?" (Marx, 2009, p. 127).

As Marx (2009) illustrates, human fallibility is unavoidable, but with better system design, organizations can create a culture where safety is paramount. Across safety-critical industries (such as medicine, energy, and transportation), there is a growing recognition that organizational culture is a key performance-shaping factor; this perspective contrasts with the mindset where blaming employees for mistakes was the go-to way of managing performance. In accordance with this shift in philosophy, there has been a surge of interest in safety culture, with recent developments, including:

1. Regulatory and guidance materials (e.g., Safety Management System [SMS]; International Civil Aviation Organization [ICAO] Annex 19, 2016; 14 C.F.R. § 5).
2. Recommendations from the Office of Inspector General (OIG, 2020).
3. Federal Aviation Administration (FAA) strategic initiatives and business plans (e.g., FAA, 2022a).
4. Mandates from the U.S. Congress to assess safety culture (e.g., Consolidated Appropriations Act 2020, P.L. 116-93, 2019).
5. International working group guidance (e.g., European Commercial Aviation Safety Team [ECAST] SMS Working Group; International Air Transport Association [IATA] Aviation Safety Culture [I-ASC], 2019; Piers et al., 2009).

The FAA has adopted an Integrated Oversight Philosophy for overseeing aviation safety, including risk-based decision making, a collaborative approach to safety management, and formalized SMSs.[1] An SMS is a formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls.[2] SMS is required for domestic air carrier operators and international operators.[3] SMS has

[1] FAA (2017).
[2] 14 C.F.R. § 5; FAA (2015, 2020); International Civil Aviation Organization [ICAO] Annex 19 (2016).
[3] Domestic air carriers operating under 14 C.F.R. § 121 (see 14 C.F.R. § 5) and international operators (see ICAO, 2016).

four components including Safety Policy, Safety Risk Management, Safety Assurance, and Safety Promotion.

The Safety Promotion component of SMS, the most relevant to this review, focuses on preserving and increasing both safety culture and safety behaviors. The Safety Promotion component often is considered central to SMS because the effectiveness of SMS is highly dependent on the extent to which safety culture and its behaviors are valued and upheld. Safety culture/climate is a leading indicator of safety performance, as argued by Jiang et al. (2019):

> "The past 35 years have witnessed a shift away from safety monitoring solely based on 'lagging indicators' or retrospective data such as accidents and injuries, towards the measurement of 'leading indicators' or predictive measures such as safety climate." (Jiang et al., 2019; p. 42).

Collaborative working groups have also come to the agreement that safety culture is a necessary component for managing human factor risks. Avers et al. (2011) reported, "A well-established safety culture is a critical foundation that must be in place before many of the human factor challenges can be addressed effectively" (p. vii).

Researchers have documented that a positive safety culture not only helps the SMSs work more effectively (French & Steel, 2017; IATA, 2019; Piers et al., 2009), but also provides the basis for making continuous improvements to SMSs (Akselsson et al., 2009). As emphasized by the IATA, "if an organization has no safety culture, its SMS investment is wasted" (2019; p. 4).

Safety culture has been linked to many important safety-related outcomes. These include organizational performance outcomes such as accident/incident rates, compliance, and production/profit - along with employee outcomes such as engagement, morale, strain/burnout, personal injury rates, willingness to report, and turnover intentions (Christian et al., 2009; Clarke, 2006, 2010, 2012; Nahrgang et al., 2011). These relationships between a positive safety culture and safety-related outcomes have been found to be stable across safety-critical industries and countries, attesting to their robustness (Zohar, 2014). Given the strength of the relationships between a positive safety culture and positive outcomes, it is reasonable to hypothesize that fostering a positive safety culture will yield positive outcomes.

Yet despite the obvious benefits of safety culture assessment and promotion, some barriers slowed its widespread success in aviation. There is a plethora of assessment tools to choose from, but in many cases, there are barriers that include assessment tools that are not well validated, expensive and/or proprietary, or that may not inform continuous

improvement. There is also a need for interventions to improve safety culture, as even a perfect assessment is of limited utility without an understanding of how to use the results to affect positive change. As noted by Pronovost and Sexton (2005), "Even with a valid measure of culture, if culture is not responsive to interventions there is no point in measuring it" (pp. 232). Organizations may not be equipped to establish the benefits of safety culture (e.g., clear linkages to safety outcomes), develop assessment methods, or improve safety culture based information collected from the assessments.

In support of FAA efforts to promote a positive safety culture, this report provides a review of the literature on safety culture assessment and promotion. Continuing research will focus on developing assessment tools and identifying methods and areas of continuous improvement.

Methods

Literature Review Resources

This review includes literature on both safety culture and safety climate. Although there are theoretical differences between culture and climate, Griffin and Curcuruto (2016) found that most researchers consider climate as one part of the larger construct of culture, where "climate is more superficial and transient than culture" (Guldenmund, 2007; p. 724). These theoretical differences are of limited importance from a practical perspective, and the aviation industry itself uses the two terms interchangeably. As such, this review devotes primary effort toward reviewing and discussing safety culture, but includes references to both safety culture and safety climate using the terms (i.e., *culture or climate*) as found in the referred manuscripts.

This review spans the literature published from 1980 through 2022. The scope of the literature review encompassed many safety critical fields, documenting a cross-section of best practices, lessons learned, and research needs. This literature review discusses research from domains such as safety culture/climate, industrial/organizational psychology, change management, organizational behavior management, or behavior-based safety. The literature review identified 538 peer-reviewed sources (i.e., journal articles, book chapters, conference proceedings, technical reports, and theses/dissertations) retrieved from Google Scholar searches using keywords such as safety culture, safety climate, safety performance, aviation, and safety. The FAA Office of Aerospace Medicine Technical Reports database also was searched, and the authors received materials from colleagues as well.

The literature were assessed for relevance, after which 184 were selected for the current review. Relevant literature were (a) in English, (b) involved safety culture or safety climate assessment, (c) or assessed organizational performance, and (d) completed with scientific rigor (e.g., established literature review procedures, empirical research methods). Literature was not limited to aviation; however, the literature specific to aviation climate/culture assessment (~120 articles) that did not add to the general understanding in this literature review are discussed in a follow-on report (Schroeder et al., in preparation).

An Introduction to Safety Culture

Defining Safety Culture and Safety Climate

The U.S. Department of Transportation (DOT) Safety Council defines safety culture as "the shared values, actions, and behaviors that demonstrate a commitment to safety over competing goals and demands" (Morrow & Coplen, 2017, p. 2). Safety culture is an index of how much employees perceive that their organization values and emphasizes safety at all organizational levels – from the front-line employees to senior leadership. It can also be defined as "how we do things around here" (McHale, 2020). This basic definition has persisted since the original paper on safety climate, where the researcher defined it as "shared employee perceptions about the relative importance of safe conduct in their occupational behavior" (Zohar, 1980, p. 96). Safety culture is foundational for effective safety management and risk-based decision-making.

The terms *safety culture* and *safety climate* often are used interchangeably in the literature, and researchers often did not clearly distinguish the two terms (Guldenmund, 2000, 2007). Morrow and Coplen (2017) discussed how different academics, industries, and regulatory agencies have defined safety culture; various definitions of safety climate/culture also are documented in literature reviews by Guldenmund (2000) and Cole et al. (2013).[4]

Some researchers have argued that the interchangeable use of the constructs threatens the overall discriminant validity (Zohar, 2014). However, Griffin and Curcuruto (2016) point out in their review that while there may be advantages to making a fine-grained distinction between safety culture and climate, they both explore the value of safety in the organization similarly. Other researchers have similar views in which,

[4] Wiegmann et al. (2002) identified common features across definitions.

"organizational culture expresses itself through organizational climate" (Guldenmund, 2000, p. 221; see also Patterson et al., 2005).

Cole et al. (2013) stated that culture is something an organization *is*, whereas climate is something an organization *has* at a particular time, alluding to the transitory nature of climate. Similarly, Wiegmann et al. (2002) drew the analogy of culture and climate to that of personality and mood, respectively. Whereas safety climate is subject to change depending on operational or economic circumstances, safety culture is more enduring and consistent, making it justifiable for researchers to identify key indicators of culture and assess culture across time (Wiegmann et al., 2002).

In summary, the attributes of safety culture are shared largely with the safety climate, but what is coherent at the organizational level often becomes fragmented knowledge at the individual level. Thus, safety climate provides a snapshot of the overall safety culture of an organization or work group.

A Historical Review of the Safety Culture Literature

Interest in safety climate/culture was driven mainly by two events in the 1980s. First, Zohar developed a 40-item questionnaire instrument to measure safety climate across 20 industrial organizations (1980). It showed agreement among employees' perceptions of safety and correlated with measures of safety performance as rated by experienced safety inspectors. Second, the International Nuclear Safety Advisory Group identified human factors as having contributed to the 1986 Chernobyl nuclear disaster, and noted, among other findings, *a general lack of safety culture* (1992).

Since the 1980s, interest in safety climate and culture has expanded to nearly all safety-critical fields. There have been over 1,135 research studies focused on defining and measuring safety climate/culture (Griffin & Curcuruto, 2016; Li et al., 2022). Typically, safety culture is assessed via questionnaires where participants self-report their perceptions, attitudes, beliefs, and values about organizational safety.[5]

Built through decades of research on safety culture, the extant literature on safety climate and culture assessment reveals the development of a more complete understanding of safety culture since the 1980s. Major hurdles in the literature have included: (a) climate and culture used interchangeably, (b) inconsistencies in factor

[5] Though safety climate was introduced in the literature before safety culture (i.e., with Zohar's 1980 instrument), there are more studies published on safety culture than climate (Li et al., 2022).

structure and lack of theoretical frameworks,[6] and (c) a lack of predictive validity assessments[7] (Cooper, 2016; Gadd & Collins, 2002; Guldenmund 2000, 2007; Zohar, 2014). As observed by Guldenmund (2000), "...while the importance of the concept of safety climate or culture is stressed by most authors, very few have attempted to support their claim by reporting an indication of its construct validity or predictive validity" (p. 216). An overreliance on surveys also has been criticized, thus demonstrating a need to contextualize the information that can be gleaned from surveys (Guldenmund, 2007; Arendt, 2020).

These limitations immediately call into question the value of safety culture assessment. However, an updated view of the literature is needed. These historical limitations have been overcome partially in recent years, with the introduction of advanced statistical techniques (e.g., meta-analysis; Christian et al., 2009; Clarke, 2006, 2010, 2012; Nahrgang, 2011). The development of more carefully constructed questionnaires that measure a broader, holistic view of safety culture and its outcomes have also helped to overcome these limitations. Two examples are the Snapshot Survey (Cooper & Fogarty, 2015; Cooper et al., 2018) and the Reciprocal Safety Culture Model (Cooper, 2000, 2018). These assessments have been successful in advancing our understanding of safety culture, illustrating the predictive ability of safety culture for a wide range of individual and organizational outcomes, developing theoretical frameworks, and preliminary investigations of intervention strategies.

The remainder of this report documents the actionable lessons learned from the literature, thereby shedding light on how to assess and promote a positive safety culture in aviation.

The Nature of Safety Culture and Climate

Safety culture can be difficult to comprehend holistically, as it can be assessed with various methods and dimensions. Fortunately, several theoretical frameworks have described the nature of safety culture, drawn hypothetical pathways of the causal relationships among variables, and helped organizations to better understand and predict safety outcomes (see Appendix A). Some commonalities emerge when looking across the

[6] Previous literature reviews have found that safety climate surveys range from 11-300 items with 2 to 19 factors, including more than 50 different variables or conceptual themes (Beus et al., 2010; Flin et al., 2000, 2006; Guldenmund, 2000).

[7] Relatively few researchers (17% in O'Connor et al., 2011; 32% in the current review) have assessed the predictive validity of their instrument, perhaps because of the difficulties associated with collecting objective data (O'Connor et al., 2011).

existing frameworks of safety culture, which suggests a rudimentary convergence in the literature.[8]

First, it is evident that most frameworks conceive safety culture as one component of the overall organizational culture. Culture, including safety culture, is shaped by many factors, such as operational environments, technology, workforce, globalization, and market demands. Many organizations have mission statements that emphasize safety; however, the day-to-day operations of organizations may reveal a tug-of-war between safety culture and other performance goals, such as production and profit (Alper & Karsh, 2009; Baron, 2009; Holden, 2009; McDonald et al., 2002). How organizations resolve this tension defines the strength of their safety culture – in this way, a positive safety culture can be characterized as the prioritization of safety and the continuous proactive actions taken to strive for safety (Guldenmund, 2000, 2018; Zohar, 2014). Therefore, it is nearly impossible to fully separate safety culture from other aspects of organizational culture.[9]

There is no such thing as a 'lack of culture'; culture is inherently present in all organizations, ranging on a continuum from undesirable to desirable. Although safety culture assessments can pinpoint perceptions at a given time, there should be no expectation that culture will remain stable over time or that it will gradually mature toward the better. Rather, safety culture should be viewed as a journey, not a destination. Contrary to popular understanding, "in reality values and beliefs held by employees about safety may spontaneously wax, wane and in some cases relapse over short periods of time… [others] refer to safety as a 'moving target' as opposed to a fixed entity" (Goncalves Filho &Waterson, 2018, p. 18; see also Becker et al., 2009; Fleming, 2001; Hudson, 2007; Wendler, 2012). Safety culture should be viewed as a journey, not a destination.

Culture transformation efforts in face of demonstrated needs should be "aligned with the fundamental identity, values, and assumptions of the organization" (Patankar et al., 2012, p. 93). Broad change efforts such as a 'safety culture program' or educational efforts alone are likely to result in superficial, not sustained, change. Instead, a better path would be to continually assess needs and then make specific, targeted efforts to improve.

Safety culture promotion requires an organization-wide change in values and behaviors that emphasize safety. It is an iterative program of continuous improvement,

---

[8] Cooper (2016) further compares safety culture models.
[9] For an in-depth discussion of organizational climate and culture (including discussion of other industries), please see Schneider et al. (2013).

awareness, and dedication to safety goals (Patankar et al., 2012; Ward et al., 2010a). Leadership cannot be the sole voice determining culture, nor can employees be the sole voice. Instead, culture consists of *shared perceptions* of what is prioritized and how priorities are demonstrated in the organization (e.g., what is measured and rewarded). Leadership, employees, and other stakeholders (e.g., regulators) have *shared responsibility* for creating and maintaining a positive safety culture. There must be organization-wide commitment, as, "[i]n safety culture transformation, in particular, there is a need for both bottom-up and top-down alignment. While leaders need to establish policies and provide resources to support the policies, all the employees need to participate in the actual transformation effort" (Patankar et al., 2012, p. 180).

Given that the nature of safety culture and climate is complex, dynamic, and evolutionary, it is essential to assess strengths and areas of improvement routinely. This allows for the development and implementation of targeted interventions designed to improve safety culture in a continuous manner.

Safety Culture Assessment

Safety culture measurement is a central component of effective safety management. Remember the adages: 'if you can't measure it, you can't manage it' and 'what gets measured gets managed'.[10] Proactive and routine assessment of safety culture perceptions empowers the development of targeted interventions and management of the safety culture evolution across time.

Methods to assess safety culture perceptions across work groups can include surveys, interviews/focus groups, observations, and incident/accident reviews. Each method has its own strengths and weaknesses, and not all are suitable for certain research questions and different organizational resource constraints. In essence, they can be thought of as different pathways to achieve positive safety culture change (see Table 1). It should be noted that a combination of methods could be used. For instance, following a survey with focus group interviews can allow stakeholders to discuss results with greater depth and help better-identify potential improvement efforts (NASEM, 2016). It is also important to note that any assessment method can be done well (e.g., through careful design and execution) and can yield valuable information; but any method can be executed poorly.

[10] Generally attributed to management consultant Peter Drucker (n.d.).

Table 1.
Strengths and Weaknesses of Methods Commonly Used in Safety Culture Assessment

Methodology	Strengths	Weaknesses
Surveys	Provides opportunity for employees to identify their areas of concern. Can promote "ownership". Quick to administer and provide an aggregate understanding of individual attitudes and perceptions. Easiest to benchmark, quantify differences between groups, and assess change.	Findings are based on self-reported attitudes or perceptions.
Interviews / Focus Groups	Provides opportunity for employees to identify their areas of concern. More detailed information.	Findings are based on attitudes or perceptions that may be influenced by unrelated factors. More time-consuming than questionnaires to administer. Participants may not be representative of the entire organization. Need to structure the interview process and content, especially if multiple groups are included.
Observations	Close interaction and cooperation between observers and employees. In some cases, the observers are trained peers, who may be able to uncover more information than management or outsiders.[11]	Requires knowledgeable observers. Observers may be intrusive and interfere with completion of employee job tasks.

[11] Either based on their own knowledge of the work environment, or through their rapport with other employees.

Methodology	Strengths	Weaknesses
Incident / Accident Reviews	Based on factual evidence. Costs of the incident can be documented.	Root issues not always well documented. Incidents are rare; data may be insufficiently sparse for analysis and may not be representative. Retrospective; may not apply to the future.

Note. For further discussion on the tradeoffs of using each method, see Cole et al. (2013), International Atomic Energy Agency (IAEA; 2002), Mason (n.d.), and National Academies of Sciences, Engineering, and Medicine (NASEM; 2016).

Surveys

Surveys are perhaps the most effective and efficient way to collect opinions and perceptions from a large number of people compared to other methods (see IAEA, 2002; Churruca et al., 2021; Wiegmann et al., 2002). Surveys can provide quantitative scores, and results can be compared readily across demographic variables of interest, such as department, location, or job role (NASEM, 2016); this helps organizations identify culture silos in need of targeted improvements. The quantitative questions in a survey may be supplemented with open-ended questions that allow respondents to provide information that is more detailed.

A key limitation of using surveys to asses culture is that "responses are self-reports in response to standard questions that may be interpreted in different ways by different respondents, who may or may not be able (or willing) to report on 'deeper' levels of culture" (NASEM, 2016, p. 148; see also Guldenmund, 2007, Schein, 2010). Obtaining a representative and sufficiently large sample can be challenging for smaller organizations or for those where trust is low. However, assuming measurement rigor and good sampling techniques are employed, a survey can provide a generalizable and representative assessment of safety culture.

Specific to aviation, safety culture/climate surveys have been developed and administered in all facets of military and commercial aviation (e.g., pilots, cabin crews, maintenance, ground handlers, air traffic control; O'Connor et al., 2011). Some of the most widely used safety culture assessments in the aviation field are:

- Command Safety Assessment Survey (CSAS; Ciavarelli, 2002; Ciavarelli et al., 2001).

- Maintenance Climate Assessment Survey (MCAS), and the Air Force Climate Survey (Camm et al., 2013). These have been used with U.S. military aviators and maintainers for 20 years (O'Connor et al., 2011).
- Snapshot Survey (Cooper & Fogarty, 2015; Cooper et al., 2018; Fogarty et al., 2018).
- EUROCONTROL survey for air traffic management (Mearns et al., 2013; Reader et al., 2015).
- NLR Aviation Safety Culture – Inquiry and Tool (ASC-IT; Balk & Bossenbroek, 2010).

Interviews and Focus Groups

Interviews and focus groups frequently are employed in safety culture assessment.[12] Instead of asking participants to document their responses, an interviewer (or focus group facilitator) documents them. Semi-structured interview formats allow the interviewer to ask follow-up questions about topics of interest, in contrast to the structured nature of survey questions that do not easily allow for follow-up. Qualitative and mixed-method studies are more likely to assess other informative aspects of safety culture, which may reveal "unexpected, richer or more contextually relevant findings" (Churruca et al., 2021, p. 9).

After interview narratives are collected and collated, a final description of safety culture is generated that is oftentimes constructed along theorized levels of cultural maturity (e.g., ranging from reactive to proactive; see Westrum, 2004).[13] In a maturity levels framework such as this, indicators of a positive or proactive safety culture may include high cooperation, safety communication is valued, risks are shared, bridging and teamwork is encouraged, failures lead to inquiry rather than scapegoating, and organizational learning (Westrum, 2004).

Although interviews and focus groups provide rich contextual information about safety culture, they can be time-consuming to administer, often resulting in fewer employees' perceptions being documented (Cole et al., 2013; NASEM, 2016). Smaller samples may be less time-consuming, but can potentially result in less-representative findings and conclusions. However, careful selection of participants who represent

[12] See Cole et al. (2013), NASEM (2016).
[13] Although the SMICG's (2019) framework is internationally recognized, it has not yet been validated in the scientific literature.

different segments of the organization will help ensure that useful input can be gained from targeted stakeholders.

The Safety Management International Collaboration Group (SMICG, 2019) developed an interview-based safety culture assessment protocol; versions were developed for assessments of culture for both regulators and the regulated. The assessment protocol, comprised of interviews with members of the workforce *and* management, qualitatively assesses of the maturity of the organization's safety culture. Interviews also have been conducted in healthcare (Churucca et al., 2020). These examples are but two that demonstrate the resource-intensive nature of interviews and focus groups. Yet, interviews and focus group methods are employed because the insights they can provide are oftentimes well worth the investment in time and effort.

Reporting Programs

Another method of assessing elements of organizational culture is to obtain employee self-reports of hazards, threats (near misses or close calls), accident precursors, and other safety-related events. This can be done by utilizing voluntary or mandatory reporting programs; to maximize success, these systems should be voluntary, confidential, and non-punitive. Some well-known employee reporting systems are the National Aeronautics and Space Administration's Aviation Safety Reporting System (ASRS) and the FAA's Aviation Safety Action Program (ASAP).

Indicators of safety culture in a reporting program typically include employee awareness and willingness to use the reporting program/system; number and quality of reports received; and how management responds (i.e., whether timely feedback is provided and safety concerns are effectively addressed). Typically, when a reporting program is implemented in a safety culture, it is immediately followed by an influx of reports from employees. This indicates that such employees are willing to raise safety concerns. In the long term, those safety concerns should be addressed, which may result in a lower reporting rate over time.

It is likely that many aviation organizations are using these programs successfully, providing at least precursory indications of safety culture. One limitation to this method is that event data often fail to include sufficient information to answer questions fully concerning the nature of the event, the factors that contributed, and the eventual outcomes (Avers et al., 2011, 2014). Also, be aware that employees may not report every safety concern,[14] so the reported data may not be wholly representative of concerns

[14] See Akselsson et al. (2009), Connell (2004), Patankar and Driscoll (2005).

encountered during normal work operations. On the other hand, reporting programs can provide an accessible, always-available way for gathering useful data against which other assessments may be considered and compared.

Observations

Observational methods involve trained experts recording safety-related information during observations of normal operations. Observational methods are typically used by auditors, and may include combinations of direct observation (whether individual one-on-one or in groups) and analysis of documentation (Nuclear Regulatory Commission, 2014; see NASEM, 2016).

Observational methods have the advantage of being able to obtain more-factual information while (a) closely examining the work environment and nature of the tasks, (b) recording behaviors, and (c) identifying room for improvement. However, observational methods are more time and resource intensive, requiring trained individuals to understand what tasks they are observing and to be able to identify hazardous conditions and potential problems. In particular, observational methods can be intrusive to the work environment, and observations must be performed by experts with both domain expertise *and* human factors knowledge,[15] usually a rare combination (Latorella & Prabhu, 2000). In some cases, the observers are trained peers, who may be able to uncover more information than management or outsiders. In other cases, the observers may be a third party (e.g., researchers, consultants) who may wish to observe areas of the organization beyond employee behavior.

Safety culture indicators include: management presence and participation in safety stand downs or safety meetings (Wiegmann et al., 2002), safety as a Key Performance Indicator (KPI) at board meetings, whether the safety manager's voice is valued, and whether supervisors engage in Safety Management by Walking Around (SMBWA) and are providing valuable feedback to employees.

Examples of observational methods include Line Operations Safety Assessments (LOSA; Ma & Rankin, 2012; Ma et al., 2011; Ma & Zylawski, 2016) and safety behavior checklists (McSween, 2003). Other observational approaches may include Behavior-Based Safety Programs, typically designed to identify targeted risky behaviors, assess proper equipment use, and provide corrective feedback for unsafe behaviors (McSween, 2003). As these examples illustrate, not all features that factor into a safety culture can be

[15] Often, organizations can use their own employees as LOSA observers. These observers intervene only if a safety issue is imminent.

observed during relatively short periods; however, observational methods may provide useful insight into certain safety performance indicators such as compliance with procedures.

Incident and Accident Reviews

Unlike the subjective perceptions gathered via questionnaires, interviews, or focus group methods, reviews of incident and accident artifact data can provide a more objective source of information. Reviews require trained human factors specialists to identify and classify the relevant contributing factors. One limitation of this method is that the rarity of incident and accident events, as well as lack of safety culture related information in general, can make it difficult to establish trends and draw conclusions regarding safety culture perceptions. Notably, there are many failure types and not all accidents or incidents may involve poor safety culture, and hence their occurrence does not imply that the organization's safety culture is poor.

Safety culture was added recently to the NTSB's list of contributing factors for events (see Czech et al., 2014). Due to the recency of its inclusion, there are not yet many examples of safety culture in NTSB findings. However, the change likely will empower the NTSB to incorporate and discuss the key role of safety culture in future investigative reports. Additionally, Cole et al. (2013) and the International Nuclear Safety Advisory Group (i.e., INSAG-7, 1992) have identified accidents outside of the aviation industry where safety culture was a contributing factor. For further discussion about the importance of incident and accident reviews, see Arendt (2020) and Mason (n.d.).

Mixed Methods

Based on the quality-resource tradeoff involved with different data collection methods, a mixed-method approach may be needed. A mix of assessment methods can help ensure that any improvement efforts are well targeted and based upon a thorough understanding of the safety culture. Operationally, a more comprehensive assessment often engages a team of specialists who use a combination of tools, such as interviews, document reviews, observations, and focus groups.

Researchers have suggested a holistic, step-wise approach when using multiple methods including:[16]

[16] See Arendt (2020), Guldenmund (2007).

1. Hold a pre-survey focus group to identify questions.[17]
2. Develop and distribute a survey questionnaire.
3. Review indices of safety culture (e.g., incident and accident reports, safety policies, audit results, observation findings).
4. Hold post-survey focus groups to dive into areas of interest.
5. Develop and execute action plan for improvement.
6. Reassess safety culture (return to Step 1).

The assessment can also be broken into phases with clear goals posted along the way. Long-term approaches may include extensive observational methods to monitor and promote safety behavior, especially on safety-critical tasks (where errors are more frequent or more severe), whereas short-term approaches may include looking at event reporting data or work process reports to prescribe immediate interventions aimed at eliminating accident precursors in the workplace.

Elements of this mixed-method approach have been utilized in the air traffic control environment and the railroad industry with some success (see Mearns et al., 2013). For example, the EUROCONTROL Experimental Centre utilized a survey plus focus group method of safety culture assessment (Gordon et al., 2006, 2007; Mearns et al., 2013). The Short Line Safety Institute (SLSI) combines a survey, employee interviews, safety document reviews, and field observations (Federal Railroad Administration, 2019). Elements of this approach also have been applied to other industries, such as healthcare (Chidester, 2016; Churruca et al., 2021; Flin et al., 2006).[18]

No matter what assessment method(s) are chosen, the assessment should strive to obtain a representative sample of respondents. Employees from all job roles should be encouraged to participate in the assessment and may need to be incentivized for doing so. A key to success of safety culture assessment and change is to involve employees from all levels of the organization (see also The Importance of Including Employees in Change Efforts).

Utility of Customized Assessment Methods

Most safety climate assessments published in the scientific literature were universal, meaning they were not tailored to a specific work environment (Jiang et al., 2019). Universal scales offer advantages such as the ability to make a large, standardized

[17] e.g., to address operational risks. See Zohar (2014).
[18] Chidester et al. (2016) in particular identified the dimensions of safety culture in the aviation and healthcare industries.

database to support comparisons across industries, discovery of group or organizational differences, and development of a parsimonious unifying theoretical framework (Jiang et al., 2019). Especially given the common dimensions discussed below, the application of universal scales would provide greater capability to compare safety culture across industries.

Well-used assessments that span across safety-critical industries include Zohar's safety climate measure for industrial organizations (1980), the Nordic Safety Climate Questionnaire (NOSACQ-50; Kines et al., 2011),[19] and the Safety Attitudes Questionnaire (SAQ; Sexton et al., 2006).[20] These focus on characteristics of safety culture that are applicable to any safety-critical work environment.

As noted by Zohar (2014), culture assessments may be more successful with the inclusion of industry and job-specific items. Given the wide variety of jobs and roles within aviation, tailoring assessments may be warranted (see NASEM, 2016). Naturally, safety culture/climate varies *across* organizations and groups, due to differences in factors such as safety policies, regulatory requirements, and the level of risk associated with the tasks (Helmreich, 1999; Isla-Díaz & Díaz-Cabrera, 1997; Zohar, 1980).

The inclusion of such topics provides richer diagnostic information about specific concerns of interest, and provides participating organizations with more useful information (Jiang et al., 2019). Zohar's (2014) review found that industry and job-specific scales offer *double* the predictive validity of universal scales, demonstrating the utility of customizing an assessment to the industry under investigation.[21]

The development of industry-specific scales begins with observational or interview methods to determine the relevant topics. It may be beneficial to work with leadership and employees who can assist with identifying topics important to the organization (e.g., organizational risk factors, demographics, and other job-specific factors).

Previous research has identified some job-specific topics for safety culture in aviation. Among safety-critical job roles, such as pilots, maintainers, and air traffic controllers, one organizational risk factor is time pressure (e.g., the conflict between productivity and safety). Pressure often is cited as a factor in either cutting corners or

---

[19] The NOSACQ-50 is so widely used that it has been translated into over 20 languages (Kines et al., 2011).
[20] Originally developed for aviation as the Flight Management Attitudes Questionnaire and subsequently adapted for the healthcare environment (Sexton et al., 2006).
[21] However, the reliability and validity of customized scales is not always known, in part due to limited organizational resources (Jiang et al., 2019).

other more-direct violations of procedures (Alper & Karsh, 2009; Mason, 1997). Other topics include the usability and availability of resources necessary to perform the work, such as work procedures, equipment and tools, and proper staffing levels (Hobbs & Williamson, 2003; Holden, 2009; Reason & Hobbs, 2003). Future research should ensure these job-specific factors are included in safety culture assessments where appropriate.

Safety Culture Dimensions

Safety culture is multi-dimensional in nature. The literature describes a complex set of pathways whereby organizational resources and safety systems influence employee engagement and behaviors, which in turn influence organizational safety outcomes. Any organization aiming to improve safety needs to assess and understand these complex relationships between individuals, work environments, and organizational factors. This will set the stage for meaningful interventions to be designed, validated, and implemented in the work environment.

Finding common dimensions when assessing safety culture is critical because they allow organizations to: (a) compare assessment results across different instruments, industries, and organizations, (b) replicate the factor structure across instruments, and (c) develop theoretical frameworks to clarify the relationships among the topics (Zohar, 2014). One potential pathway to success is to measure dimensions of safety culture found in previous safety culture research that were effective in supporting positive change.

In order to find the dimensions of safety culture, the scientific literature and regulatory guidance were reviewed to identify the overarching principles and key dimensions that may be of consideration for high-risk organizations when assessing safety culture. Holistically, the research literature showed continuity and reliability of the constructs surrounding safety culture. Many of the factors originally identified as key constructs of safety culture in the literature (e.g., Flin et al., 2000; Gadd & Collins, 2002; Guldenmund, 2000) persisted in later reviews (e.g., Beus et al., 2019; O'Connor et al., 2011). Similarly, there was considerable overlap of the safety culture dimensions identified by different regulatory agencies such as the DOT (Morrow & Coplen, 2017) and IAEA (2020). The IAEA (2020) developed a harmonized safety culture model using these elements, supplemented with specific actions and behavioral changes that can support safety culture promotion. There is also overlap in the dimensions of safety culture identified in other industries such as healthcare (Chidester, 2016; Churruca et al., 2021; Flin et al., 2006) and construction (Gillen et al., 2014).

The first and senior authors identified the most-recently published review paper from each safety-critical field, then worked independently to map the dimensions

identified in each review.[22] During the mapping process, we found that some literature discussed categories with finer-grained detail or higher specificity than others did, necessitating a combination of certain dimensions. Future researchers may want to consider separating the dimensions of interest for specific industries or work groups. We noted, for example, that more specificity might be warranted for (a) Competence versus Organizational Learning, (b) Communication versus Safety Rewards, and (c) Work Procedures versus Work Pressure.

The mapping also revealed that the safety culture dimensions have evolved across time. Since critical reviews published in the early 2000s (e.g., Guldenmund et al., 2000), researchers have begun to empirically address those criticisms by considering (and incorporating) a wider variety of safety culture and outcome measures. As such, topics have since emerged that include organizational learning, respectful work environment, and safety involvement (e.g., employee empowerment). Other topics are studied less frequently because they are from narrow literature on SMS (e.g., safety system, risk management, resource allocation) or behavior based safety (e.g., safety rewards).

Our analysis revealed that previous studies used an average of 8.4 dimensions (*range* = 5-11). With the addition of the newer topics, we arrived at eleven dimensions. Overall, we believe this updated set of eleven dimensions reflects the current understanding about the most critical safety culture dimensions and may be beneficial to organizations aiming to identify qualities or traits that may need improvement (see Table 2). For each dimension, a review of the relevant literature is provided. The bulleted action items provided for each dimension are strategies that can be used to improve safety culture.[23]

Table 2.
Safety Culture Dimensions Frequently Identified in the Literature

Safety Culture Dimension	Agreement
Management and Supervisory Commitment	100%
Organizational Learning	89%
Safety Communication	89%
Ownership and Involvement	78%

[22] Initial inter-rater agreement was 91%. Differences were resolved through discussion, with final inter-rater agreement of 100%.
[23] For operationalized guidance, please see EUROCONTROL / FAA Action Plan 15 Group (2008) and NASEM (2016).

Safety Culture Dimension	Agreement
Safety System	78%
Resource Allocation	67%
Work Procedures	67%
Decision-Making	56%
Respectful Work Environment	56%
Risk Management	56%
Just Culture	44%

Trends in the empirical research suggests that these identified dimensions are becoming increasingly important. The judgement of the authors, together with the trends provided by previous empirical research, informs this report. It must be recognized that the dimensions provided are not mutually exclusive, and that other researchers may disagree with the way dimensions are categorized in this report. The dimensions presented in this report are not intended by the authors to form the basis of a new standard or new taxonomy, nor are they meant to represent any organizational intent among other researchers. Rather, they are to be used as a common point for new discussion.

Safety System: Formalized Safety and Risk Management Systems

Safety System refers to "…any formalised strategic system to control HSE" [24] (Cooper, 2018) and the extent to which "issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance" (Keefe et al., 2014; Morrow & Coplen, 2017).[25,26]

- Identify "…safety as a core value or guiding principle of the organization" (Wiegmann et al., 2002).
- Consider safety culture as a complex ecological system that includes not only individuals but also organizations, communities, and social norms (Ward et al., 2010b).

[24] i.e., Health, Safety, and Environment.
[25] This statement now forms part of the Nuclear Regulatory Commission's (2022) Safety Culture Policy Statement. See https://www.nrc.gov/about-nrc/safety-culture/sc-policy-statement.html
[26] See also O'Connor et al. (2011).

- Regularly assess safety climate because of the dynamic nature of safety climate and safety behavior (Cooper & Phillips, 2004).
- Establish long-term solutions for permanent and enduring shifts in culture. Short-term solutions are temporary (Ward et al., 2010b).
- Continue to persist in assessing and improving safety culture as a "way of life" within the organization (McSween, 2003).
- Recognize the importance of employee perceptions of management values, safety communication, safety practices, safety training and safety equipment (Griffin & Neal, 2000).
- Promote and provide safety policies and safety equipment (Flin et al., 2000).
- Establish and maintain a viable system of safety audits and reporting of safety risks and hazards:
    - Make reporting easy and support trust (Reason, 1998).
    - Make reporting forms readily available and easy to use (Leva et al., 2015).
    - Communicate and provide feedback regarding actions taken in response to hazard reporting (Cooper, 2000; Reason, 1998).
    - Allow and engage members of the safety community to submit concerns (Ward et al., 2010b).
- To promote reporting, it is recommended that a good reporting system should:
    - Provide a clear policy on just culture (Reason, 1998).
    - Provide motivation for reporting, a user-friendly reporting form (Leva et al., 2015).
    - Provide adequate training and instructions for reporting usable content (Cooper, 2000; Reason, 1998).
    - Provide feedback to those reporting (Cooper, 2000; Reason, 1998).
    - Provide regular follow-ups that demonstrate reporting outcomes.

Risk Management: Identifying and Mitigating Risks

Risk Management refers not just to the higher perception of threats, but also "…to (a) risk appraisal; (b) risk assessment; and (c) risk controls" (Cooper, 2018; O'Connor et al., 2011). Both employees and management need to mutually acknowledge and understand the risks within their operations to achieve a positive safety culture (Chidester, 2016; SMICG, 2019). Specific behaviors that convey a positive safety culture include:

- "[Acknowledge] the high- risk nature of an organization's activities…" (Chidester, 2016).
- "…Understand the unique risks…" (IAEA, 2020).

- "…Recognize and plan for the possibility of mistakes, unforeseen problems and unlikely events…" (IAEA, 2020).
- "…Recognize that complacency often comes with success and continually strive to avoid it in themselves and others" (IAEA, 2020).
- "…Stop when uncertain and seek advice" (IAEA, 2020).
- "…Question assumptions and [be] prepared to offer different perspectives…" (IAEA, 2020).
- Recognize the importance of reporting risks/hazards and near misses (Leva et al., 2015; Williamsen, 2013).

Decision Making: Decisions that Put Safety First

Decision making, in a safety culture context, refers to the "…systematic, rigorous, and thorough…" nature of decisions (Keefe et al., 2014). Decision making also encompasses problem identification, resolution, and risk management. In a healthy safety culture, decision makers will prioritize safety even if it conflicts with achieving operational demands. Specific behaviors that convey a positive safety culture include:

- "…Use a consistent, systematic approach to evaluate relevant factors, including risk, when making decisions" (IAEA, 2020).
- Collect "…high-quality information…" from all relevant sources (IAEA, 2020).
- Determine that actions are "…safe before proceeding, rather than proceeding until proven unsafe" (IAEA, 2020).
- Recognize the inherent conflict between safety and productivity (Reason, 1998).
    - "…Emphasize that safety is prioritized over competing demands" (Morrow & Coplen, 2017).
    - "…Consistently choose safety over performance when faced with the choice of cutting corners to increase performance" (Morrow & Coplen, 2017).
    - Increase the number of supervisor communications with employees on safety rather than productivity (Zohar, 2002).
- "…Develop the ability to adapt" (IAEA, 2020).

Organizational Learning: Informing the Future by Looking for Lessons to Learn

Organizational Learning refers to "a learning-oriented environment that continually searches for opportunities to improve safety" (Morrow & Coplen, 2017). Organizations must be willing to look to the past for lessons that can inform safety

improvements for the future (SMICG, 2019). Organizations with a strong learning culture exhibit a "…willingness and ability … to proactively learn and adapt its operations…" (Wiegmann et al., 2002). Specific behaviors that convey a positive safety culture include:

- Regularly monitor and assess safety "…through a variety of techniques…" (IAEA, 2020; Patankar et al., 2012).
- Systematically and effectively collect, evaluate, and implement "…relevant internal and external lessons learned" (IAEA, 2020).
- "[Learn] from other organization's practices, including other industries" (IAEA, 2020).
- Share lessons learned with relevant organizations (IAEA, 2020).

In the earliest safety culture literature, this dimension focused on employee competence and training; consequently, interventions targeted employee training to increase knowledge about safety culture. Training can help to reinforce the organization's shared goals and values, and may be viewed as a necessary precursor to behavioral change. For this reason, safety-related training usually is part of the organization's intervention, and should be directed at employees at all levels of the organization. However, caution is warranted when implementing training.

Early safety-related training efforts were focused on shifting individual employee behaviors (e.g., compliance) rather than holistic organizational change. These courses led to passive attitude change among employees, but backlash occurred when employees felt that the programmatic approach to culture change promised by management failed to meet their expectations (McDonald et al., 1997, 2000; Taylor & Patankar, 2001).

A more successful approach is one that strives for changes at both the individual and the organizational level and is behavior-based (Taylor & Patankar, 2001). Such training should emphasize shared responsibility for safety, commitment to long-term safety goals, safety behavior changes (rather than attitude changes), and building trust between front-line employees and supervisors. In various case studies, positive outcomes included: attitude changes for self and others, ability for management to identify root causes and make process changes to prevent similar errors in the future, and readily observable behavior changes on the part of employees (Taylor & Patankar, 2001).

One successful illustration of shared responsibility for safe performance is the "Wobbly Steps" metaphor (Cromie et al., 2015). This metaphor illustrated how the foundation for safety performance is based on resources from both the individual (i.e., experience, risk awareness, skills, initiative) and the organization (i.e., tools, equipment, documentation, training, supervision, personnel). If the employee does not have enough

resources to complete the task safely, there is a temptation to add some "wobbly steps" to reach the goal. For additional detail about this safety-related training program, see Appendix B.

In summary, safety-related training is effective for shifting attitudes, intentions to change, and sometimes, achieving positive outcomes. However, evidence of sustained culture change through training efforts is limited. One interpretation of these results is that training alone is not enough to alter safety culture in the long term. Training can create a shared vision of the organizational values, but organizations that do not follow up the training and other intervention efforts risk the organizational and safety culture collapsing. Specific actions for improving safety culture through training include:

- Ensure that all employees have sufficient job-related training (Flin et al., 2000; Reason & Hobbs, 2003), and conduct competence assessments (Flin et al., 2000).
- Ensure managers are knowledgeable of the role of human, technical, organizational, and environmental factors that influence system safety (Morrow & Coplen, 2017).
- Promote an informed culture (Reason, 1998).
- Use human and organizational factors training as a risk management intervention (Cromie, et al., 2015). "… [Provide] effective training and [ensure] knowledge transfer…" (IAEA, 2020).
- Develop competent leaders through "…leadership training and succession management processes" (IAEA, 2020).

Just Culture: Fair, Just, and Consistent Responses to Safety Concerns

Just Culture refers to a "…blame- free environment where individuals are able to report errors or near misses without fear of reprimand or punishment" (Chidester, 2016; Morrow & Coplen, 2017). This includes not only the reporting system, but also the structured feedback system to inform employees that their suggestions or concerns are being addressed (Wiegmann et al., 2002). Specific behaviors that convey a positive safety culture include:

- "[Clearly state and effectively implement] a policy that supports an individual's rights and responsibilities to raise safety concerns" (IAEA, 2020).
    - The organizational policies should clearly spell out a just, learning, and reporting culture. This ensures employees that the organization will learn from events, which is key to ensuring participation (Reason & Hobbs, 2003).

    - Policies should also clearly distinguish between acceptable and unacceptable behavior. Punishments should not be a first-line correction, but rather should when there is a clear violation of acceptable behavior (Hudson, 2003).
- "…Respond to safety concerns in a manner that employees perceive as fair, just, and consistent" (Morrow & Coplen, 2017).
- "…Ensure that employees will not experience reprisals or negative outcomes as a result of using the reporting system…" (Wiegmann et al., 2002).[27]
- Avoid blame and shame (Reason & Hobbs, 2003).
- Reporting incidents should not be a negative experience for employees (McSween, 2003).
- "…Have a structured feedback system to inform the employees that their suggestions or concerns have been reviewed and what kind of action will be taken to solve the problems" (Wiegmann et al., 2002).
- "[Provide timely feedback] to the concerned individual" (IAEA, 2020).
- Normalize safety reporting and "[implement] at least one method for raising and resolving concerns that is confidential and independent of line management influence" (IAEA, 2020).

Resource Allocation: Availability of Resources to Achieve Safety

Resource Allocation includes "…the efforts put forth to ensure that every aspect of its operations, such as equipment, procedures, selection, training, and work schedules, are routinely evaluated and, if necessary, modified to improve safety" (Wiegmann et al., 2002). Furthermore, "those who manage and operate the system must have up-to-date knowledge about the human, technical, organizational, and environmental factors that determine the safety of the system as a whole, and they must have the tools and equipment to perform their jobs as safely as possible" (Morrow & Coplen, 2017).[28] Specific behaviors that convey a positive safety culture include:

- "…Demonstrate an enduring, positive attitude toward safety, even in times of fiscal austerity" (Wiegmann et al., 2002).
- "…Ensure that the personnel, procedures, and other resources needed to ensure safety are available" during the course of operations (Morrow & Coplen, 2017).

---

[27] Wiegmann et al. (2002) discussed this as a requirement of "Safety Systems".
[28] See Beus et al. (2019) for a discussion of "Safety Equipment and Housekeeping"; see Chidester (2016); see also O'Connor et al. (2011) for a discussion of "Resources".

    - Maintain a proper balance between job demands and job resources (Cooper & Fogarty, 2015; Cooper et al., 2018).
    - "Provide training, equipment, and human resources to facilitate the [culture] change" (Patankar et al., 2012).
    - Implement procedures to mitigate employee fatigue (Caldwell et al., 2019).
- When they arise, "[commit] resources to address safety concerns" (Chidester, 2016).

Management and Supervisory Commitment

Management and Supervisory Commitment refers to the involvement of an organization's leaders in critical safety activities with active oversight of everyday operations (Wiegmann et al., 2002). Overall, management must have a clear role (McSween, 2003), promote safety, establish safety policies, allocate the necessary resources for safe completion of work tasks, and establish employee priorities when addressing change (Flin et al., 2000). Their involvement is supported by frequent, purposeful, committed, and clear communications between management and employees that reinforce a positive safety culture (Beus et al., 2019; Keefe et al., 2014; O'Connor et al., 2011; Wiegmann et al., 2002). This also includes "what leaders are being held accountable for" (Cooper, 2018).

The commitment and investment of leadership and safety champions were identified as key factors in successful culture change efforts (Hale et al., 2010). Eklöf et al. (2017) stated, "change is dependent on a collective reconceptualization of the degree to which safety is valued within the organization, based on perceptual cues of a change in policy, procedures and practice, *largely emanating from managerial activities*" (p. 12, emphasis added). Leadership safety commitment and involvement are the biggest 'pieces of the pie' (i.e., variance) when accounting for perceptions of safety culture (Zohar, 2014).[29]

As Zohar (2014) noted, "the more coherent and comprehensive safety policies are and the more frequently they are communicated and implemented…the greater is perceived management commitment to employee protection, *constituting the core meaning of safety climate*" (p. 318, emphasis added).

---

[29] Most models of safety culture include management and supervision elements. For instance, Thompson et al. (1997) developed a model linking management support, organizational climate, and self-reported safety outcomes, underscoring the important role that management plays in promoting workplace safety.

Organizational emphasis on safety often begins with senior management through formal safety policies (Flin et al., 2000; McSween, 2003), but should be shared with all employees in formal written and oral communications. It is important to note that senior and middle management implement these policies, but employees gain an understanding through the communications and actions of their front-line leadership (i.e., supervisors and team leads). Supervisors serve as important intermediaries in translating and communicating safety policies/procedures, and are a key influence on safety outcomes (Flin et al., 2000; Hofmann et al., 2017; Patankar et al., 2012; Zohar, 2000). Supervisors play a role in promoting safety by affecting the level of fairness in their organization's climate, which in turn, impacts perceived compliance with safety rules (Thompson et al., 1997). As such, leaders must "walk the walk" and model the desired behaviors for successful change management to occur. Behn et al. (1999) found that specific actions intended to demonstrate the importance of safety can lead to higher perceptions of management and supervisory support for safety, along with higher perceived workplace safety. Specific behaviors that may promote a safety culture include daily safety huddles or meetings, leadership involvement and attendance at meetings, and empowering and engaging experts to identify and resolve safety issues as they come up (see IAEA, 2020; Wiegmann et al., 2002). Other behaviors of management and supervisors that convey a positive safety culture include:

- "…[Personal involvement] in critical safety activities…" (Wiegmann et al., 2002).
- "…Presence and contribution to safety seminars and training active oversight of safety critical operations…" (Wiegmann et al., 2002).
- "'Stay in touch' with the risks…" (Wiegmann et al., 2002).
- "…Involvement in work and safety activities…" (O'Connor et al., 2011).
- Management should take time to walk the floor of the area they manage (Peters & Waterman, 1982).
- Management should talk with employees about their on the job (OTJ) performance in addition to walking the floor they manage (Komaki, 1998).
- "…Frequent, informal communications between workers and management…" (O'Connor et al., 2011).
- Leaders in safety should be forward thinking, knowledgeable about safety status quo, and willing to embrace practices such as constructive criticism and open dialogue (Ward et al., 2010b).
- "…Model safety-first attitudes and behaviors…" (Morrow & Coplen, 2017).

- "…Establish and promote organizational priorities that place safety above competing goals" (IAEA, 2020).[30]
- "…Set an example for safety" (IAEA, 2020).
- "…Seek the active involvement of individuals at all levels in identifying and resolving issues" (IAEA, 2020).
- "…Ensure that personnel, equipment, procedures, and other resources are available and adequate to support safety" (IAEA, 2020).
- "…Ask questions, communicate, coach, and reinforce standards and expectations" (IAEA, 2020).
- "…Listen to and act upon the concerns and feedback from the workforce" (IAEA, 2020).
- "…Ensure rewards and sanctions encourage attitudes and behaviors that promote safety" (IAEA, 2020).
- "…Use a systematic process for communicating and implementing change…" (IAEA, 2020).
- "[Assess the impact of the change] on safety before, during, and after the change" (IAEA, 2020).
- "…Ensure that authorities, roles, and responsibilities are clearly defined and understood" (IAEA, 2020).

Respectful Work Environment: Fostering Mutual Trust

Respectful Work Environment refers to trust and respect across roles within an organization (Keefe et al., 2014). A respectful work environment built on trust and respect is more likely to have employees who are willing to raise safety concerns (Morrow & Coplen, 2017). This includes how the organization responds to differing professional opinions and deference to expertise. In the management literature, psychological safety is achieved when individual employees feel comfortable voicing their ideas and concerns with their team, without fear or risk to their individual stature or to their career (Edmondson, 1999; Kahn, 1990; see Newman et al., 2017, for a review). Specific behaviors that convey a positive safety culture include:

- "…Understand and accept the value of diverse thinking in optimizing safety" (IAEA, 2020).
- "[Encourage individuals] to ask questions, voice concerns, and provide suggestions" (IAEA, 2020).

[30] See IAEA (2020) recommendations for Safety Communication (discussed below).

- "[Solicit and respect] differing opinions…" (IAEA, 2020).
- "[Resolve conflicts] in a timely manner" (IAEA, 2020).
- Foster openness, honesty, and trust between individuals, work groups, and throughout the entire organization (IAEA, 2020; Patankar et al., 2002, 2012).

Ownership and Involvement

Ownership and Involvement in a positive safety culture requires that employees recognize the importance of safety and take personal responsibility for it (Keefe et al., 2014; SMICG, 2019).[31] This also includes "employees' appraisal of the extent to which their fellow coworkers are committed to workplace safety" (Beus et al., 2019).

Involvement is the voice that employees have in initiating and achieving safety improvements, as well as holding themselves and others accountable for safety (Beus et al., 2019; Wiegmann et al., 2002). This also includes employee empowerment, where a positively empowered attitude "…can lead to increased motivation to 'make a difference,' to go beyond the call of duty for organizational safety and take responsibility for ensuring safe operations (Geller, 1994; see Wiegmann et al., 2002). In a positive safety culture, employees are constantly vigilant for inappropriate or unsafe conditions and are encouraged to speak up to help resolve safety issues (Beus et al., 2019; Keefe et al., 2014; Morrow & Coplen, 2017).

Organizational change will only be successful if there is a shared responsibility and active involvement by all stakeholders (Neal & Griffin, 2006; Wachter & Yorio, 2013). As previously discussed, leadership, employees, and other stakeholders (e.g., regulators) have a *shared responsibility* for creating and maintaining a positive safety culture. Effective safety management requires first-hand knowledge of the job resources, job demands, and day-to-day work processes of the organization—this is information that front-line employees contribute. By requesting that employees report their safety concerns, the organization can identify targeted areas in need of improvement (Cook & McSween, 2000). Specific behaviors that convey a positive safety culture include:

- Recognize the importance of safety (SMICG, 2019).
- "…Take personal responsibility for safety" (Keefe et al., 2014).
- "…Take more ownership in safety procedures…" (Morrow & Coplen, 2017).
- "…Understand and accept the importance of standards, processes, procedures, expectations and work instructions" (IAEA, 2020).

[31] See also O'Connor et al. (2011) for a discussion of "Operations Personnel" and SMICG (2019) for a discussion of "Behavior".

- "…Adhere to standards and expectations" (IAEA, 2020).
- "…Speak up when they see other employees behaving in an unsafe manner" (Morrow & Coplen, 2017).
- "…Promote safe behaviours in all situations and coach others when necessary" (IAEA, 2020).
- "…Help each other achieve goals by communicating and coordinating their activities within and across organizational boundaries" (IAEA, 2020).
- Involve employees in decision-making and acknowledge the importance of employee morale (Cooper & Phillips, 2004; Cox & Flin, 1998; Fogarty, 2004).
- Encourage participation in safety activities, as it can increase safety motivation (Neal & Griffin, 2006; Wachter & Yorio, 2013).
- Include all employees (administrators, management, and subordinates) in safety processes and decisions, as this results in improved communication, understanding of employee concerns, and overall safety resource allocation (Cook & McSween, 2000; McSween, 2003).

Safety Communication: Information Sharing across the Organization

Safety Communication refers to "…employees' perception of the effectiveness of communication regarding safety issues" (Beus et al., 2019) and "…the extent to which information is distributed to the right people in the organization" (SMICG, 2019). "Employees must feel comfortable communicating to their supervisors about safety issues and communicating with their peers when they see unsafe behaviors" (Morrow & Coplen, 2017). Direct communication across work groups, which may be "informal and spontaneous", helps support a positive safety culture (O'Connor et al., 2011). Communication across levels of an organization must "…maintain a focus on safety" (Keefe et al., 2014) and promote collaboration so that different parts of an organization can work together when seeking solutions to safety problems (Chidester, 2016).

Communication is an essential function of safety management. Kanki (2010) provides an excellent structure for the functions communication plays in aviation and aviation safety, such as conveying information, establishing relationships, establishing behavior and expectations, maintaining attention, and is a management tool (see also Krivonos, 2007). Safety-related information exchange, and more importantly, perceptions of how the information is utilized influences interpersonal trust and psychological safety (Patankar et al., 2002). Specific behaviors that convey a positive safety culture include:

- "…Communicate openly and candidly, both up, down, and across the organization" (IAEA, 2020).

- "…Frequently communicate and reinforce the expectation that safety is emphasized over competing goals" (IAEA, 2020).[32]
- "[Include safety communication] in all work activities so that everyone has the information necessary to work safely and effectively" (IAEA, 2020).
- "…Ensure that the reasons for technical and administrative decisions are communicated to the appropriate individuals in a timely manner" (IAEA, 2020).

High-quality exchanges between supervisors and employees can result in higher perceptions of safety climate and safety consciousness, which can reduce safety-related events and occupational injuries (Barling et al., 2002). For this reason, efforts to improve the safety culture have often focused on the role of supervisor safety communications, and there is strong evidence that changing supervisor behaviors can lead to culture change. In an evaluation of over 20 safety culture interventions, those promoting dialogue between front-line, and supervisors were rated as most successful (Hale et al., 2010).

For example, in one large-sample study conducted over a three year-period, researchers implemented a program of SMBWA (Luria & Morag, 2012). Managers, supervisors, and peers walked around observing technicians' behaviors, and provided feedback (i.e., positively reinforced safe behavior, questioned inappropriate behavior, or provided job training on proper task completion). Following each tour, reports were made of the number of occasions positive or corrective feedback was provided and when OTJ training occurred. This approach was viewed as a powerful learning mechanism and was positively associated with identification and correction of safety hazards in the work environment. Both positive and corrective feedback increased over time. This program was shown to be successful in that it reduced non-compliance, increased identification of hazards, and increased safety communications (Luria & Morag, 2012). Other research using similar safety communication intervention strategies have found significant improvements in safety climate, safety behavior, subjective workload, teamwork, and safety audit scores for experimental groups, compared to a control group with no intervention (Zohar & Polachek, 2014).[33]

Supervisors may need to be explicitly trained on why and how to increase safety-related communication. Studies have shown that training supervisors on effective communication practices with their employees can improve many safety-related

---

[32] See IAEA (2020) recommendations for *Management and Supervision* (discussed above).

[33] A notable exception is that safety behavior increased in the control group as well as the experimental group, suggesting that the change in safety behavior may have been due to being measured in the study, rather than an actual change in safety behavior due to intervention (i.e., the Hawthorne effect; Landsberger, 1958).

outcomes (e.g., use of personal protective equipment (PPE), safety culture ratings, injury rates, safety performance; Kines et al., 2010; Zohar, 2002). This kind of safety communication intervention strategy has been successful in various fields including dairy production plants (Eklöf et al., 2017), firefighter crews (Allen et al., 2010), and manufacturing (Cooper & Phillips, 2004). These findings demonstrate the importance of the role of supervisors' communications in ensuring that employees follow procedures and that safety behaviors are reinforced in the workplace.

Previous literature reviews on safety culture suggest that when supervisors monitor and reinforce safe behaviors, employees perform more safely in the future (Hofmann & Morgeson, 2004). For example, one literature review revealed that targeting specific safety behaviors were effective in improving safety behaviors in all nine studies; eight found lower injury and illness rates (Grindle et al., 2000). Meta-analytic studies have shown that safety rewards such as money, feedback, and social recognition can positively influence task performance (Stajkovic & Luthans, 2003) and reduce accident and injury rates (Tuncel et al., 2006). Importantly, the reward systems should be "formally documented, consistently applied, and thoroughly explained and understood" (Wiegmann et al., 2002). Specific actions may include:

- Align performance evaluation and reward metrics with the desired behaviors (Patankar et al., 2012).
- Specifically define how employees (at all levels) will behave in a healthy, improved safety culture (Patankar et al., 2012; see also Hudson, 2003).
- Provide praise, recognition, or other rewards for safe behavior (Beus et al., 2016, 2019; Wiegmann et al., 2002).

A remaining question is whether these behavior-based interventions can improve the safety culture itself; thus, additional research is needed.

Work Procedures and Rules

Work Procedures and Rules refers to the way work activities are planned, documented, and completed while ensuring safety is maintained (Cooper, 2018; Keefe et al., 2014; O'Connor et al., 2011). This includes perceptions of safety rules and attitudes towards rules and compliance (O'Connor et al., 2011). This also includes managing work pressure, i.e., "…the conflict that stems from competing priorities, lack of resources or of a willingness to treat safe production as the number one priority" (Cooper, 2018).[34] Often

[34] O'Connor et al.'s (2011) treatment of "Operations Personnel" incorporates work pressure, which is discussed as *Commitment and Accountability* (below).

pressure is cited as a factor in either cutting corners or other more-direct violations of procedures, as "in the course of real work, under conditions of time pressure, uncertainty, and competing responsibilities, people must continually balance thoroughness in performance of their work with efficiency" (Patankar et al., 2012, p. 157; see also Alper & Karsh, 2009; Mason, 1997). Specific behaviors that convey a positive safety culture include:

- Establish "…a systematic approach of selecting, scheduling, coordinating, and completing work activities such that safety is emphasized" (IAEA, 2020).
- Preserve safety margins. "…Safety margins are understood, carefully maintained and changed only through a systematic and rigorous process" (IAEA, 2020).
- "Documentation, including procedures, is complete, accurate, accessible, user-friendly, understandable, and up-to-date. Changes are tracked" (IAEA, 2020).
- Understand the influence of work group norms on procedure following (McDonald, 2001).

Employees sometimes develop and follow non-approved methods and work norms for task completion.[35] These norms may be social, adaptive responses to environmental circumstances such as time pressure to complete tasks faster and easier (Civil Aviation Authority, 2003; Holden, 2009; Leveson, 2004). Management should be aware that work norms are an inevitable part of human performance, should implement methods to detect and mitigate norms of deviance, and should set clear criteria for acceptable behavior (Hudson, 2003). For further discussion, see Key et al. (2022).

Resolving 'blockers' to effective and safe completion of work tasks is one way of improving safety culture. In one intervention, Ward et al. (2010a) created a checklist of 'blockers' that could be noted during task performance. The checklist of blockers included: parts and materials, equipment and tools, people resources/manpower, environment, technical documentation, process clarity, and communication (Ward et al., 2010a). When tasks needed more time to complete than planned (i.e., task overrun), the employee was asked to indicate a reason: (a) availability of tools, (b) unclear procedure, (c) communication with other staff, (d) planning too tight, or (e) other (please specify). In the first 20 tasks involving aircraft checks, Ward et al.'s checklist found 141 blockers to safe performance. These results identified areas where additional resources were needed to ensure safe performance of work procedures and tasks. Overall, this action-oriented research effort focused on improving work processes was successful; the work tasks were

[35] i.e., where there are no written procedures documenting or prohibiting the alternative method of completing the task.

completed on time, and both management and staff were pleased with the revised processes.

Summary

The most important indicators of a positive safety culture and risk found across the literature are summarized in Table 3. Interestingly, these indicators overlap with the organizational culture literature,[36] which helps lend support to the importance of these indicators.

Table 3.
Indicators of a Positive Safety Culture and Indicators of Risk

Indicators of a Positive Safety Culture	Indicators of Risk

• Adequate resource allocation (e.g., staffing, facilities; IAEA, 2020).
  • Includes adequate allocation of financial resources (FAA, 2022b).
• Leadership expresses commitment with words and actions (IAEA, 2020).
  • Includes management presence in the work environment (e.g., on the shop floor).
• Communication across all levels of the organization is clear, frequent, and transparent (IAEA, 2020).
  • There is at least one mechanism for the workforce to report safety concerns.
  • Safe behavior is rewarded; unsafe behavior is corrected.
• Decisions prioritize safety (i.e., over business needs; IAEA, 2020).
	• Ineffective use of resources (financial, staffing, facilities; see IAEA, 2020).
	• Procedures are inaccurate, unclear, or otherwise difficult to follow (IAEA, 2020).
	  • Includes tribal knowledge and other group norms of deviance.
	• Failure to communicate safety information across all departments within the organization (see IAEA, 2020).
	• Employees provide insincere responses to questions (e.g., during focus groups, surveys; IATA, 2019; NASEM, 2016).
	• Work pressure on employees that stems from competing priorities, lack of resources, etc. (Cooper, 2018).

[36] See Beer et al. (2005), Kane-Urrabazo (2006), Okumus (2003), Papanthymou and Darra (2017).

Indicators of a Positive Safety Culture	Indicators of Risk

• Safety information is incorporated in decisions.
• Risks are identified, analyzed, and mitigated (IAEA, 2020).
  • This includes acknowledgment that operations are high-risk in nature, vigilance for hazards, and a questioning attitude.
• Leadership and management provide fair and consistent responses to safety concerns at all levels of the organization (IAEA, 2020).
• The work environment is one of mutual trust and respect (including labor relationships (FAA, 2022b).
• The organization has in place a process for resolving conflicts and differing opinions (IAEA, 2020).
• Employees hold both themselves and others accountable for safety (i.e., safety is a shared responsibility; IAEA, 2020).
	• Employees (at any level of the organization) blame others for mistakes, errors (IAEA, 2020).
	• High employee turnover (at any level of the organization; FAA, 2020b).
	• Bureaucracy impedes collaboration and communication across business units.
	• Leaders and employees within the organization exhibit low respect for the voice of the safety department (Baker, 1998; Kanki & Hobbs, 2018).
	• The organization experiences rapid growth or downsizing (FAA, 2020b).
	• The organization has a weak relationship with its regulator (FAA, 2020b).
	  • Failure to oversee operations conducted under the certificate.

Managing Safety Culture Change

Safety culture promotion can be a significant organizational change, and should be managed as such. Many initiatives for change struggle to achieve their intended objectives. Features of successful initiatives may include:[37]

- ***Evidence-based and Data-driven.*** Change efforts should be based on a thorough assessment of current culture that identifies strengths, gaps, and opportunities for improvement.

[37] For reviews, see Beer (2003), Blackburn et al. (2011), Burnes (2004), By (2005), Isern and Pung (2006), Luecke (2003), McDonald (2015), Meaney and Pung (2008), Nytrø et al. (2000), Smith (2002).

- ***Appropriately Scoped.*** The success of change efforts is to some extent, dictated by the amount and nature of change needed.[38] Similarly, the success of change efforts may be dependent on the approach taken. Systemic adjustments to organizational systems, technology, and procedures may be more likely to succeed than interventions focused on shifting attitudes.
- ***Well-communicated***. Proactively communicating the organizational values/priorities and the action plan for change has multiple benefits, including improving employee engagement and buy-in, and reducing resistance to change (Blackburn et al., 2011).[39]

The change process will likely be iterative, which can give a perception that it is time-consuming, difficult, and prone to failure – but the benefits of a positive safety culture outweigh the up-front investments of time and effort. Remember, cultural interventions are more effective when they are managed as a significant organizational change. When done properly, they should result in improved organizational outcomes and safety culture when compared to baseline assessments.

Identifying Where Change Efforts are Needed

Following a baseline assessment of safety culture, organizations must identify what aspects of the workplace and safety culture need improvement. Critically, to protect the anonymity of responses this should be done by an unbiased party. When scoring and interpreting the results, raters must remember that no organization has a flawless safety culture; the results likely will be mixed. Positive results should be celebrated and rewarded while areas of improvement should be identified and addressed (Patankar et al., 2012).

The results should be shared back to employees, to let them know their voices are heard and that management is actively seeking ways to improve safety. In a user guide for culture assessment in healthcare, "the more broadly the results are disseminated, the more useful the information is likely to become and the more likely respondents will feel that taking the survey was worthwhile" (Sorra et al., 2019; p. 26). The action plan should also be communicated to ensure commitment of all relevant stakeholders (IATA, 2019). Communicating the results and action plan can potentially increase participation in

---

[38] However, future research is needed to better characterize this dependency.

[39] As part of a critical review of change management, By (2005) indicated that "…theories and approaches to change management... currently available to academics and practitioners are *often contradictory, mostly lacking empirical evidence* and supported by unchallenged hypotheses concerning the nature of contemporary organizational change management" (p. 369, emphasis added).

change management activities and trust in management, which are important foundations for improvement efforts to build on (Armenakis & Harris, 2002, 2009; Nytrø et al., 2000).

The Importance of Including Employees in Change Efforts

Employees from all levels of the organization should be directly involved in safety management and should champion any change efforts. If employees do not trust that management will follow through with the change efforts, or that the change efforts will improve the outcomes that employees care about, employees may only passively participate or may actively resist the change (Erwin & Garman, 2010; Furst & Cable, 2008). Resistance to change has been identified as a problem in aviation before (McDonald et al., 2002), but it can be managed by: (a) ensuring a high level and quality of communication, (b) ensuring employee understanding of, and confidence in, the success of the effort, (c) management consistency, and (d) employee participation in the process.

Employee participation in the change efforts is critical because employees from different workgroups will likely have different perceptions of areas and methods of change. Safety culture varies across individuals, groups, and organizations; as a function of national culture, job types/professional culture; and across sub-units within a single organization.[40] Safety culture perceptions vary by job role, as management and administrative personnel tend to have higher perceptions of safety culture than the workforce (Singer et al., 2003; Taylor, 2002; Zohar & Luria, 2005). Perceptions may also vary within job roles as a function of work units or supervisors, potentially due to differences in leadership characteristics (Zohar, 2000; see also Zohar, 2010, 2014; Zohar & Hofmann, 2012; Zohar & Luria, 2003, 2005).[41] Assessments should attend to the amount of variation across groups, as the variation itself can be an important indicator of the strength of the organization's safety culture (NASEM, 2016). Overall, variations in perceptions underscore the importance of including employees in assessment and change efforts.

---

[40] For reviews, see Atak and Kingma (2011), Helmreich (1999), Helmreich et al. (1996), Isla-Díaz and Díaz-Cabrera (1997), McDonald et al. (1997, 2000), Patankar (2003), Patankar and Taylor (2004), Singer et al. (2003), Taylor and Thomas (2003), Zohar (2000, 2010, 2014), Zohar and Hofmann (2012), Zohar and Luria (2003, 2005).

[41] Zohar (2014) explored how these variations may arise from multiple factors including the nature of the work (e.g., degree of routinization), the influence of unit management/supervision, the degree of supervisor discretion, and the degree of variation in common practices.

Most organizations will find it useful, perhaps even essential, to have safety champions or a guiding coalition within the organization who are dedicated to organizational change efforts (Patankar et al., 2012).[42] This is often someone from the organization's safety department or an outside consultant. Responsibilities will include obtaining management buy-in for the change initiatives, promoting the change and encouraging participation, defining logistics of the change efforts, analysis of results, implementation and monitoring of interventions, and identification and dissemination of the outcomes. Importantly, this person should be strongly committed to the organizational change efforts and be able to motivate participation by others.

Monitoring the Effectiveness of Change Efforts

Any organizational change effort involves the assessment of the response to intervention, to determine whether the intervention plan actually improved safety behaviors. Evaluations need to be conducted periodically to identify whether adjustments are needed and to ensure that steady progress is being made to achieve the designated objective(s). It would be beneficial to reassess safety culture annually or biannually, because there is some evidence that culture change is slow, and that actual improvements to safety culture may lag up to two years after the intervention begins (Bergman et al., 2014; Neal & Griffin, 2006). However, for specific behavioral changes, reassessment could occur more frequently. Organizations should develop measurable, specific performance goals and a corresponding timeline, and should assess progress routinely (Patankar et al., 2012). In short, the change process and reassessment timeline should be tailored to organizational needs.

Following through with the safety culture promotion plan as intended will be the most successful strategy for supervisors/managers to use to ensure culture promotion, and can prevent backlash, which can occur if the employees feel that their organization is not following through with the plan to improve (as discussed by Taylor & Patankar, 2001). The organization should continue any promotion efforts in-progress because if the plan is stopped prematurely or not followed correctly, then the safety culture may actually decrease. For an example of a successful change management effort in aviation, see Appendix C. Culture Change in Aviation: A Case Study. One consideration when taking on safety culture change and promotion is the "strong role" of research organizations that has helped ensure successful outcomes (Corrigan & McDonald, 2014). In Corrigan and McDonald's case study, the aviation organization and research team had been working together for over 15 years (2014). Because it is possible that not all organizations will

[42] See Soltanifar (2022) for guidance on occupational health and safety champions.

have that level of support for their safety culture change, a remaining question is how elements from previous successful efforts can be readily adapted, scaled, and implemented in organizations with more limited resources.

Discussion

This review identified the methods and strategies for safety culture assessment, improvement, and promotion. These methods, along with accompanying interpretive frameworks, must be used judiciously so that they provide accurate, useful, and actionable results that can help foster a positive safety culture. A synthesis of recommendations was selected from the pertinent scientific literature for discussion. Recommendations and lessons learned were collected from the literature, and are provided as recommendations to help future efforts for safety culture promotion achieve success and encourage organizations to follow paths that can help transition employees toward a positive safety culture. In other words, this review of the literature is intended to roadmap future research and safety culture promotion efforts.

The current review revealed several lessons. There are some measurement weaknesses from the older literature, such as inconsistent factor structure, limited recognition of the importance of factors that moderate/mediate the relationship between safety culture and accidents/incidents, and sparse attempts to link safety culture to its outcomes (Flin et al., 2000; Guldenmund, 2000). These have been overcome partially by the more recent studies using advanced statistical analyses and questionnaires with a wider set of organizational and individual factors. As discussed in this report, the newer literature provides actionable safety culture tools, methods, and guidance for managing change. We are hopeful that this review, documenting the actionable recommendations from the literature, will empower organizations to make continual strides towards a safer and more inclusive organizational culture through a better understanding of the different assessment methods, change management efforts, and monitoring efforts that are available today.

Limitations and Future Directions

First, our review provides a reasonably thorough, but not exhaustive, discussion of safety culture. An exhaustive discussion could include unnecessary detail and thus limit the practical import of the paper. Therefore, we selected the most important (or well-discussed) dimensions and intervention strategies from the literature, leaving others for future research.

A related limitation is that our categorization of safety culture dimensions were characterized as they have been most often described in the literature. It should be noted that the dimensions contained in this report are not a comprehensive list, but rather an indication that there are numerous intertwined elements of safety culture. There may be interactions or correlation among the dimensions. For example, safety involvement may be linked inextricably with communication. Similarly, there may be an interaction between learning culture and the quality of information shared. Employees may be more forthcoming when it comes to sharing safety-related mistakes and concerns if they trust that information will be used for learning rather than blaming them. Better information from employees, in turn, provides a richer base of information from which the organization can continue to learn and improve. It is also possible that some dimensions are more visible, such as the role of management and supervision. Their commitment and actions permeate and shape perceptions of other stakeholders, and are evidently a key driver of safety culture and performance (Zohar, 2014).

Finally, there are methodological limitations of the literature. Most of the available studies measured outcomes using employee self-reports and/or accidents, incidents, and injury records. A more holistic picture can emerge by also examining objective measures of safety behavior, compliance, participation, and errors. One recommendation, which is endorsed strongly here, is the *need for objective measures of safety outcomes and the inclusion of multiple outcomes rather than just injuries/accidents* (Beus et al., 2010). Cooper (2000) noted a need for objective measures of safety culture itself, as questionnaires only measure beliefs and thoughts, not actual safety culture behaviors. As Beus et al. (2010) noted that theoretical frameworks and developmental designs could help to determine which specific factors to focus on. Other recommendations for researchers include representative samples of organizations (Pronovost & Sexton, 2005) and tracking the relationships between safety culture, mediators, and outcomes across time (Beus et al., 2010; Neal & Griffin, 2006; Pronovost & Sexton, 2005). A longitudinal design is necessary to assess the impacts of organizational change and other events (e.g., technology, regulation change) that may influence safety culture over the long-term.

Practical Implications and Conclusions

Despite these limitations, it is evident from the literature that there is value for any organization aiming to assess and foster a positive safety culture. The literature in this review provide a synthesis of the current scientific understanding of safety culture. Safety culture assessments have been successfully applied across all phases of transportation, the oil and gas industry, manufacturing, construction, medicine and other

industries (Chidester, 2016; Keefe et al., 2014; Morrow & Coplen, 2017; NASEM, 2016). While our review points to areas in need of improvement, there is clear evidence of the benefits of improving an organization's safety culture (McSween, 2003; Zohar, 2014). Further, the common dimensions of safety culture identified here can support further development of theoretical frameworks for safety and organizational culture. Finally, this review identified areas where additional research is needed to make methodological improvements and establish best practices for safety culture assessment and promotion.

A key theme identified in this report is that the nature of safety culture is multi-dimensional and dynamic – requiring routine assessment, dedicated promotion, and continuous vigilance. Leadership, employees, and other stakeholders (e.g., regulators) have shared responsibility for creating and maintaining safety culture; everyone must do their part, or the safety promotion efforts will falter.

Safety culture promotion leans on the effectiveness of formalized safety systems and policies, risk management processes, and organizational decision-making that prioritizes safety over competing demands. This requires open communication and information sharing, so that pertinent safety-related information gets to the right decision-makers on time. There must also be an emphasis on organizational learning coupled with an understanding that no organization has a flawless safety culture, and that the quality of the culture is subject to change over time.[43]

Leadership commitment plays a key role in setting the overall tone, policies, and operational environment of the organization. However, stating safety policies is not enough; leadership must demonstrate their commitment and accountability for safety in their actions (i.e., they must "walk the talk"). This includes providing adequate resources for ensuring safety, rewarding and reinforcing safe behavior, and promoting a just culture (i.e., where there is a fair, just, and consistent response to safety concerns). Other important leadership actions are asking questions, ensuring open safety communication and information sharing. Finally, leaders should foster a respectful work environment where diverse professional voices are heard and trust is mutual. This environment is foundational for efforts to improve safety culture.

Employees play a complementary role. They must be committed, held accountable, and involved in safety. Their behaviors should include ensuring compliance with work procedures, processes, and standards; holding themselves and each other responsible for safe behavior, coaching others when needed; and remaining vigilant for

[43] The evolution of culture is shaped by changes in the workforce, as culture is learned from peers and supervisors (Schein, 2010; Zohar, 2014).

unsafe conditions and speaking up so that safety issues can be resolved in a timely manner. Of course, it is only fair to expect safe performance when employees are competent and provided with the necessary work training, procedures, rules, and other resources necessary for safe completion of work tasks. Ensuring that employees are equipped with the right training and resources for the job is an important part of safety management.

Ultimately, it is our hope that this review of common safety culture elements will support rigorous assessment and targeted continuous improvement in aviation safety culture.

References

Akselsson, R., Koornneef, F., Stewart, S., & Ward, M. (2009). Resilience safety culture in aviation organisations. In *HILAS (Human integration into the lifecycle of aviation systems)* (Preprint).

Allen, J. A., Baran, B. E., & Scott, C. W. (2010). After-action reviews: A venue for the promotion of safety climate. *Accident Analysis & Prevention*, *42*(2), 750-757. https://doi.org/10.1016/j.aap.2009.11.004

Alper, S. J., & Karsh, B. T. (2009). A systematic review of safety violations in industry. *Accident Analysis and Prevention, 41*(4), 739-754. https://doi.org/10.1016/j.aap.2009.03.013

Arendt, D. (2020). Safety and regulator cultures and impacts on safety performance: Exploration of concepts. *Proceedings of the European Association for Aviation Psychology.*

Armenakis, A. A., & Harris, S. G. (2002). Crafting a change message to create transformational readiness. *Journal of Organizational Change Management, 15*(2), 169-183. https://doi.org/10.1108/09534810210423080

Armenakis, A. A., & Harris, S. G. (2009). Reflections: Our journey in organizational change research and practice. *Journal of Change Management*, *9*(2), 127-142. https://doi.org/10.1080/14697010902879079

Atak, A., & Kingma, S. (2011). Safety culture in an aircraft maintenance organization: A view from the inside. *Safety Science*, *49*(2), 268-278. https://doi.org/10.1016/j.ssci.2010.08.007

Avers, K. E., Johnson, W. B., Banks, J. O., Wenzel, B., & Nei, D. (2011). *Prioritizing maintenance human factors challenges and solutions: Workshop proceedings* (Technical Report No. DOT/FAA/AM-11/11). Federal Aviation Administration, Office of Aviation Medicine. https://rosap.ntl.bts.gov/view/dot/23065

Avers, K. B., Johnson, W. B., Banks, J. O., & Wenzel, B. (2014). *The transition from event reports to measurable organizational impact: Workshop proceedings report* (DOT/FAA/AM-14/5). Federal Aviation Administration, Office of Aviation Medicine. https://rosap.ntl.bts.gov/view/dot/27203

Baker, R. H. (1998). *Climate survey analysis for aviation maintenance safety* [Master's thesis, Naval Postgraduate School]. https://apps.dtic.mil/sti/citations/ADA356610

Bakker, A. B., & Demerouti, E. (2007). The Job Demands-Resources model: State of the art. *Journal of Managerial Psychology, 22*(3), 309-328. http://dx.doi.org/10.1108/02683940710733115

Balk, A. D., & Bossenbroek, J. W. (2010). *Aircraft ground handling and human factors: A comparative study of the perceptions by ramp staff and management* (Report No. NLR-CR-2010-125). National Aerospace Laboratory, Air Transport Safety Institute. https://www.easa.europa.eu/sites/default/files/dfu/Aircraft-Ground-Handling-and-Human-Factors-NLR-final-report.pdf

Barling, J., Loughlin, C., & Kelloway, E. K. (2002). Development and test of a model linking safety-specific transformational leadership and occupational safety. *Journal of Applied Psychology*, *87*(3), 488. https://doi.org/10.1037/0021-9010.87.3.488

Baron, R. I. (2009). An exploration of deviations in aircraft maintenance procedures. *International Journal of Applied Aviation Studies, 9*(1), 197-206. https://www.academy.jccbi.gov/ama-800/Winter_2009.pdf#page=79

Becker, J., Knackstedt, R. and Pöppelbuß, J. (2009). Developing maturity models for IT management – a procedure model and its application. *Business & Information System Engineering, 3*, 213-222. http://doi.org/10.1007/s12599-009-0044-5

Beer, M. (2003). Why total quality management programs do not persist: The role of management quality and implications for leading a TQM transformation. *Decision Sciences*, *34*(4), 623-642. https://doi.org/10.1111/j.1540-5414.2003.02640.x

Beer, M., Voelpel, S. C., Leibold, M., & Tekie, E. B. (2005). Strategic management as organizational learning: Developing fit and alignment through a disciplined process. *Long Range Planning, 38*(5), 445-465. http://doi.org/10.1016/j.lrp.2005.04.008

Behn, L. D., Thompson, R. C., & Hilton, T. F. (1999). *Follow-up assessment of the Federal Aviation Administration's logistics center safety climate* (Technical Report No. DOT/FAA/AM-99/19. Federal Aviation Administration, Office of Aviation Medicine. https://rosap.ntl.bts.gov/view/dot/57903

Bergman, M. E., Payne, S. C., Taylor, A. B., & Beus, J. M. (2014). The shelf life of a safety climate assessment: How long until the relationship with safety–critical incidents expires? *Journal of Business and Psychology*, *29*(4), 519-540. https://doi.org/10.1007/s10869-013-9337-2

Beus, J. M., McCord, M. A., & Zohar, D. (2016). Workplace safety: A review and research synthesis. *Organizational Psychology Review*, *6*(4), 352-381. https://doi.org/10.1177/2041386615626243

Beus, J. M., Payne, S. C., Arthur Jr, W., & Muñoz, G. J. (2019). The development and validation of a cross-industry safety climate measure: Resolving conceptual and operational issues. *Journal of Management, 45*(5), 1987-2013. http://doi.org/10.1177/0149206317745596

Beus, J. M., Payne, S. C., Bergman, M. E., & Arthur, W., Jr. (2010). Safety climate and injuries: An examination of theoretical and empirical relationships. *Journal of Applied Psychology, 95*(4), 713-727. http://dx.doi.org/10.1037/a0019164

Blackburn, S., Ryerson, S., Weiss, L., Wilson, S., & Wood, C. (2011). *How do I implement complex change at scale*. McKinsey.

Burnes, B. (2004). *Managing change: A strategic approach to organizational dynamics*. Pearson Education.

By, R. T. (2005). Organizational change management: A critical review. *Journal of Change Management, 5*(4), 369-380. https://doi.org/10.1080/14697010500359250

Caldwell, J. A., Caldwell, J. L., Thompson, L. A., & Lieberman, H. R. (2019). Fatigue and its management in the workplace. *Neuroscience & Biobehavioral Reviews, 96*, 272-289. https://doi.org/10.1016/j.neubiorev.2018.10.024

Camm, F., Werber, L., Kim, J., Wilke, E., & Rudavsky, R. (2013).*Charting the course for a new air force inspection system*. RAND Corporation.

Chidester, T. R. (2016). Creating a culture of safety. In K. J. Ruskin, M. P. Stiegler, & S. H. Rosenbaum (Eds.), *Quality and Safety in Anesthesia and Perioperative Care*. Oxford University Press.

Christian, M. S., Bradley, J. C., Wallace, J. C., & Burke, M. J. (2009). Workplace safety: A meta-analysis of the roles of person and situation factors. *Journal of Applied Psychology*, *94*(5), 1103-127. https://doi.org/10.1037/a0016172

Churruca, K., Ellis, L. A., Pomare, C., Hogden, A., Bierbaum, M., Long, J. C., Hogden, A., Bierbaum, M., Long, J. C., Olekalns, A., & Braithwaite, J. (2021). Dimensions of safety culture: A systematic review of quantitative, qualitative and mixed methods for assessing safety culture in hospitals. *BMJ Open, 11*(7), http://dx.doi.org/10.1136/bmjopen- 2020-043982

Ciavarelli, A. (2002). *The development, validation, and application of online organizational safety effectiveness surveys* (Working Paper). Naval Postgraduate School, School of Aviation Safety.

Ciavarelli, A., Figlock, R., Sengupta, K., & Roberts, K. H. (2001). *Assessing organizational accident risk through survey questionnaire methods* [Paper Presentation]. 11th International Aviation Psychology Conference, Columbus, Ohio.

Civil Aviation Authority (2003). *Aviation maintenance human factors (EASA/JAR145 approved organisations): Guidance material on the UK CAA interpretation of Part-145 human factors and error management requirements (Chapter 3)*.

Clarke, S. (2006). The relationship between safety climate and safety performance: A meta-analytic review. *Journal of Occupational Health Psychology*, *11*(4), 315-327. http://doi.org/10.1037/1076-8998.11.4.315

Clarke, S. (2010). An integrative model of safety climate: Linking psychological climate and work attitudes to individual safety outcomes using meta-analysis. *Journal of Occupational and Organizational Psychology*, *83*(3), 553-578. https://doi.org/10.1348/096317909X452122

Clarke, S. (2012). The effect of challenge and hindrance stressors on safety behavior and safety outcomes: a meta-analysis. *Journal of Occupational Health Psychology*, *17*(4), 387. https://doi.org/10.1037/a0029817

Cole, K. S., Stevens-Adams, S. M., & Wenner, C. A. (2013). A Literature Review of Safety Culture (Report No. SAND2013-2754). Sandia National Laboratories. https://www.osti.gov/servlets/purl/1095959

Connell, L. J. (2004). Cross-industry applications of a confidential reporting model. In J. R. Phimister, V. M. Bier, & H. C. Kunreuther (Eds.) *Accident Precursor Analysis and Management: Reducing Technological Risk Through Diligence* (pp. 139-146). National Academies Press.

Consolidated Appropriations Act 2020, P.L. 116-93 (2019). https://www.govinfo.gov/app/details/PLAW-116publ93

Cook, S., & McSween, T. E. (2000). The role of supervisors in behavioral safety observations. *Professional Safety*, *45*(10), 33.

Cooper, M. D. (2000). Towards a model of safety culture. *Safety Science*, *36*, 111-136. https://doi.org/10.1016/S0925-7535(00)00035-7

Cooper, M. D. (2016). *Navigating the safety culture construct: A review of the evidence*. https://www.behavioral-safety.com/articles/safety_culture_review.pdf

Cooper, M. D. (2018). The Safety culture construct: Theory and practice. In C. Gilbert, B. Journé, H. Laroche, & C. Bieder (Eds.), *Safety cultures, safety models: Taking stock and moving forward* (pp. 47-61). Springer Open. https://library.oapen.org/bitstream/handle/20.500.12657/23084/1007074.pdf?sequence=1

Cooper, M. D., & Phillips, R. A. (2004). Exploratory analysis of the safety climate and safety behavior relationship. *Journal of Safety Research*, *35*(5), 497-512. http://doi.org/10.1016/j.jsr.2004.08.004

Cooper, R. M. & Fogarty, G. J. (2015). The snapshot survey: An x-ray view. *Aviation Safety Spotlight*, *3*, 34-39. https://eprints.usq.edu.au/29124/

Cooper, R. M., McMahon, S., & Fogarty, G. J. (2018) *Snapshot: A safety climate survey* (Technical Report). Australian Government, Department of Defence. http://eprints.usq.edu.au/id/eprint/34102

Corrigan, S., & McDonald, N. (2014). MASCA (Managing System Change in Aviation): What makes for successful change? Evidence from industrial-based research. *Journal of Airport Management*, *8*(4), 360-372.

Cox, S., & Flin, R. (1998). Safety culture: Philosopher's stone or man of straw? *Work and Stress, 12*(3), 189-201. https://doi.org/10.1080/02678379808256861

Cromie, S., Ross, D., Corrigan, S., Liston, P., Lynch, D., & Demosthenous, E. (2015). Integrating human factors training into safety management and risk management: A case study from aviation maintenance. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, *229*(3), 266-274. http://doi.org/10.1177/1748006X15572498

Curcuruto, M., & Griffin, M. A. (2018). Prosocial and proactive "safety citizenship behaviour" (SCB): The mediation role of affective commitment and psychological ownership. *Safety Science, 104*, 29-38. https://doi.org/10.1016/j.ssci.2017.12.010

Czech, B. A., Groff, L., & Strauch, B. (2014). *Safety cultures and accident investigation: Lessons learned from a National Transportation Safety Board forum* [Paper Presentation]. International Society of Air Safety Investigators 2014 Seminar, Adelaide, Australia.

Demerouti, E., Bakker, A. B., Nachreiner, F., & Schaufeli, W. B. (2001). The Job Demands-Resources model of burnout. *Journal of Applied Psychology, 86*(3), 499-512. https://doi.org/10.1037/0021-9010.86.3.499

Demerouti, E., Veldhuis, W., Coombes, C., & Hunter, R. (2019). Burnout among pilots: Psychosocial factors related to happiness and performance at simulator training. *Ergonomics*, *62*(2), 233-245. https://doi.org/10.1080/00140139.2018.1464667

Edmondson, A. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly*, *44*(2), 350-383. https://doi.org/10.2307/2666999

Eklöf, M., Pousette, A., & Törner, M. (2017). An intervention in management teams to improve workers' safety climate: A mixed-methods study of intervention process and effects. *Safety Science Monitor*, *20*(1).

Erwin, D. G., & Garman, A. N. (2010). Resistance to organizational change: linking research and practice. *Leadership & Organization Development Journal, 31*(1), 39-56. https://doi.org/10.1108/01437731011010371

EUROCONTROL / FAA Action Plan 15 Group (2008). *Safety culture in air traffic management* (White Paper). https://www.skybrary.aero/bookshelf/books/564.pdf

Federal Aviation Administration. (2015). *Safety management systems for aviation service providers.* (Advisory Circular No. 120-92B). https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-92B.pdf

Federal Aviation Administration. (2017). *FAA integrated oversight philosophy* (Order No. 8000.72[1-4c]). https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8000.72_s.pdf

Federal Aviation Administration. (2020). *Safety Management System* (Order No. 8000.369C). https://www.faa.gov/documentLibrary/media/Order/Order_8000.369C.pdf

Federal Aviation Administration. (2022a). *FY 2022 AVS business plan.* https://www.faa.gov/about/plansreports/avs-fy-2022-business-plan

Federal Aviation Administration. (2022b). *Safety assurance system: Planning* (Order No. 8100.1(10)(3)(1)). https://drs.faa.gov/browse/ORDER_8900.1

Federal Railroad Administration (2019). *Short line safety institute: Early outcomes after a safety culture assessment*. (Technical Report No. DOT/FRA/RR 19-18). Department of Transportation. https://rosap.ntl.bts.gov/view/dot/42484

Fleming, M. (2001). *Safety culture maturity model* (Report No. OTO-2000/049). Health and Safety Executive. https://www.osti.gov/etdeweb/biblio/20148920

Flin, R., Burns, C., Mearns, K., Yule, S., & Robertson, E. M. (2006). Measuring safety climate in health care. *Quality and Safety in Health Care, 15*(2), 109–115. https://doi.org/10.1136%2Fqshc.2005.014761

Flin, R., Mearns, K., O'Connor, P., & Bryden, R. (2000). Measuring safety climate: Identifying the common features. *Safety Science*, *34*(1-3), 177-192. https://doi.org/10.1016/S0925-7535(00)00012-6

Fogarty, G. J. (2004). The role of organizational and individual differences variables in aircraft maintenance performance. *International Journal of Applied Aviation Studies*, *4*(1), 73-90. https://eprints.usq.edu.au/926

Fogarty, G. (2005). Psychological strain mediates the impact of safety climate on maintenance errors. *International Journal of Applied Aviation Studies, 5*(1), 53-63.

Fogarty, G. J., Cooper, R. & McMahon, S. (2018). A demands-resources view of safety climate in military aviation. *Aviation Psychology and Applied Human Factors, 8*(2), 76-85. https://doi.org/10.1027/2192-0923/a000141

French, S., & Steel, T. (2017). *The investigation of safety management systems and safety culture* (International Transport Forum Discussion Paper No. 2017-20). Organisation for Economic Co-operation and Development, International Transport Forum. https://www.itf-oecd.org/sites/default/files/docs/investigation-sms-safety-culture.pdf

Furst, S. A., & Cable, D. M. (2008). Employee resistance to organizational change: managerial influence tactics and leader-member exchange. *Journal of Applied Psychology*, *93*(2), 453. https://doi.org/10.1037/0021-9010.93.2.453

Gadd, S., & Collins, A. M. (2002). *Safety culture: A review of the literature* (Report No. HSL/2002/25). Health and Safety Laboratory. https://www.hse.gov.uk/research/hsl_pdf/2002/hsl02-25.pdf

Geller, E. S. (1994). Ten principles for achieving a total safety culture. *Professional Safety, 39*(9), 18.

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

Gonzalez-Mulé, E., Kim, M. M., & Ryu, J. W. (2021). A Meta-Analytic Test of Multiplicative and Additive Models of Job Demands, Resources, and Stress. *Journal of Applied Psychology, 106*(9), 1391-1411. http://dx.doi.org/10.1037/apl0000840

Gordon, R., Kennedy, R., Mearns, K., Jensen, C. L., Kirwan, B., (2006). *Understanding safety culture in air traffic management* (EEC Note No. 11/06). EUROCONTROL. https://www.eurocontrol.int/sites/default/files/library/014_Safety_Culture_in_ATM.pdf

Gordon, R., Kirwan, B., & Perrin, E. (2007). Measuring safety culture in a research and development centre: A comparison of two methods in the air traffic management domain. *Safety Science, 45*(6), 669-695. https://doi.org/10.1016/j.ssci.2007.04.004

Griffin, M. A., & Curcuruto, M. (2016). Safety climate in organizations. *Annual Review of Organizational Psychology and Organizational Behavior*, *3*, 191-212. https://doi.org/10.1146/annurev-orgpsych-041015-062414

Griffin, M. A., & Neal, A. (2000). Perceptions of safety at work: A framework for linking safety climate to safety performance, knowledge, and motivation. *Journal of Occupational Health Psychology, 5*(3), 347-358. https://doi.org/10.1037/1076-8998.5.3.347

Grindle, A. C., Dickinson, A. M., & Boettcher, W. (2000). Behavioral safety research in manufacturing settings: A review of the literature. *Journal of Organizational Behavior Management*, *20*(1), 29-68. https://doi.org/10.1300/J075v20n01_03

Guldenmund, F. W. (2000). The nature of safety culture: A review of theory and research. *Safety Science*, *34*(1-3), 215-257. https://doi.org/10.1016/S0925-7535(00)00014-X

Guldenmund, F. W. (2007). The use of questionnaires in safety culture research - an evaluation. *Safety Science*, *45*(6), 723-743. https://doi.org/10.1016/j.ssci.2007.04.006

Guldenmund, F. W. (2018). Understanding safety culture through models and metaphors. In C. Gilbert, B. Journé, H. Laroche, & C. Bieder (Eds.), *Safety cultures, safety models: Taking stock and moving forward* (pp. 21-34). Springer Open.

https://library.oapen.org/bitstream/handle/20.500.12657/23084/1007074.pdf?sequence=1#page=29

Hale, A. R., Guldenmund, F. W., Van Loenhout, P. L. C. H., & Oh, J. I. H. (2010). Evaluating safety management and culture interventions to improve safety: Effective intervention strategies. *Safety Science*, *48*(8), 1026-1035. https://doi.org/10.1016/j.ssci.2009.05.006

Hansez, I., & Chmiel, N. (2010). Safety behavior: Job demands, job resources, and perceived management commitment to safety. *Journal of Occupational Health Psychology*, *15*(3), 267-278. https://doi.org/10.1037/a0019528

Helmreich, R. L. (1999). Building safety on the three cultures of aviation. *Proceedings of the IATA Human Factors Seminar*, 39-43. Bangkok, Thailand.

Helmreich, R. L., Merritt, A. C., & Sherman, P. J. (1996). Human factors and national culture. *ICAO Journal*, *51*(8), 14-16.

Hobbs, A., & Williamson, A. (2003). Associations between errors and contributing factors in aircraft maintenance. *Human Factors*, *45*(2), 186-201. https://doi.org/10.1518/hfes.45.2.186.27244

Hofmann, D. A., & Morgeson, F. P. (2004). The role of leadership in safety. In J. Barling & M. R. Frone (Eds.) *The psychology of workplace safety.* American Psychological Association.

Hofmann, D. A., Burke, M. J., & Zohar, D. (2017). 100 years of occupational safety research: From basic protections and work analysis to a multilevel view of workplace safety and risk. *Journal of Applied Psychology*, *102*(3), 375-368. https://psycnet.apa.org/doi/10.1037/apl0000114

Holden, R. J. (2009). People or systems? To blame is human. The fix is to engineer. *Professional Safety, 54(*12), 34-41. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3115647/

Hollnagel, E. (2009). The four cornerstones of resilience engineering. In C. P. Nemeth, E. Hollnagel, & S. Dekker (Eds.), *Resilience engineering perspectives: Preparation and restoration* (pp. 117-137). Ashgate.

Hudson, P. (2003). Achieving a safety culture for aviation. *Journal of Aviation Management*, 27-47.

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

International Air Transport Association. (2019). *Creating a positive safety culture: Best practices to align with Annex 19's new recommendations*. https://www.iata.org/en/services/statistics/safety-data/i-asc/

International Atomic Energy Agency. (2002). *Self-Assessment of Safety Culture in Nuclear Installations: Highlights and Good Practices* (Report No. IAEA-TECDOC-1321). https://www.iaea.org/publications/6615/self-assessment-of-safety-culture-in-nuclear-installations-highlights-and-good-practices

International Atomic Energy Agency. (2020). *A harmonized safety culture model* (Working Document). https://www.iaea.org/sites/default/files/20/05/harmonization_05_05_2020-final_002.pdf

International Civil Aviation Organization Annex 19. (2016). *Safety Management* (2nd Ed.). https://store.icao.int/en/annex-19-safety-management

International Nuclear Safety Advisory Group. (1992). *The Chernobyl accident: Updating of INSAG-1* (Report No. 75-INSAG-7). International Atomic Energy Agency. https://www-pub.iaea.org/MTCD/publications/PDF/Pub913e_web.pdf

Isern, J., & Pung, C. (2006, July). Organizing for successful change management: A McKinsey global survey. *The McKinsey Quarterly*. http://www.mckinsey.com/business-functions/organization/our-insights/driving-radical-change?cid=eml-web

Isla-Díaz, R., & Díaz-Cabrera, D. (1997). Safety climate and attitude as evaluation measures of organizational safety. *Accident Analysis and Prevention, 29*(5), 643-650. https://doi.org/10.1016/S0001-4575(97)00015-8

Jiang, L., Lavaysse, M., & Probst, T. M. (2019). Safety climate and safety outcomes: A meta-analytic comparison of universal vs. industry-specific safety climate predictive validity. *Work & Stress, 33*(1), 41-57. https://doi.org/10.1080/02678373.2018.1457737

Kahn, W. A. (1990). Psychological conditions of personal engagement and disengagement at work. *Academy of Management Journal*, *33*(4), 692-724. https://doi.org/10.5465/256287

Kane-Urrabazo, C. (2006). Management's role in shaping organizational culture. *Journal of Nursing Management, 14*(3), 188-194. https://doi.org/10.1111/j.1365-2934.2006.00590.x

Kanki, B. G. (2010). Communication and crew resource management (2nd ed.). In B. Kanki, R. Helmreich, & J. Anca (Eds.), *Crew resource management*. Academic Press.

Kanki, B. G., & Hobbs, A. (2018). Organizational factors and safety culture. In *Space safety and human performance* (pp. 621-651). Butterworth-Heinemann. https://doi.org/10.1016/B978-0-08-101869-9.00014-5

Keefe, M., Frahm, R., Martin, K., Sigmon, R., Shoop, U., Morrow, S., Sieracki, D., Powell, R., Shaeffer, S., Rutkowski, J., & Ruesch, E. (2014). *Safety culture common language* (Report No. NUREG-2165). U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation. https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr2165/index.html

Key, K. N., Schroeder, D. J., Durham, J. D., Choi, I., Hu, P. T., & Avers, K. E. (2022). *Procedural Noncompliance in Aviation Maintenance: A Multi-Level Review of Contributing Factors and Corresponding Mitigations* (Technical Report No. DOT/FAA/AM-22/01). Federal Aviation Administration. https://www.faa.gov/sites/faa.gov/files/data_research/research/med_humanfacs/oamtechreports/Procedural_Noncompliance_in_Aviation_Maintenance.pdf

Kines, P., Andersen, L. P., Spangenberg, S., Mikkelsen, K. L., Dyreborg, J., & Zohar, D. (2010). Improving construction site safety through leader-based verbal safety communication. *Journal of Safety Research*, *41*(5), 399-406. https://doi.org/10.1016/j.jsr.2010.06.005

Kines, P., Lappalainen, J., Mikkelsen, K. L., Olsen, E., Pousette, A., Tharaldsen, J., Tomasson, K., & Törner, M. (2011). Nordic safety climate questionnaire (NOSACQ-50): A new tool for diagnosing occupational safety climate. *International Journal of Industrial Ergonomics*, *41*(6), 634-646. https://doi.org/10.1016/j.ergon.2011.08.004

Komaki, J. L. (1998). When performance improvement is the goal: A new set of criteria for criteria. *Journal of Applied Behavior Analysis*, *31*(2), 263-280.

Krivonos, P. D. (2007, June 9-10). *Communication in aviation safety: Lessons learned and lessons required* [Paper presentation]. Regional Seminar of the Australia and New Zealand Societies of Air Safety Investigators, Wellington, New Zealand. https://asasi.org/wp-content/uploads/2021/05/Communication_in_Aviation_Safety_Paul_Krivonos.pdf

Landsberger, H. A. (1958). *Hawthorne Revisited*. Cornell University.

Latorella, K. A., & Prabhu, P. V. (2000). A review of human error in aviation maintenance and inspection. *International Journal of Industrial Ergonomics, 26*, 133-161. https://doi.org/10.1016/S0169-8141(99)00063-3

Leva, M. C., Cromie, S., & Douglas, E. (2015). Development of the framework for a self-assessment tool to assess the effectiveness of reporting within a safety critical industry. *ESREL, ETH, Zurich.* http://doi.org/10.13140/RG.2.1.2141.3204

Leveson, N. G. (2004). A new accident model for engineering safer systems. *Safety Science, 42* (4), 237-270. https://doi.org/10.1016/S0925-7535(03)00047-X

Li, J., Goerlandt, F., Van Nunen, K., Ponnet, K., & Reniers, G. (2022). Conceptualizing the contextual dynamics of safety climate and safety culture research: a comparative scientometric analysis. *International Journal of Environmental Research and Public Health*, *19*(2), 813. https://doi.org/10.3390/ijerph19020813

Luecke, R. (2003). *Managing Change and Transition*. Harvard Business School Press.

Luria, G., & Morag, I. (2012). Safety management by walking around (SMBWA): A safety intervention program based on both peer and manager participation. *Accident Analysis & Prevention*, *45*, 248-257. https://doi.org/10.1016/j.aap.2011.07.010

Ma, J., Pedigo, M., Blackwell, L., Gildea, K., Holcomb, K., Hackworth, C., & Hiles, J. J. (2011). *The line operations safety audit program: Transitioning from flight operations to maintenance and ramp operations* (Technical Report No. DOT/FAA/AM-11/15). Federal Aviation Administration, Office of Aerospace Medicine. https://rosap.ntl.bts.gov/view/dot/57082/dot_57082_DS1.pdf

Ma, M., & Zylawski, C. (2016, October). Frontline volunteers. *Aerosafetyworld*, 18-23.

Ma, M. J., & Rankin, W. L. (2012). *Implementation guideline for maintenance line operations safety assessment (M-LOSA) and ramp LOSA (R-LOSA) programs* (Technical Report No. DOT/FAA/AM-12/9). Federal Aviation Administration, Office of Aerospace Medicine. https://apps.dtic.mil/sti/pdfs/ADA566771.pdf

Marx, D. (2009). *Whack-a-mole: The price we pay for expecting perfection*. By Your Side Studios.

Mason, S. (1997). Procedural violations – causes, costs, and cures. In F. Redmill & J. Rajan (Eds.), *Human factors in safety-critical systems*. Butterworth-Heinemann.

Mason, S. (n.d.). *The safety health of maintenance engineering (SHoMe) tool* [PowerPoint]. HSEC.

McDonald, N. (2001). Human systems and aircraft maintenance. *Air & Space Europe, 3*(3-4), 221-224. https://doi.org/10.1016/S1290-0958(01)90100-5

McDonald, N. (2015). The evaluation of change. *Cognition Technology and Work*, *17*(2), 193-206. https://doi.org/10.1007/s10111-014-0296-9

McDonald, N., Corrigan, S., Daly, C., & Cromie, S. (2000). Safety management systems and safety culture in aircraft maintenance organizations. *Safety Science*, *34*(1-3), 151-176. https://doi.org/10.1016/S0925-7535(00)00011-4

McDonald, N., Corrigan, S., & Ward, M. (2002). Cultural and Organizational factors in system safety: Good people in bad systems. In *Proceedings of the 2002 International Conference on Human-Computer Interaction in Aeronautics (HCI-Aero 2002)* (pp. 205-209). https://www.aaai.org/Library/HCI/2002/hci02-033.php

McDonald, N., Cromie, S. D., & Ward, M. (1997). The impact of safety training on safety climate and attitudes. In Soekkha, H. M. (Ed.) *Aviation safety: Human factors, systems engineering, flight operations, economics, strategies, management* (pp. 649-661). Taylor and Francis.

McHale, S. (2020). *The insider's guide to culture change: Creating a workplace that delivers, grows, and adapts.* HarperCollins.

McSween, T. E. (2003). *Values-based safety process: Improving your safety culture with behavior-based safety*. John Wiley and Sons. http://doi.org/10.1002/0471721611

Meaney, M., & Pung, C. (2008, August). McKinney global results: Creating organizational transformations. *The McKinsey Quarterly*, pp. 1-7.

Mearns, K., Kirwan, B., Reader, K., Jackson, J., Kennedy, R., Gordon, R. (2013). Development of a methodology for understanding and enhancing safety culture in Air Traffic Management. *Safety Science, 53*, 123-133. https://doi.org/10.1016/j.ssci.2012.09.001

Morrow, S., & Coplen, M. (2017). *Safety culture: A significant influence on safety in transportation* (Report No. DOT/FRA/OR-17/09). Department of Transportation, John A. Volpe National Transportation Systems Center. https://rosap.ntl.bts.gov/view/dot/32538/dot_32538_DS1.pdf

Nævestad, T. O., Hesjevoll, I. S., & Elvik, R. (2021). How can regulatory authorities improve safety in organizations by influencing safety culture? A conceptual

model of the relationships and a discussion of implications. *Accident Analysis & Prevention*, *159*, 106228. https://doi.org/10.1016/j.aap.2021.106228

Nahrgang, J. D., Morgeson, F. P., & Hofmann, D. A. (2011). Safety at work: A meta-analytic investigation of the link between job demands, job resources, burnout, engagement, and safety outcomes. *Journal of Applied Psychology, 96*(1), 71-94. http://doi.org/10.1037/a0021484

National Academies of Science, Engineering, and Medicine. (2016). Safety culture assessment and measurement. In *Strengthening the safety culture of the offshore oil and gas industry*. National Academies Press. https://doi.org/10.17226/23524

Neal, A., & Griffin, M. A. (2006). A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. *Journal of Applied Psychology*, *91*(4), 946-953. https://doi.org/10.1037/0021-9010.91.4.946

Newman, A., Donohue, R., & Eva, N. (2017). Psychological safety: A systematic review of the literature. *Human Resource Management Review*, *27*(3), 521-535. https://doi.org/10.1016/j.hrmr.2017.01.001

Nuclear Regulatory Commission. (2014). *Guidance for conducting an independent NRC safety culture assessment* (Attachment No. 95003.02). http://pbadupws.nrc.gov/docs/ML1409/ML14090A072.pdf

Nuclear Regulatory Commission. (2022). *Safety culture policy statement.* https://www.nrc.gov/about-nrc/safety-culture/sc-policy-statement.html

Nytrø, K., Saksvik, P. Ø., Mikkelsen, A., Bohle, P., & Quinlan, M. (2000). An appraisal of key factors in the implementation of occupational stress interventions. *Work & Stress*, *14*(3), 213-225. https://doi.org/10.1080/02678370010024749

O'Connor, P., O'Dea, A., Kennedy, Q., & Buttrey, S. E. (2011). Measuring safety climate in aviation: A review and recommendations for the future. *Safety Science*, *49*(2), 128-138. https://doi.org/10.1016/j.ssci.2010.10.001

Office of Inspector General (2020). *FAA has not effectively overseen Southwest Airlines' systems for managing safety risks* (Report No. AV2020019). Department of Transportation. https://www.oversight.gov/report/dot/faa-has-not-effectively-overseen-southwest-airlines-systems-managing-safety-risks

Okumus, F. (2003). A framework to implement strategies in organizations. *Management Decision, 41*(9), 871-882. http://dx.doi.org/10.1108/00251740310499555

Operating requirements: Domestic, flag, and supplemental operations, 14 C.F.R. § 121 (2022). https://www.ecfr.gov/current/title-14/chapter-I/subchapter-G/part-121?toc=1

Papanthymou, A., & Darra, M. (2017). Quality management in higher education: Review and perspectives. *Higher Education Studies, 7*(3), 132-147. http://doi.org/10.5539/hes.v7n3p132

Patankar, M., Taylor, J., & Goglia, J. (2002). Individual professionalism and mutual trust are key to minimizing the probability of maintenance errors. In *Proceedings of the Aviation Safety & Security Symposium*, April 17 & 18, Washington, D.C.

Patankar, M. S. (2003). A study of safety culture at an aviation organization. *International Journal of Applied Aviation Studies*, *3*(2), 243-259.

Patankar, M. S., Brown, J. P., Sabin, E. J., & Bigda-Peyton, T. G. (2012). *Safety culture: Building and sustaining a cultural change in aviation and healthcare*. Ashgate.

Patankar, M. S., & Driscoll, D. (2005). Factors affecting the success or failure of aviation safety action programs in aviation maintenance organizations. http://www2.hf.faa.gov/docs/508/docs/maintFY04ASAPrpt.pdf

Patankar, M. S. & Taylor, J. C. (2004). *Risk management and error reduction in aviation maintenance*. Ashgate.

Patterson, M. G., West, M. A., Shackleton, V. J., Dawson, J. F., Lawthom, R., Maitlis, S., Robinson, D. L., & Wallace, A. M. (2005). Validating the organizational climate measure: Links to managerial practices, productivity and innovation. *Journal of Organizational Behavior*, *26*(4), 379-408. https://doi.org/10.1002/job.312

Peters, T., & Waterman, R. (1982). *In search of excellence: Lessons from America's best run companies.* Harper and Row.

Piers, M., Montijn, C., & Balk, A. (2009). *Safety culture framework for the ECAST SMS-WG*. European Union Aviation Safety Agency, European Commercial Aviation Safety Team (ECAST). https://www.easa.europa.eu/sites/default/files/dfu/WP1-ECASTSMSWG-SafetyCultureframework1.pdf

Pronovost, P., & Sexton, B. (2005). Assessing safety culture: Guidelines and recommendations. *BMJ Quality & Safety, 14*(4), 231-233. http://dx.doi.org/10.1136/qshc.2005.015180

Reader, T.W., Noort, M.C., Shorrock, S., and Kirwan, B. (2015). Safety sans frontières: An international safety culture model, *Risk Analysis*, 35(5), 770-789. https://doi.org/10.1111/risa.12327

Reason, J. (1997). *Managing the risks of organizational accidents.* Ashgate.

Reason, J. (1998). Achieving a safe culture: Theory and practice. *Work and Stress 12*(3), 293–306. https://doi.org/10.1080/02678379808256868

Reason, J., & Hobbs, A. (2003). *Managing Mx error: A practical guide*. Ashgate.

Safety Management International Collaboration Group (2019). *Industry safety culture evaluation tool and guidance.* https://www.skybrary.aero/index.php/Industry_Safety_Culture_Evaluation_Tool_and_Guidance

Safety Management Systems, 14 C.F.R. § 5 (2022). https://www.ecfr.gov/current/title-14/chapter-I/subchapter-A/part-5

Schein, E. H. (2010). *Organizational culture and leadership* (4th Ed.). Jossey-Bass.

Schneider, B., Macey, W. H., Ehrhart, M. G. (2013). *Organizational climate and culture: An introduction to theory, research, and practice*. Taylor & Francis.

Schwarz, M., & Kallus, K. W. (2015). Safety culture and safety-relevant behavior in air traffic management. *Aviation Psychology and Applied Human Factors, 5*(1), 3-17. https://doi.org/10.1027/2192-0923/a000068

Schwarz, M., Kallus, K. W., & Gaisbachgrabner, K. (2016). Safety Culture, Resilient Behavior, and Stress in Air Traffic Management. *Aviation Psychology and Applied Human Factors, 6*(1), 12-23. https://doi.org/10.1027/2192-0923/a000091

Sexton, J. B., Helmreich, R. L., Neilands, T. B., Rowan, K., Vella, K., Boyden, J., Roberts, P. R., & Thomas, E. J. (2006). The Safety Attitudes Questionnaire: Psychometric properties, benchmarking data, and emerging research. *BMC Health Services Research*, *6*(1), 1-10. https://doi.org/10.1186/1472-6963-6-44

Singer, S. J., Gaba, D. M., Geppert, J. J., Sinaiko, A. D., Howard, S. K., & Park, K. C. (2003). The culture of safety: Results of an organization-wide survey in 15 California hospitals. *BMJ Quality & Safety*, *12*(2), 112-118. http://dx.doi.org/10.1136/qhc.12.2.112

Smith, M. E. (2002). Success rates for different types of organizational change. *Performance Improvement*, *41*(1), 26-33. https://doi.org/10.1002/pfi.4140410107

Soltanifar, M. (2022). *ISO 45001 implementation: How to become an occupational health and safety champion.* Routledge.

Sorra, J., Yount, N., Famolaro, T., Gray, L. (2019). *AHRQ hospital survey on patient safety culture version 2.0: User's guide* (Publication No. 19-0076). Department of Health and Human Services, Agency for Healthcare Research and Quality. https://www.ahrq.gov/sops/surveys/hospital/index.html

Stajkovic, A. D., & Luthans, F. (2003). Behavioral management and task performance in organizations: conceptual background, meta-analysis, and test of alternative models. *Personnel Psychology, 56*(1), 155-194. https://doi.org/10.1111/j.1744-6570.2003.tb00147.x

Taylor, J. C. (2002). *Tools and techniques for evaluating the effects of Maintenance Resource Management (MRM) in air safety*. National Aeronautics and Space Administration, Ames Research Center. https://ntrs.nasa.gov/citations/20020046777

Taylor, J. C., & Patankar, M. S. (2001). Four generations of maintenance resource management programs in the United States: An analysis of the past, present, and future. *Journal of Air Transportation World Wide, 6*(2), 3-32. https://ntrs.nasa.gov/api/citations/20010103213/downloads/20010103213.pdf

Taylor, J. C., & Thomas, R. L. (2003). Toward measuring safety culture in aviation maintenance: The structure of trust and professionalism. *The International Journal of Aviation Psychology*, *13*(4), 321-343. https://doi.org/10.1207/S15327108IJAP1304_01

Thompson, R. C., Hilton, T. F., & Witt, L. A. (1997). *Where the safety rubber meets the shop floor: A confirmatory model of management influence on workplace safety* (Technical Report No. DOT/FAA/AM-97/8). Federal Aviation Administration, Office of Aviation Medicine. https://rosap.ntl.bts.gov/view/dot/57580

Tuncel, S., Lotlikar, H., Salem, S., & Daraiseh, N. (2006). Effectiveness of behaviour based safety interventions to reduce accidents and injuries in workplaces: Critical appraisal and meta-analysis. *Theoretical Issues in Ergonomics Science*, *7*(3), 191-209. https://doi.org/10.1080/14639220500090273

Van Noorden, R. (2018). Leadership problems in the lab. *Nature, 557*(3). https://doi.org/10.1038/d41586-018-05143-8

Wachter, J. K., & Yorio, P. L. (2013). Human performance tools: Engaging workers as the best defense against errors & error precursors. *Professional Safety*, *58*(2), 54-64.

Ward, M., McDonald, N., Morrison, R., Gaynor, D., & Nugent, T. (2010a). A performance improvement case study in aircraft maintenance and its implications for hazard. *Ergonomics*, *53*(2), 247-267. http://doi.org/10.1080/00140130903194138

Ward, N. J., Linkenbach, J., Keller, S. N., & Otto, J. (2010b). *White paper on traffic safety culture* (Paper No. 2). Federal Highway Administration.

Wendler, R. (2012). The maturity of maturity model research: A systematic mapping study. *Information and Software Technology, 54*(12), 1317- 1339. https://doi.org/10.1016/j.infsof.2012.07.007

Westrum, R. (2004). A typology of organisational cultures. *BMJ Quality & Safety, 13*(suppl 2), ii22-ii27. http://dx.doi.org/10.1136/qshc.2003.009522

Wiegmann, D. A., Zhang, H., Von Thaden, T., Sharma, G., & Mitchell, S. (2002). *A synthesis of safety culture and safety climate research* (Technical Report No. ARL-02-3/FAA-02-2). Federal Aviation Administration. https://www.nrc.gov/docs/ML1025/ML102500649.pdf

Williamsen, M. (2013, May). Near-miss reporting: A missing link in safety culture. *Professional Safety.*

Zohar, D. (1980). Safety climate in industrial organizations: Theoretical and applied applications. *Journal of Applied Psychology*, *65*(1), 96-102. https://doi.org/10.1037/0021-9010.65.1.96

Zohar, D. (2000). A group-level model of safety climate: Testing the effect of group climate on microaccidents in manufacturing jobs. *Journal of Applied Psychology*, *85*(4), 587-596. http://doi.org/10.1037/0021-9010.85.4.587

Zohar, D. (2002). Modifying supervisory practices to improve subunit safety: A leadership-based intervention model. *Journal of Applied Psychology, 87*(1), 156-163. https://doi.org/10.1037/0021-9010.87.1.156

Zohar, D. (2010). Thirty years of safety climate research: Reflections and future directions. *Accident Analysis and Prevention*, *42*(5), 1517-1522. https://doi.org/10.1016/j.aap.2009.12.019

Zohar, D. (2014). Safety climate: Conceptualization, measurement, and improvement. In B. Schneider & K. M. Barbera (Eds.). *The Oxford handbook of organizational climate and culture*, pp. 317-334. Oxford University Press.

Zohar, D., & Hofmann, D. A. (2012). Organizational culture and climate. In S. W. J. Kozlowski (Ed.), *Oxford handbook of industrial and organizational psychology,* pp. 643-666. Oxford University Press.

Zohar, D., & Luria, G. (2003). The use of supervisory practices as leverage to improve safety behavior: A cross-level intervention model. *Journal of Safety Research*, *34*(5), 567-577. https://doi.org/10.1016/j.jsr.2003.05.006

Zohar, D., & Luria, G. (2005). A multilevel model of safety climate: Cross-level relationships between organizations and group-level climates. *Journal of Applied Psychology*, *90*(4), 616-628. http://doi.org/10.1037/0021-9010.90.4.616

Zohar, D., & Polachek, T. (2014). Discourse-based intervention for modifying supervisory communication as leverage for safety climate and performance improvement: a randomized field study. *Journal of Applied Psychology*, *99*(1), 113. https://doi.org/10.1037/a0034096

Appendix A
Theoretical Frameworks of Safety Culture

Safety culture can be difficult to comprehend holistically, as it can be assessed with various methods and dimensions. Frameworks provide a way to organize data, identify room for improvements towards a positive safety culture, and develop targeted interventions. Further, frameworks help not only to understand hierarchical relationships across dimensions, but also to draw hypothetical pathways of the causal relationships among variables (i.e., Descriptive and Explanatory Frameworks). In some cases, these frameworks ultimately help organizations predict safety outcomes (i.e., Predictive Frameworks).

Some common features emerge when looking across the existing frameworks of safety culture, which suggests a rudimentary convergence in the literature. First, it is evident that most frameworks conceive safety culture as a component of the overall organizational culture. Most organizations have many cultures (e.g., productivity culture, innovation culture; Schein, 2010), in which these other cultures may interact with the safety culture. Another shared feature across frameworks is the strong emphasis on organizational safety systems and management/supervision as key drivers of safety culture. Finally, many of the frameworks describe a pathway whereby organizational resources and safety systems influence employee engagement and behaviors, which in turn influence organizational safety outcomes.

The overarching conclusion from these theoretical frameworks is that the relationship between safety culture and safety performance is complex and indirect; several variables are impacted by the organization's safety culture, which then impact performance in the workplace. Any organization aiming to improve their safety performance needs to assess and understand these complex relationships between individuals, the safety culture, and the organizational factors. This will set the stage for meaningful interventions to be designed, validated, and implemented in the work environment.

Descriptive and Explanatory Frameworks

Schein's Organizational Culture Model

Schein (2010) and Guldenmund (2000, 2018) endorsed a three-layered organizational culture framework comprised of: (a) artefacts or behaviors, which are visible but cannot be used to comprehend the underlying organizational culture; (b) espoused beliefs and values, which are relatively explicit, conscious, and measurable; and (c) core assumptions, which are invisible but can be inferred from behavior. These assumptions may arise by exploring contradictions between behaviors and espoused beliefs; for example, many leaders say that safety is a top priority but incentivize production (see NASEM, 2016). As noted by Cooper (2016), a taxonomy of

assumptions would further extend the usefulness of this model, but it does lay the foundation for understanding organizational culture, of which safety culture is a part.

Reason's Model of Safety Culture

Reason (1997, 1998) proposed that a safety culture is comprised of: (a) informed, (b) reporting, (c) just, (d) learning, and (e) flexible sub-cultures. Reason argued that a safety culture is an informed culture; however, becoming informed requires employees' reporting of safety events and hazards. Critically, the willingness of employees to report hinges on the pre-existence of a just culture, or extent to which fair and consistent actions are taken in response to safety events. The justness of a culture can be supported further by the emphasis on learning from events rather than punishing employees, along with adaptiveness or flexibility. The validity of Reason's model is not well established; however, the model has been useful heuristically and has been used as a foundation for building guidelines for promoting each of these elements of culture (Nævestad et al., 2021; see also Schwarz & Kallus, 2015).

Cooper's Reciprocal Safety Culture Model

In Cooper's Reciprocal Safety Culture model (2000, 2016), safety culture is the product of multiple goal-oriented interactions of personal characteristics (e.g., internal values and attitudes), behaviors, and situational or organizational workplace factors. Per this model, the six major safety culture characteristics are management/supervision, safety systems, risk, work pressure, competence, and procedures/rules (as defined in *Methods for Assessing Safety Culture*). The Reciprocal Safety Culture model has previously been validated using exploratory factor analysis (Cooper & Phillips, 2004).

Predictive Frameworks

Zohar's Safety Climate Model

Zohar's (2014) model of safety climate explores the antecedent variables of safety climate, such as leadership, work ownership, commitment to safety, job stress and burnout. These antecedents comprise a higher-order 'g factor' of group safety climate, which in turn predicts employees' safety knowledge and motivation, safety behaviors (e.g., compliance, citizenship) and engagement, and organizational outcomes. Zohar's model places high emphasis on leadership. Here, safety culture is a multi-level construct within an organization, such that the policies set at the organization-level establish the overall company-wide culture, but enforcement of policies at the individual-supervisor level create differences in culture/climate at the sub-group level (Zohar & Luria, 2003, 2005). Zohar's model (2014) has been validated previously in the rail transport industry using confirmatory factor analysis (Curcuruto & Griffin, 2018).

The Job Demands-Resources (JD-R) Model

According to the Job Demands-Resources (JD-R) model, the organization provides Job Resources and places Job Demands, which interact to influence both culture and employee behaviors (Bakker & Demerouti, 2007; Demerouti et al., 2001). In this model, Job Resources and Job Demands interact to shape Individual Outcomes such as satisfaction and morale, well-being, and motivation to work safely (Demerouti et al., 2019). In turn, the Individual Outcomes contribute to the Organizational Outcomes, or safety performance indicators. For example, if Job Demands (e.g., risks, hazards, complexity) exhaust an employee's mental and physical resources, health impairment such as burnout, strain, and fatigue may result. Conversely, sufficient Job Resources (e.g., knowledge, autonomy, supportive environment) are likely to result in positive Individual Outcomes such as job satisfaction and engagement, thus reducing accidents and errors. Job Resources may also buffer against detrimental impacts of Job Demands. These pathways have been examined through meta-analysis (Clarke, 2012; Nahrgang et al., 2011; c.f. Gonzalez-Mulé et al., 2021) and SEM analysis (Fogarty, 2004, 2005; Fogarty et al., 2018; Hansez & Chmiel, 2010; Schwarz et al., 2016).

Appendix B.
The Wobbly Steps

Cromie et al. (2015) developed one successful safety-related training program. Their human factors training program, using the "Wobbly Steps" metaphor, focused on safety and risk management. The extensive multi-phase training effort was centered on the human and organizational factors that contribute to risk and the role of risk management strategies that support a stronger safety culture. The training included a workshop with senior management to emphasize leadership in safety, an e-learning module about human and organizational factors contributing to safety, and a workshop with employees and management to complete interactive exercises about the training materials. The training also featured segments regarding routine risk management, reporting and collaboration, safety culture, and just culture.

The "Wobbly Steps" metaphor illustrated how the foundation for safety performance is based on resources from both the individual (i.e., experience, risk awareness, skills, initiative) and the organization (tools, equipment, documentation, training, supervision, personnel). If the employee does not have enough resources to complete the task safely, there is a temptation to add some "wobbly steps" to reach the goal. The "wobbly steps" involve; hurrying, juggling, deviation, the wrong tool, not checking, and "can do" attitude. The behavior of adding wobbly steps is rewarding for the individual and the organization in the short-term but can result in incidents/accidents/injuries in the end. Though attendees view this training positively, objective assessments of its effectiveness have not been published.

Appendix C
Culture Change in Aviation: A Case Study

One evidence-based approach to change management in aviation originating in Europe was Managing System Change in Aviation (MASCA; Corrigan & McDonald, 2014; McDonald, 2015). These efforts involved airport collaborative decision-making, implementation of SMSs for a major airline, a performance management system at a small regional airport, and assessment of risk within a regional airline. The elements of MASCA include gathering information concerning the work processes (Managing Information), information analysis (Analysis), identification of new ways of doing things through interactive simulations (Serious Gaming), and mentoring and training. These efforts are used to generate additional capacity (Capacity Building), which then leads to new processes that demonstrate higher value (Achieving Value).

Their description of the case studies illustrates the many features that required outside support: development and implementation of the extensive training activities, new software systems, and the analyses of the knowledge database to support improvement planning and applications for management.

Although these results seem promising, there is little empirical evidence concerning the efficacy of these approaches. Given the lack of research in the literature, future research should investigate these limitations and test which interventions effectively increase safety culture and safety behaviors. Another consideration of this approach is the "strong role" of research organizations that has helped to ensure successful outcomes (Corrigan & McDonald, 2014). A remaining question is how elements of these efforts can be readily adapted, scaled, and implemented in small organizations with more limited resources.