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REVIEW

Defining and Measuring Safety Climate: A Review of the Construction Industry Literature

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ABSTRACT

Safety climate measurements can be used to proactively assess an organization's effectiveness in identifying and remediating work-related hazards, thereby reducing or preventing work-related ill health and injury. This review article focuses on construction-specific articles that developed and/or measured safety climate, assessed safety climate's relationship with other safety and health performance indicators, and/or used safety climate measures to evaluate interventions targeting one or more indicators of safety climate. Fifty-six articles met our inclusion criteria, 80% of which were published after 2008. Our findings demonstrate that researchers commonly defined safety climate as perception based, but the object of those perceptions varies widely. Within the wide range of indicators used to measure safety climate, safety policies, procedures, and practices were the most common, followed by general management commitment to safety. The most frequently used indicators should and do reflect that the prevention of work-related ill health and injury depends on both organizational and employee actions. Safety climate scores were commonly compared between groups (e.g. management and workers, different trades), and often correlated with subjective measures of safety behavior rather than measures of ill health or objective safety and health outcomes. Despite the observed limitations of current research, safety climate has been promised as a useful feature of research and practice activities to prevent work-related ill health and injury. Safety climate survey data can reveal gaps between management and employee perceptions, or between espoused and enacted policies, and trigger communication and action to narrow those gaps. The validation of safety climate with safety and health performance data offers the potential for using safety climate measures as a leading indicator of performance. We discuss these findings in relation to the related concept of safety culture and offer suggestions for future research and practice including (i) deriving a common definition of safety climate, (ii) developing and testing construction-specific indicators of safety climate, and (iii) focusing on construction-specific issues such as the transient workforce, subcontracting, work organization, and induction/acculturation processes.

KEYWORDS: safety behavior; safety commitment; safety culture; safety indicators; safety perceptions; safety performance; worker involvement

INTRODUCTION

The term safety culture, a subset of organizational culture, is used to broadly describe the value an organization places on the safety and health of its workforce through its policies, procedures, and practices (Guldenmund, 2000). It became an integral part of the occupational safety and health business lexicon in the 1980s in response to catastrophic events in the nuclear power, offshore oil, and commercial aviation industries (Cox and Flin, 1998). More recently, the healthcare sector has turned to understanding safety culture as a means to improve patient safety and prevent medical errors (Sammer *et al.*, 2010). A second related construct, 'safety climate', has been investigated as an indicator of the overall strength of an organization's safety culture. Safety climate measurements can be used to proactively assess an organization's effectiveness in identifying and remediating work-related hazards, thereby reducing or preventing work-related ill health and injury.

The term safety climate first appeared in the academic literature in 1980 when Zohar (1980) measured workers' perceptions of various aspects of job safety in manufacturing organizations with high and low accident rates. He defined safety climate as the 'summary of molar perceptions that employees share about their work environment [in relation to safety]' (p. 96) and found that safety climate was related to safety audit scores. Since then, others have examined the usefulness and accuracy of measuring safety climate and whether such data can be used to understand or predict workplace safety and health performance across numerous industries. While the construction industry is a relative latecomer to the safety climate discussion, recent work by academics and practitioners has applied this construct as one way to understand and improve workplace safety and health (Gillen *et al.*, 2014).

Meta-analytic and review articles on safety climate have included numerous industries in their reviews; however, specific attention to the construction industry has not been given. Christian *et al.* (2009), Clarke (2006, 2010), and Nahrgang *et al.* (2011) all conducted meta-analytic reviews of safety climate studies across multiple industries, including construction. Glendon (2008) reviewed all safety culture and climate literature across industries. Only Choudhry (2007b) reviewed safety 'culture' (not 'safety climate') as it pertained specifically to the construction industry.

To date, no one has conducted a thorough review of the literature to examine how the safety climate construct has been defined, measured, and used to improve safety and health outcomes in construction. This presents a significant gap in the field because construction has a number of characteristics that are less common in fixed industry that may have a negative impact on safety climate. Among these are a job site in continual flux, a high degree of subcontracting, a transient workforce, and individual craft cultures. Our primary goal is to begin filling this gap by gaining a more comprehensive understanding of where consensus about safety climate definition and measurement does and does not exist in order to move both research and practice forward.

METHODS

Our starting point was Glendon's (2008) review of the safety climate/culture literature published between 1 January 1980 and 31 January 2008, where he identified 203 articles, 20 (7.4%) of which focused on the construction industry. Next, using the terms 'safety climate', 'safety culture', and 'construction', we searched Web of Science, PsychInfo, Pubmed, and the American Society of Civil Engineering publications website (ASCELibrary.org) for all articles published between 1 February 2008 and 1 March 2014. We also found several safety climate research reports in the 'gray literature'.

Inclusion criteria

The article had to be published in English and address at least one of the following: (i) safety climate survey development and/or testing in a construction population; (ii) examination of the relationship between safety climate and safety and health performance or other related outcome variables; or (iii) application of a safety climate survey to measure the effectiveness of an intervention designed to improve one or more indicators of safety climate. Finally, since the terms safety climate and safety culture are frequently used interchangeably both in research and practice and the vast majority of safety climate researchers follow the Zohar's (1980) tradition by measuring safety climate using worker perception surveys, articles that said they were measuring safety culture using worker perception surveys were also included.

RESULTS

Glendon's 1980–2008 search results (N = 203) combined with our search from 1 January 2008 to 1 March 2014 (N = 753) resulted in a total of 956 safety culture and/or safety climate-related articles across all industries published since 1980. Comparison of the pre- and post-2008 searches revealed that there has been a surge in safety culture and/or safety climate research in recent years.

Fifty-six articles met our inclusion criteria, 80% of which were published since 2008 (Fig. 1 and Supplementary Table S2, available at *Annals of Occupational Hygiene* online). About 40% (n = 22) were conducted in the USA with the remainder carried out in Australia (n = 9, 16%), Hong Kong (n = 7, 13%), China (n = 4, 7%), Singapore (n = 3, 5%), Sweden (n = 2, 4%), and a number of other countries that were infrequently represented (n = 9, 16%). Two conducted cross-country comparisons: one compared construction safety climate in the UK, Spain, and Hong Kong (Meliá *et al.*, 2008), while the other comparison was across five Nordic countries (Kines *et al.*, 2011). The median study population sample size was 281 employees (interquartile range 181–596) and included primarily white males. Five articles (9%) specifically studied safety climate with Latino workers.

Defining safety climate

The most frequent definition of safety climate we found was that it reflected employee perceptions of safety in the workplace (n = 38, 68%). Only 3 of these 38 articles (8%) specifically stated that they reflected worker and manager perceptions, and included managers as well as employees as survey subjects. Eight of the 38 (21%) specified that perceptions were 'shared' among employees. Twenty-two (58%) stated that safety climate generally reflects workers' perceptions of how safety is valued by the organization, while 13 (34%) defined it more specifically as workers' perceptions of workplace safety policies, procedures, and practices.

Five of the 56 (9%) studies claimed that safety climate reflected employee attitudes rather than perceptions. This distinction was noted as important by both Kines *et al.* (2011) and particularly Pousette *et al.* (2008), whose findings showed that attitudes and perceptions predict safety outcomes differently, with attitude questions being more susceptible to social desirability bias.

Rather than providing a definition of safety climate, some authors took a different approach. For example,

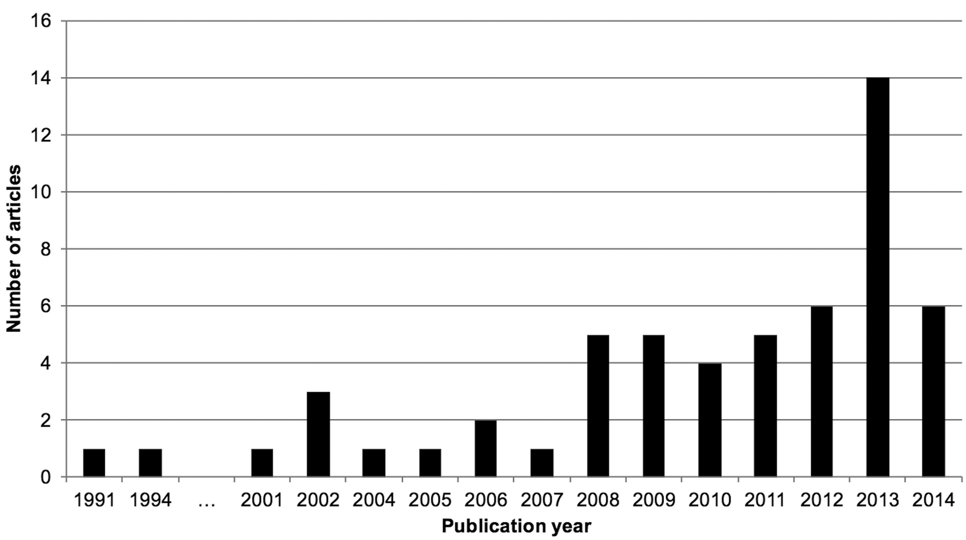

Figure 1 Articles describing safety climate in construction published between 1991 and 2014.

instead of an overarching definition, Cigularov *et al.* (2010) described the specific indicators of safety climate (e.g. error management climate and safety communication). Ten of the 56 studies (18%) defined safety climate as an indicator of safety culture. Two studies (3.5%) defined it as an indicator of organizational climate (Meliá *et al.*, 2008; Kapp, 2012), and five studies (8.9%) provided no safety climate definition (Shoji and Egawa, 2006; Burt *et al.*, 2008; Kines *et al.*, 2010; Abbe *et al.*, 2011; Lopez del Puerto *et al.*, 2013).

Finally, in 5 of the 56 studies reviewed (8.5%) the authors claimed to be studying safety culture, but defined (and measured) it in a manner more reflective of safety climate (Molenaar *et al.*, 2002; Fung *et al.*, 2005; Molenaar *et al.*, 2009; Gilkey *et al.*, 2013; Feng *et al.*, 2014).

Measuring safety climate

We found that researchers typically had three overarching goals for measuring safety climate: (i) develop a new safety climate survey instrument or adapt an existing one to reflect unique characteristics of construction; (ii) compare safety climate scores across groups of workers; or (iii) examine the relationship between safety climate survey findings and safety and health outcome measures (e.g. self-reported safety behaviors). Each of these is discussed below.

Develop or adapt a safety climate survey instrument

Survey sources

Fifteen (27%) of the studies developed their own safety climate survey instrument. However, the majority ($n = 41$, 73%) adapted and used an instrument developed for construction or a different industry. The most commonly adapted safety climate surveys are discussed below.

Surveys developed for construction

Only 7% of the 56 articles used safety climate surveys that had been developed specifically for, or validated previously in, the US construction industry. In an effort to replicate Zohar's (1980) safety climate factor model, Dedobbeleer and Beland (1991) developed and tested a survey in the US construction industry; this same instrument was used in three subsequent US studies (Gillen *et al.*, 2002; Arcury *et al.*, 2012; Sparer *et al.*, 2013). Mohamed (2002) developed and tested a survey in the Australian construction industry, which Teo and Feng (2011) later used in Singapore. Kines *et al.* (2011) first developed and tested the Nordic Safety Climate Questionnaire in the construction industries of several Nordic countries, and then tested it in other industries.

Surveys developed in other industries but adapted for and used in construction

The majority of the studies ($n = 37$, 66%) used or made adaptations to previously developed non-construction specific surveys. The most common source ($n = 10$) was the UK's Health and Safety Executive (HSE) safety climate questionnaire (Davies *et al.*, 2001) or the Climate Survey Tool (CST) (HSE, 1997). The CST was subsequently renamed the Safety Climate Tool (SCT) and modified (Sugden *et al.*, 2009). The SCT was adapted for use on the London Olympic construction site (Healey and Sugden, 2012).

Besides the CST, five researchers have adapted safety climate surveys from Zohar (2000); four from Neal *et al.* (2000); three each from Geller (1990) and the National Institute for Occupational Safety and Health (NIOSH) (Dejoy *et al.*, 1995); and two from Burt *et al.* (1998). Some researchers utilized other surveys, but due to the low frequency with which they were used, they were not included in our review.

Indicators

Some of the studies that created or adapted safety climate surveys focused on identifying the key 'factors' of the latent safety climate construct. Construction practitioners seem to prefer the term indicator to factor (which comes from the statistical procedure factor analysis). Therefore, in an effort to move the field of safety climate survey research toward more practical applications we will use the term 'indicator(s)'.

The average number of safety climate indicators across all the surveys was 4.01 (range = 1–10), and each indicator was measured by an average of 21.92 questions (range = 1–78). To help make sense of the variation, we developed a categorization scheme for grouping 'like' indicators (see Supplementary Table S1, available at *Annals of Occupational Hygiene* online). We found that two categories, (i) safety policies/resources/training and (ii) general management commitment to safety, were used by over half the articles (Table 1). This was followed by supervisor commitment to safety and general organizational commitment to safety (37.5 and 35.7%, respectively). Three

Table 1. Frequency of safety climate indicators most commonly measured in 56 construction-specific safety climate articles

Safety climate indicator	Number	%
General management commitment to safety	30	53.5
Safety policies, resources, and training	28	50.0
Supervisor commitment to safety	21	37.5
General organizational commitment to safety	20	35.7
Co-workers commitment to safety	18	32.1
Safety communication	16	28.5
Worker involvement in safety	13	23.2
Risk appraisal and risk taking	9	14.3

other indicators were included in approximately >25% of the articles. Additional indicators were reported but at low frequency so they are not shown in Table 1. Seventeen (30%) of the surveys in the 56 articles were tested for reliability and validity using statistical tests such as principal components analysis (PCA) and confirmatory factor analysis (CFA).

Comparing safety climate scores across groups

Twenty-eight studies (50%) compared safety climate scores across worker subgroups to determine if there were significant differences in perception of worksite safety climate. Seven studies (12.5%) found significant differences in perception of worksite safety climate at the 'work-group level' (Glendon and Litherland, 2001; Lingard *et al.*, 2009; Kines *et al.*, 2010; Lingard *et al.*, 2010; Biggs and Banks, 2012; Lingard *et al.*, 2012; Tholen *et al.*, 2013). The study samples varied between work groups within a single company and from multiple companies. At the 'company level', three studies (5%) measured safety climate on multiple job sites of one general contractor. Two studies found significant differences at different job sites (Gittleman *et al.*, 2010; Fang and Wu, 2013) and one study did not (Chen *et al.*, 2013). At the 'job-site level' (one job site with multiple companies), five studies (9%) found that safety climate scores were more similar among workers employed by the same company than workers employed by other companies (Probst *et al.*, 2008; Lingard *et al.*, 2010; Healey and Sugden 2012; Liao *et al.*, 2013; 2014). At both the 'worker and management level', four studies (7%) compared the safety climate scores across workers and management on single sites with multiple contractors and found that management rated safety climate significantly higher (Molenaar *et al.*, 2002; Fung *et al.*, 2005; Gittleman *et al.*, 2010; Gilkey *et al.*, 2012). A lower perception of climate among workers compared to managers could suggest that company safety programs are not operating as intended, thus providing lesser levels of protection.

Other group comparisons were conducted 'across ethnicities' (Latino versus non-Latino), 'construction trades', and 'union status'. Cigularov *et al.* (2013b) found no difference in safety climate perceptions between Latino and non-Latino workers or among different construction trades (Cigularov *et al.*, 2013a). However, others found that Latino workers were likely to perceive a significantly poorer safety climate than non-Latino workers (Sokas *et al.*, 2009; Gilkey *et al.*, 2013), and some construction trades perceived significantly poorer safety climate than others (Abbe *et al.*, 2011; Arcury *et al.*, 2012). Gillen *et al.* (2002) found that union workers reported a significantly more positive safety climate than non-union workers.

Examining the relationship between safety climate and safety performance or other variables

Thirty-seven of the 56 studies (66%) investigated the relationship(s) between safety climate survey scores and one or more antecedent, mediating, or outcome variables.

A number of studies investigated the degree to which organizational or personal worker or supervisor characteristics act as antecedents to safety climate perceptions. Overall, the data suggest that organizations that value human relations (i.e. cohesion and morale), or value both human relations and goal attainment (i.e. efficiency and productivity), have a more positive safety climate compared to organizations that primarily value internal processes (i.e. stability, control, formalization) or a combination of internal processes and goal attainment (Colley *et al.*, 2013).

The most commonly studied outcome variable (n = 14, 25%), self-reported worker safety behavior, was consistently found to be significantly positively associated with the safety climate score. Of the five articles (9%) that studied the relationship between safety climate perceptions and self-reported injuries, four found a significant negative relationship and one reported no relationship. Of the 10 articles that studied safety climate's relationship to injuries derived from contractor records (n = 10, 18%), 9 articles found a significant negative relationship and 1 article reported no relationship.

Only three studies (5%) demonstrated a null relationship between safety climate and safety outcomes. Sparer *et al.* (2013) found no significant relationship between company safety climate scores and a proprietary composite safety outcome variable called the Construct Secure Safety Assessment Program score (CSAP). CSAP scores are based on a combination of contractor's experience modification rating, lost-time and Occupational Safety and Health Administration (OSHA) recordable rates, number of OSHA citations, and the company's safety management system assessed via document analysis. Glendon and Litherland (2001) found that safety climate was not correlated with project or company safety behavioral observation scores, contradicting earlier findings in non-construction industry settings (Zohar, 1980); however, a small sample size (n = 92) may have contributed to the null findings. Martin and Lewis (2013) compared safety climate scores between accident and non-accident groups, and did not find any significant differences.

Healey and Sugden (2012) examined the correlation between safety climate scores and injury accident rates, reportable accident rates, and near-miss reports across 15 companies at the London Olympic Park construction site. They found that, in general, the mean safety climate scores of the project's construction companies were higher than industry averages in the UK and were significantly negatively correlated with injury accident rates, but positively associated with reportable accident rates. Near-miss reports were not significantly associated with safety climate scores. While it is unclear what the exact definitions of these types of injuries are in the author's study, it seems as though 'reportable accident rates' reflect injuries that rise to the level of federal reporting requirements whereas 'injury accident rates' reflect injuries that do not rise to the level of federal reporting requirements. These disparate findings may indicate that a positive safety climate is associated with fewer minor injuries, but more severe injuries that rise to the level of federal reporting requirements. This may indicate better injury reporting practices on job sites with a positive safety climate. However, the authors admit that these findings are not conclusive as there may have been some measurement error (e.g. reportable accidents include 'major injuries' and 'three-day reportable accidents') and they had a low frequency of these outcomes.

All of the studies just described were cross-sectional. Only three (5%) were longitudinal and they found that safety climate was predictive of self-reported safety behaviors (Pousette *et al.*, 2008; Tholen *et al.*, 2013) and negatively related to injury incident rates (Han *et al.*, 2014) over time at the individual level.

Using safety climate survey data to measure intervention effectiveness

Kines *et al.* (2010) hypothesized that workers' safety climate perceptions would improve after their supervisors participated in a safety communication intervention. They found that only one of the five safety climate indicators—'attention to safety'—improved significantly while the composite safety climate score did not. Sokas *et al.* (2009) evaluated the degree to which an OSHA 10-h training course improved safety climate perceptions, but no improvement was detected at follow-up.

In the London Olympic Park study, the Olympic Delivery Authority, acting as construction manager, established a Health, Safety and Environment Standard to guide the procurement of designs and construction, appoint contractors, and administer a safety culture/climate survey process (Bust, 2011).

They compared safety climate scores and accident injury rates over time for two contractors and found a positive trend for safety climate scores and a negative trend for accident injury rates.

DISCUSSION

The purpose of this review was to better understand how investigators have defined and measured the safety climate construct and how they have used safety climate survey scores to predict or explain safety and health outcomes specifically in the construction industry. This type of research has grown in recent years with almost two-thirds of the reviewed studies having been published since 2010. Our findings mirror those from the broader safety climate literature, which suggest that while safety climate is a promising indicator of work-related safety and health, more precision is needed in how it is defined and measured. The following sections outline gaps identified in the review and present recommendations for improvement. These recommendations are not meant to be exhaustive; rather, they are intended to provide a starting point for moving construction related safety climate research and practice forward.

Definitions and measurement

Definitions

The majority of researchers defined safety climate as employee perceptions of workplace safety. However, only a few specified what the perceptions referred to or distinguished between safety climate and safety culture. Guldenmund (2007) found similar ambiguity in the broader safety climate literature, noting that many researchers define safety climate in an implicit manner and that none defined safety climate with a particular population in mind.

At a 2013 workshop on construction safety culture and climate, 70 US construction industry stakeholders examined the state of research and practice and called for improved definitions of safety culture, safety climate, and project safety climate (Gillen *et al.*, 2014). Parallel efforts are underway elsewhere (Lingard *et al.*, 2014), lending support to the notion that researchers and practitioners should make a concerted effort to use agreed-upon definitions when researching and working with the safety climate construct in the construction industry.

Indicators

As with previous safety climate reviews across other industry sectors, we found that a plethora of general versus industry-specific surveys comprising a variety of indicators have been used to measure safety climate in construction. Certain indicators have been more commonly viewed as comprising the safety climate construct (e.g. management commitment). Flin *et al.* (2000) tentatively proposed the 'Big Five' indicators of safety climate. However, there remains great variation in both assigned labels and the survey items designed to measure the indicators. The most populated category in our categorization scheme, 'safety policies, resources, and practices', included numerous indicators related to general perceptions of safety and health practices as well as perceptions of particular components of a safety system (e.g. training).

We believe that the use of multiple reliable and validated indicators provides more detailed guidance on which areas need improvement within an organization. Some organizations use safety climate indicator surveys as learning opportunity. For example, Gittleman *et al.* (2010) used safety climate indicators related to management commitment as part of a safety needs assessment after multiple workers died on a construction site in a short period of time. This, in fact, may be a more effective use of safety climate than as a benchmarking tool. Indeed, the process provided the workers with an opportunity to have their voices heard, and the company's management team with feedback on how to improve worker safety and health. Alternatively, safety climate scores could be used as benchmarks, whether within or across organizations; however, this runs some risk as they are largely based on subjective perceptions. Scores based upon five- or seven-point Likert scales may not be stable or comparable over time or across organizations. Other approaches to measurement, such as a rubric-based method discussed below, may be more appropriate for benchmarking purposes.

Safety climate researchers have suggested that there may be a core set of indicators that can be used across industries (e.g. management commitment, employee involvement) as well as indicators that may not be as generalizable (Cox and Flin, 1998; Zohar, 2011). For example, Huang *et al.* (2013) developed safety climate indicators for lone workers using a truck driver sample. Their 'delivery limits' and 'cell phone disapproval' indicators are very specific to trucking. Gillen *et al.*'s (2014) workshop report presents indicator labels selected by practitioners and researchers to best represent the construction industry, and the criteria within each indicator were specific to the construction industry. For example, leadership involvement includes criteria such as 'the foreman sets the safety tone on the job site'. Future research needs to consider features that are particular to the construction industry that affect safety climate and its accurate assessment.

Employee versus management perceptions

The level at which safety climate is defined and measured, bears further attention. Many of the reviewed studies defined perceptions as worker/employee based, but few specifically stated that they could reflect both worker and manager perceptions. Additionally, very few studies compared safety climate scores between management and workers. Unlike workers, management's responses to safety climate questions may reflect a more idealized safety climate. Comparing safety climate indicators across occupational levels could reveal the quality of safety and health communication within the organization and a divergence between espoused and enacted policies and procedures. Indeed, Gittleman *et al.*'s (2010) research in construction and Huang *et al.* (2013) research in the trucking industry demonstrates the usefulness of conducting a gaps analysis between management and worker level safety climate perceptions.

Reliability and validity

Over a decade ago, both Flin *et al.* (2000) and Guldenmund (2000) noted that the majority of safety climate surveys had not been assessed for their reliability and validity. Our review reveals little progress, at least with respect to the construction industry, with a minority of studies having conducted the appropriate statistical analyses. Of the 17 studies (30%) that conducted some form of factor analysis to validate their survey, 7 (41%) used PCA, a technique better suited to reducing the number of survey questions rather than determining the relationships among them (Fabrigar *et al.*, 1999; see Brown, 2011: p. 22). Exploratory factor analysis (EFA) and CFA are more appropriate for assessing the way in which the survey items 'hang together', thus being a more accurate reflection of the instrument's reliability. We encourage investigators to evaluate both new or adapted survey instruments using EFA or CFA. Such analyses may reveal opportunities for safety climate survey improvement in measurement reliability and validity.

Language and culture

It is clear from this review that safety climate research is occurring in numerous countries around the world; however, few of the articles addressed linguistic and cultural issues relevant to safety climate measurement. The use of written safety climate surveys among low-literacy or non-native speaking workers may not provide reliable information. Furthermore, the use of safety climate surveys amongst a diverse group of workers from multiple cultural origins may lead to misleading results. For example, in the USA about one-quarter of the construction industry workforce was born in a foreign country with a large majority (82%) coming from Latin American countries (Center for Construction Research and Training, 2013). Many Latino workers not only use Spanish as their first language and have low literacy rates (Brunette, 2004) but they also bring cultural values to work, such as 'machismo', 'respeto' and 'familia', values that may impact workers' interpretation of USA-based safety climate questions (Menzel and Gutierrez, 2010). More cross-cultural research is needed on the adoption or adaptation of ethnocentric safety climate indicators to other cultures as well as safety climate survey translation in multiple languages and for low-literacy workers.

Alternative methods

A potential complement to quantitative safety climate perception surveys is a rubric-based approach that uses narrative descriptors covering a spectrum from poor to exemplary for the targeted indicators (CWPR, 2014; Gillen *et al.*, 2014). Rubric descriptors themselves need to be validated through qualitative methods, followed by a comparison of climate assessment through perception surveys and the rubric method. Researchers at CPWR: The Center for Construction Research and Training and Washington State University are currently validating a new construction-specific tool called the Safety Climate Assessment Tool (S-CAT). It uses rubrics to measure eight leading indicators of safety climate contained in the published workbook entitled 'Strengthening Jobsite Safety Climate; Eight Worksheets to Help You

Use and Improve Leading Indicators' (L. Goldenhar and T. Probst, personal communication). Lingard *et al.* (2014) have proposed such a tool to use within the Australian construction industry.

Association with other safety- and health-related variables

The dominant focus in the literature on validating safety climate measures alongside subjective outcomes such as worker self-reported safety behaviors is problematic. Self-reported behaviors or injuries and illnesses data are easy to collect, but the dominant focus on this outcome may put undue emphasis on frontline workers' responsibility for creating the job site's safety climate while ignoring the influence of higher-level management. Indeed, preventing work-related ill health and injury depends on both organizational and employee level actions. Researchers should expand the scope of their safety climate validation efforts to include other safety and health performance measures (e.g. supervisor safety leadership or organizational resources devoted to safety and health).

Some studies correlated safety climate scores with objective safety outcomes such as injury/illness rates, workers' compensation claims, or recordable/reportable accidents. Reasons for this likely include (i) that it is easier to collect 'self-reported' injury and illness data, (ii) that it is difficult for researchers to access administrative injury and illness data, and (iii) uncertainty as to the appropriate time sequence between collecting climate and follow-up injury and illness data. In addition, since injury and illness incidents on any one construction site are rare, it is difficult to achieve enough statistical power to detect causality between safety climate and adverse outcomes. The London Olympic project is one example where such outcome data were readily available (Healey and Sugden, 2012). While they found significant relationships between safety climate and objective injury outcome data, they also admitted difficulty in finding definitive trends due to a low accident rate among the sample of 15 companies.

Construction industry-specific issues

Transience of the industry

Because construction job sites are always in flux as projects begin, progress, and end, and workers move between contractors, the degree of transience should be taken into consideration when discussing safety climate. In the manufacturing industry, Beus *et al.* (2010) found that job tenure was significantly positively associated with safety climate strength because employees had the opportunity to develop shared perceptions. The high turnover that characterizes construction employment might be expected to hamper development of shared perceptions; however, at least one study compared and found consistency in safety climate scores across multiple sites of a single contractor, suggesting that an individual company can influence safety climate beyond one site at one particular moment in time (Chen *et al.*, 2013). More research is needed to determine if and how a strong safety climate can develop within transient work environments where workers travel from job site to job site.

Subcontracting

On most construction worksites multiple contracting businesses work together to finish a particular project. The general and subcontracting entities come to the project with their own safety values, policies, and procedures. It is plausible that the project-specific safety climate is, or may be, established and influenced primarily by the general contractor (Lingard *et al.*, 2010). Research designed to gather and carefully aggregate multilevel data is needed to address how multiple contractors on the same job site may influence each other's safety climate.

Work organization

On the job site, the foreman-led work crew is the basic unit to which the worker belongs. Indeed, most construction work occurs away from the contractor's main office or shop. Antonsen's (2009b) study of safety culture among seamen on oil platform supply ships provides insights into the culture of a relatively isolated occupational group and ways in which safety improvements must be approached in such groups. He asks for greater appreciation by researchers of the 'differentiation' perspective on organizational culture which argues that cultural understandings (and perhaps by extension climate perceptions) are sometimes shared, but only within subcultural boundaries (Antonsen, 2009a). Defining what constitutes the 'cultural unit' thus becomes critical. As in the subcontracting discussion above, administration of questions and analysis of data at the work-group, project, and organizational levels are needed to better elucidate the critical points for influencing and improving safety culture and climate (Lingard *et al.*, 2014).

Induction/acculturation process

In many settings workers are trained and acculturated via the apprenticeship model. In union environments, the ties between craft workers may be especially strong, and union workers may rely on their fellow members for safety and health protection more than a distant general contractor (Applebaum, 1981). None of the research we reviewed discussed the role of unions in the development of their safety climate indicators. Additional ethnographic research modeled on the work of Antonsen (2009b), Gherardi *et al.* (1998), and others would provide a stronger basis for understanding how induction and acculturation into the industry may influence perceptions by which safety climate is often measured.

Relationship to construction safety 'culture' research

While this review focuses on safety climate, the related construct of safety culture must also be discussed, particularly if investigators propose that measuring safety climate via surveys is actually measuring an organization's underlying safety culture. Various models of construction safety culture have been offered, (Choudhry *et al.*, 2007a,b; Molenaar *et al.*, 2009; Zou, 2011; Fang and Wu, 2013), and they share the view that multiple elements interact to affect safety and health performance and safety culture. Thus, measuring safety climate alone using perception surveys risks missing important elements of the Occupational Health and Safety management system, environmental and behavioral factors,

Table 2. Recommendations for advancing safety climate research and practice in construction

1 **Create and use a shared, construction-specific definition of safety climate**[a]

- Based on worker and management perceptions
- Contractor-specific and project-specific definitions

2 **Develop construction-specific measures of safety climate**[a]

- Consider relevance to construction work
- Use agreed-upon indicators
- Use appropriate question referents (e.g. supervisor, job site, general contractor, etc.)
- Use rigorous survey research methods
- Consider various evaluation tools—Likert scales or rubrics

3 **Test construction-specific indicators of safety climate for reliability and validity**[a]

- Use rigorous survey analytic methods
- Test relationship with leading and lagging indicators of safety and health

  Objective outcomes

  - Injury and illness records (e.g. OSHA logs or workers' compensation claims)
  - Safety and health performance records (e.g. site safety audit scores)

  Subjective outcomes

  - Company or site focused (e.g. company and site safety leadership)
  - Employee focused (e.g. near misses)
- Use prospective study designs

[a]Construction-specific issues to consider for each recommendation: (i) transience of the industry, (ii) subcontracting, (iii) work organization, and (iv) induction/acculturation process.

and an organization's underlying safety and health-related values and beliefs. Some have argued that only triangulated methods (e.g. safety climate surveys, key informant interviews, job-site observations, etc.) can fully investigate these deeper cultural features (Glendon and Stanton, 2000). While safety climate surveys are the least expensive and least labor-intensive means of collecting perception data, alone they may not provide a comprehensive understanding of which indicators need to be targeted and which interventions are most likely to ultimately improve safety outcomes.

Construction safety climate research and practice recommendations

Based on the aforementioned discussion, we offer a number of recommendations for advancing construction safety climate research and practice in Table 2.

CONCLUSIONS

The safety climate construct has captured the attention of many in the construction industry. While we found some inconsistencies in definitions and indicators, the results generally show us that safety climate may be a useful leading indicator of construction safety and health performance. We urge researchers and practitioners to continue studying and refining the safety climate construct using the recommendations provided, so we can continue to advance our understanding of the best methods to develop and sustain a strong safety climate and thereby improve safety and health outcomes for construction workers.

SUPPLEMENTARY DATA

Supplementary data can be found at http://annhyg.oxfordjournals.org/.

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