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# Safety climate and safety behaviors in the construction industry: The importance of co-workers commitment to safety

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**Abstract**.
**BACKGROUND:** There is growing empirical evidence that as safety climate improves work site safety practice improve. Safety climate is often measured by asking workers about their perceptions of management commitment to safety. However, it is less common to include perceptions of their co-workers commitment to safety. While the involvement of management in safety is essential, working with co-workers who value and prioritize safety may be just as important.
**OBJECTIVE:** To evaluate a concept of safety climate that focuses on top management, supervisors and co-workers commitment to safety, which is relatively new and untested in the United States construction industry.
**METHODS:** Survey data was collected from a cohort of 300 unionized construction workers in the United States. The significance of direct and indirect (mediation) effects among safety climate and safety behavior factors were evaluated via structural equation modeling.
**RESULTS:** Results indicated that safety climate was associated with safety behaviors on the job. More specifically, perceptions of co-workers commitment to safety was a mediator between both management commitment to safety climate factors and safety behaviors.
**CONCLUSIONS:** These results support workplace health and safety interventions that build and sustain safety climate and a commitment to safety amongst work teams.

Keywords: Safety leadership, construction safety, construction workers, safety management practices

## 1. Introduction

More than thirty years ago, Herbert A. Applebaum wrote a case study on the culture within the construction industry titled "Royal blue: The culture of construction workers." In Applebaum's chapter titled "Accidents, danger, and death," he notes a lunchtime swapping of stories related to work-related accidents and why accidents occur. At the end of the discussion, one worker concluded, "What's the use of looking for a 'why'? An accident is something that happens. There is no 'why.' It just is. That's all there is." Applebaum noted that "this blunt realism epitomizes construction work culture" [1]. Although this irremediable attitude persists today, there have been significant advances in

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improving safety culture within the United States construction industry. Since 1990, academics, safety professionals, construction organizations (e.g., Center for Construction Research and Training), and governmental agencies (e.g., National Institute for Occupational Safety and Health (NIOSH)) together have made significant strides in raising the awareness of health and safety issues and the importance of safety culture in the construction industry. Across the United States, the non-fatal injury rate among construction workers has decreased by 54% from 2002 to 2010 and the fatality rate decreased by 34% between 1992 and 2010 [2]. The importance of the safety culture that Applebaum eluded to, is now a leading theme in construction health and safety research and practice [3]. The importance of safety culture is echoed by the NIOSH construction sector goal 8.0, which focuses on the measurement of and interventions for safety culture in the construction industry [4].

Despite many new and effective control measures (from design to personal protective equipment) to reduce injury risk on the job-site, high rates of injuries and deaths continue in the construction industry. Construction workers account for a disproportionate number of the injuries and deaths among the United States (US) workforce. Compared to other industries, construction work still poses a significant risk for injuries [5], chronic diseases, and functional limitations [6]. This risk may be especially pronounced among some vulnerable worker populations such as older workers [7], younger workers [8], or Hispanic workers [9]. In 2012, the fatality rate FOR workers in a construction occupation was almost double the rate FOR workers in protective services (e.g., police and firefighters), 12.9 versus 6.7 per 100,000 full-time equivalent workers (FTE) [10]. In 2013, the number of injuries resulting in days away from work was 200.9 per 100,000 FTE's, compared to 109.4 for all occupations [11]. Over the course of a 45-year career, a construction worker has a 75% likelihood of sustaining a disabling injury [12]. Similar trends can be seen in Europe. For example, 7% of construction workers reported health problems due to working conditions, and among them 75% attributed their health problem to a musculoskeletal health issues [13]. The occupational non-fatal and fatal incident rates among construction workers in the European Union were 2,958 and 6.6, respectively, per 100,000 workers [14].

In addition to the innovative designs that eliminate risk and new PPE that minimizes exposure, an understanding of macro-level (e.g., safety climate) factors that influence health and safety on the job may also facilitate the continued improvements in health and safety on construction jobsites.

### 1.1. Safety climate

Safety climate represents "shared perceptions among the members of a social unit, of policies, procedures and practices related to safety in the organization" [15]. Zohar [16, 17] notes that these perceptions reflect: 1) the relative priority of safety alongside other competing organizational goals, 2) how much of the espoused safety policies are used in practice, 3) the consistency with which the safety practices are carried out, and 4) management's commitment to safety. An important tenant of safety climate is that safety climate perceptions are shared amongst workers who work in similar environments. Flin [18] noted in his review of safety climate literature that there are a variety of factors (or indicators) used to represent and measure safety climate perceptions. However, management commitment to safety is the most common. It is less common to consider co-workers commitment to safety as a factor of safety climate (see discussion below).

Many studies have linked safety climate to other proximal (e.g., safety knowledge) and distal (e.g., safety behaviors and injuries) outcomes [19]. Measures of safety climate have also been used as an indicator of health and safety in the construction industry [15, 20, 21]. For example, after eight construction workers died within a period of 18 months on a large Las Vegas construction project, Gittleman et al. [22] stratified safety climate measures focused on management commitment and safety practices to understand major health and safety concerns by organizational level (e.g., foremen vs. workers). Interestingly, average safety climate perceptions were more positive among management than workers.

#### 1.1.1. Perceptions of management

One focal point in the safety climate literature is the prominence that company management plays in the development of climate. At the heart of safety climate are worker's perceptions of management's true priority or value of safety. Since management is responsible for setting company priorities and carrying them out in practice, their actions are key indicators of safety climate. Meta-analyses of safety climate studies conducted over a decade ago found that management related factors were the most common factors included in safety climate measurements

[18, 23]. Since then, management commitment to safety continues to be a common safety climate measurement factor [15, 24]. Although other factors of safety climate are commonly considered (e.g., safety systems and safety training), it is becoming more common to think of safety climate perceptions in terms of "who" is or "who" is not carrying out company safety policies, procedures and practices. Recently, there has been greater emphasis on how a variety of "safety agents" within an organization *respond* to jobsite safety rather than the actual practices employed [25, 26]. Conceptually, other previously researched dimensions of safety climate (e.g., safety training) are "at least partially dependent on management commitment to safety" [27].

Previous research suggests that it is not sufficient to assess safety climate based on perceptions of management as a whole. The first author who proposes a multi-level view of safety was Meliá [28], who distinguished between four actors and analysis levels: worker, co-workers, supervisors and the management. Zohar and Luria [29] contends that measures tapping into the organization and group level are more useful than measures that address only the organization. While top management is responsible for setting company priorities and outlining procedures, supervisors are tasked with disseminating and integrating these concepts into daily practice within their work groups. Zohar and Luria's (2005) results demonstrated this effect by showing that perceptions of supervisor's commitment to safety fully mediated the relationship between perceptions of top management's commitment to safety and safety behaviors.

In the construction industry, this distinction is especially conspicuous. Typical construction work takes place on job sites away from company main offices. The distance created from this type of work gives supervisors and mid-level management a great amount of responsibility and discretion in carrying out day-to-day safety practices. This responsibility and discretion contributes to the development of safety climate perceptions beyond the organizational level. This means that workers develop distinct perceptions of top management safety climate and supervisor safety climate [17]. Thus, the role of supervisors on construction job site safety cannot be understated. In qualitative studies, researchers found that supervisors can be helpful when they model safe behaviors, put safety before production, and encourage reporting when workers feel unsafe [30]. Construction workers also see their supervisor as having the second most influential position with respect to safety, with the safety manager being the first [31]. In quantitative studies, the amount of time supervisors spent talking with their crews about safety had a direct impact on their crew's safety performance [32]. Furthermore, Lingard et al. [33] found that supervisor safety climate significantly mediated the relationship between top management safety climate and injury frequency rate.

### *1.2. Co-workers commitment to safety*

Co-workers commitment to safety may be an important variable in the relationship between safety climate perceptions and safety behaviors. In a recent meta-analysis, Chiaburu et al. [34] found that co-workers influence each other even after accounting for managerial influences. In the construction industry, this may be especially true due to a mobile workforce, mixed union and non-union worksites, varying job sites away from the contractor's office, and sub-contracting. These characteristics lead to a workforce that is relatively disconnected with top management and more connected with their crews. While the management sets the stage for the safety of their job sites, crews' commitment to safety may be more likely to affect safety behaviors on the job. This means that in order for management to affect safety behaviors, workers might need to perceive that their co-workers are committed to safety. A few prior research studies demonstrate the importance of co-workers who care about each other's safety [35], practice good safety behaviors [25, 36], and support each other after a work-related injury [37] in the construction industry.

The relationship between co-workers commitment to safety and the aforementioned safety climate management dimensions was investigated in three prior studies outside of the US. The researchers argue that co-workers commitment to safety is a factor of safety climate [15, 25, 26]. As an extension of Zohar and Luria's [29] organizational and group level safety climate, Melia et al. [25] and Brondino et al. [26] included perceptions of co-workers commitment to safety as a factor of safety climate. They wanted to understand the influence of various "safety agents" (top management, supervisors, and co-workers) on job safety. Their results demonstrated that co-workers commitment to safety is just as important as top management and supervisor commitment to safety. In fact, Brondino et al. [26], using structural equation modeling (SEM), found significant mediation effects among a blue collar European sample of workers. This provides evidence for a concept consistent with a partially causal path of "safety agent" influences on safety behavior, starting from top management and ending at worker safety behavior.

In addition to having distinct perceptions of top management and supervisors in the construction industry, construction workers are also likely to have distinct perceptions of how committed their co-workers are to safety. This is due to a mobile workforce, mixed union and non-union worksites, varying job sites away from the contractor's office, and subcontracting. These characteristics lead to a workforce that is relatively disconnected with top management and more connected with their crews (i.e., supervisor and co-workers). While the management sets the stage for the safety of their job sites, safety climate perceptions of crews may be more likely to affect safety behaviors on the job.

Although the contribution of co-workers in the development of safety climate in the construction industry may be critical, the contributing effects are not well understood. Kines et al.'s [15] tested the NOSACQ-50 in the Nordic construction industry and found that co-worker factors were significantly related to worker safety motivation and safety behavior. In a sample of construction workers from Hong Kong and Spain, Melia et al. [25] also found support for the importance of co-workers commitment to safety as an important factor of safety climate that is related to safety behaviors.

### *1.3. Present study*

After interviewing 23 construction workers and supervisors, Torner and Pousette [38] concluded that safety performance "is dependent on the development of open and mutually trustful vertical as well as horizontal relationships within the contractor company . . . [furthermore], the complexity of construction work demands . . . the need for collective norms favoring safety" (pg., 407). While the involvement of management in safety is essential, working with co-workers who value and prioritize safety may be just as important.

Increasing our understanding of safety climate perceptions related to co-worker safety commitment within a framework that includes top management and supervisors will allow for a more detailed understanding of how each "safety agent" influences one another and how their combined effect contributes to safety performance. Thus, the purpose of the present study is to evaluate the usefulness of Melia et al.'s [25] and Brondino et al.'s [26] concept of safety climate in the US construction industry. The present study is the first to assess the relationship between top management, supervisor, and co-worker commitment to safety factors of safety climate as well as the cumulative effect of these safety climate factors on proximal safety outcomes (i.e., safety behaviors) in a US construction cohort.

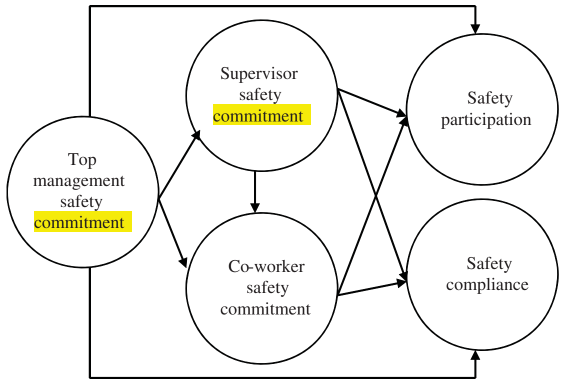


Fig. 1. Hypothesized model of the effect of safety climate on safety behaviors.

We evaluated the hypothesized model in Fig. 1. It is similar to the hypothesized relationships in Melia et al.'s [25] and Brondino et al.'s [26] studies; however, we distinguished between two types of safety behaviors (i.e., compliance and participation). The purpose of including the two types of safety behaviors was to determine if there was a differential effect of the safety climate factors on the two kinds of safety behaviors. This is because previous research found that safety climate factors have a greater effect on behaviors related to promoting safety practices (i.e., participation) than behaviors related to complying with rules (i.e., compliance) [39].

Following previous research findings, we hypothesized (H1) that top management safety climate would be positively associated with supervisor safety climate (e.g. 29) and that (H2) both top management and supervisor safety climate would be positively associated with safety participation and safety compliance behaviors (e.g. 40).

To evaluate the role of co-workers in job site safety, we tested the hypothesis (H3) that co- workers commitment to safety would be positively associated with both safety participation and safety compliance behaviors. Finally, we investigated the indirect effect that top management safety commitment can have on safety behaviors. Given the aforementioned prior research, we believed that top management and supervisor safety commitment would still have a direct impact on worker behavior. However, we hypothesized that (H4) the relationship between top management safety commitment and safety participation and safety compliance behaviors would be partially mediated by not only supervisor safety commitment but also co- workers safety commitment.

## 2. Methods

### 2.1. Participants and procedure

Three medium-sized mechanical construction firms (e.g., installation of plumbing and heating/ventilation systems) in the Pacific Northwest region of the US participated in the study. A total of 300 construction workers completed the surveys, which represents a response rate of 71%. The majority of participants were Caucasian (82%) and male (96%) with an average age of 41.4 years (SD = 11.6). Participants had been with their company an average of 38 months (SD = 50), with their immediate supervisor for 12 months (SD = 23), and had worked in their craft for an average of 15 years (SD = 10.7). The sample represented 18 pre-apprentices, 41 apprentices, 136 journeymen, 72 foremen, 5 superintendents, 5 top management, and 20 individuals from other positions (e.g., engineers). The main trades represented by this sample include unionized plumbers, pipefitters, and sheet metal workers. The University Institutional Review Board approved all study related methods.

Surveys were distributed during normal work hours during breaks or pre-scheduled meetings (e.g., morning huddles, tool box talks, or safety meetings). Before the surveys were distributed, all workers were informed that their participation was voluntary and that no individual identifying information would be collected from them. They were told the survey would take 15–20 minutes to complete. The majority of surveys were distributed to the workers by the research investigators at the jobsite. Members of the company's safety team distributed surveys to workers that were not present when the investigators were on the jobsite. Regardless of who distributed the survey, all surveys were collected upon completion and placed into a sealed envelope, in which the investigators collected and maintained at the university.

### 2.2. Measures

#### 2.2.1. Safety climate

In the present study, safety climate was defined as "shared perceptions among the members of a social unit, of policies, procedures and practices related to safety in the organization" [15]. Workers were asked to respond to questions referring to their top management, supervisor's, and co-workers' safety commitment.

The survey items were adapted from the NOSACQ-50 [15], which was tested in the construction industry and includes a variety of distinct safety climate dimensions that represent company safety policies, procedures and practices. Three of the seven management focused dimensions of safety climate in the NOSACQ-50 were used in the present study. These included: 1) management safety priority, commitment, and competence 2) management safety empowerment, and 3) management safety justice. The three other dimensions were excluded because either they did not pertain to the present study (e.g., perceptions of their trust in the efficacy of their workplace safety systems) or because of survey length restrictions.

In order to evaluate safety climate factors that reflect perceptions of both top management and supervisors, Kines et al.'s [15] management factors were altered to reflect the referents "top management" and "my current, immediate supervisor" instead of "management." This was accomplished by splitting Kines et al.'s [15] management factors according to Zohar's [17] conceptualization of the specific safety activities or focuses that each respective level of management is concerned with. For example, top management is concerned with financial expenditures, reducing production in favor of safety and providing workers with information; on the other hand, supervisors monitor and reward workers and stick to safety rules when production falls behind. An example question for top management was, "Top management places safety before production." An example question for supervisors was, "My current, immediate supervisor looks the other way when someone is careless with safety."

This resulted in six factors: 1) top management safety priority, commitment, and competence (4 items), 2) top management safety empowerment (3 items), 3) top management safety justice (3 items), 4) supervisor safety priority, commitment, and competence (5 items), 5) supervisor safety empowerment (4 items), and 6) supervisor safety justice (3 items).

All items were assessed on a 6-point likert scale (i.e., never to always).

In Kines et al.'s [15] original measure, the management factors had high factor correlations ($r = 0.60 – 0.80$), which suggests the possibility for a second order management factor. Thus in the present study, a second order factor was created for the top management safety climate factors and supervisor safety climate factors for the sake of parsimony.

The final safety climate factor adapted from Kines et al. [15] was the "co-workers safety commitment" factor (6 items). Co-workers safety commitment represents whether or not peers care about each other's safety, and if they promote safety on the job. An example item is, "My coworkers and I take responsibility for each others' safety."

*2.2.2. Safety behaviors*

Safety behaviors were assed by employing a measurement tool that asked questions related to self reports of safety compliance and participation behaviors [41]. Three items of this measurement tool were used to assess safety compliance (e.g., "I use all the necessary safety equipment to do my job") and three items assessed safety participation (e.g., "I promote the safety program within the organization"). The measure was chosen because it was found reliable and valid [24, 42] and for its short length as compared to other measures of safety behaviors [40]. All items were assessed on a 6-point likert scale (i.e., never to always). Since Brondino et al.'s [26] findings suggested that safety climate factors may have a different effect on each factor representing safety behaviors, a second order safety behaviors factor was not tested.

### 2.3. Analyses

The psychometric properties of all factors included in the study (i.e., safety climate and safety behavior factors) were assessed via confirmatory factor analysis (CFA). The direct and indirect effects of all paths in Fig. 1 were determined via SEM. Descriptive analyses in SPSS 21 revealed that the variables exhibited moderate non-normality. Thus, CFA and SEM models were estimated using maximum likelihood parameter estimates with standard errors and a chi-square test statistic that are more robust to non-normality in MPlus version 7.0 software (Mplus code: ANALYSIS = MLR). Additionally, MLR is also a full information maximum likelihood (FIML, also known as direct maximum likelihood) estimation method that can account for missing data. Unlike pairwise or listwise deletion, FIML estimates all parameters at once with all available data [43, 44]. Model fit was assessed by examining the chi-square model test statistic, RMSEA, GFI, CFI, and SRMR. Acceptable fit was indicated by values >0.95 for CFI and TLI, <0.06 for RMSEA and SRMR [43]. The chi-square model test statistic indicates acceptable fit when the statistic value is low, $p > 0.05$ and/or the ratio of the chi-square test statistic over degrees of freedom (DF) is <2.0 [45]. When comparing nested models (e.g., adding or removing paths) to find the best model fit, the chi-square difference test specific to the MLR estimator was calculated [46]. A failure to reject the chi-square test indicates that the more restrictive (null) model with fewer paths estimated is better than the less restrictive model (alternative) with more paths estimated [44]. Finally, indirect effects (i.e., mediation effects) were estimated using the MODEL INDIRECT command and a bias-corrected bootstrapping method to estimate the significance of the effects [47].

## 3. Results

### 3.1. Confirmatory factor analysis

A confirmatory factor analysis with all 34 questions representing 7 first order safety climate factors, 2 first order safety behavior factors, and 2 second order safety climate factors (top management and supervisor) had poor to moderate fit, $\chi^2 = 810$ (511), $p = 0.000$, RMSEA = 0.044 95% CI = 0.038–0.050, CFI = 0.918, TLI = 0.910, SRMR = 0.062. While a model without the 2 higher order factors fit the data better ($\chi^2 = 33$ (20), $p < 0.05$), the higher order factors were retained because 1) the first order factor loadings onto the higher order factors were high ($\beta = 0.70 – 0.97$) and 2) the fit indices did not change appreciably. Thus, the higher order factors were kept for the sake of parsimony.

To improve the fit of the latter model, all items were inspected for insignificant or low factor loadings and low squared multiple correlations. Of the 34 items, 5 items had low factor loadings ($\beta = 0.16 – 0.44$) and squared multiple correlation values (0.02 – 0.19), but were statistically significant. Despite their significance, their low factor loadings indicated that the items were not related to their proposed factors. Removing the insignificant items resulted in a poor to moderately good fitting model, $\chi^2 = 595$ (361), $p = 0.000$, RMSEA = 0.047 95% CI = 0.040–0.053, CFI = 0.928, TLI = 0.920, SRMR = 0.060.

Table 1
Means, standard deviations (SD), and factor correlations of all study variables

| | Mean | SD | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| 1. Top management safety commitment | 4.14 | 0.73 | 1.000 | 0.662 | 0.549 | 0.450 | 0.402 |
| 2. Supervisor safety commitment | 4.35 | 0.64 | | 1.000 | 0.577 | 0.390 | 0.241 |
| 3. Co-worker safety commitment | 4.29 | 0.70 | | | 1.000 | 0.617 | 0.591 |
| 4. Safety compliance (SC) | 4.41 | 0.63 | | | | 1.000 | 0.629 |
| 5. Safety participation (SP) | 3.83 | 0.94 | | | | | 1.000 |

*Note.* All correlations are significant ($p < 0.001$). Items were rated on a frequency scale from 0 to 5, Never to Always.

Modification indices were inspected from the latter model to determine additional sources of model misfit. The largest modification index value was related to a correlated errors term for two of the co-worker safety commitment factor item's errors, and are indicative of variance that cannot be accounted for by the factors on which the items load. Theoretically, this inclusion made sense because the items were worded very similarly [43]. Including the correlated error term in the model resulted in significantly improved model fit ($\chi^2 = 17$ (1), $p < 0.05$), and resulted in moderately good fit, $\chi^2 = 549$ (360), $p = 0.000$, RMSEA = 0.042 95% CI = 0.035–0.049, CFI = 0.942, TLI = 0.935, SRMR = 0.056.

Additional modification indices from the latter model indicated that the fit of the model would be significantly improved if one item from the supervisor safety priority, commitment, and competence factor was allowed to cross-load onto the supervisor safety empowerment factor. Including the cross-loading item in the model resulted in significantly improved fit ($\chi^2 = 42.90$ (1), $p < 0.05$), and resulted in good fit, $\chi^2 = 501$ (359), $p = 0.000$, RMSEA = 0.036 95% CI = 0.029–0.044, CFI = 0.957, TLI = 0.951, SRMR = 0.048. All item factor loadings were significant ($p < 0.01$) and had standardized factor loadings ranging from 0.503 to 0.979. One factor loading, which cross loaded onto two supervisor factors as previously mentioned, had a significant but low factor loading ($\beta = 0.274$) on the supervisor safety priority, commitment and competence factor, but it was kept. Inter-item reliability scores were good ($\alpha = 0.68$–$0.85$). A detailed table with item loadings, standard errors, $p$-values, and Cronbach's alpha for each factor can be seen in Appendix A. Table 1 shows the correlations for all factors in the final conceptual model.

### 3.2. Structural equation modeling

The hypothesized model (see Fig. 1) provided good fit, $\chi^2 = 507$ (359), $p = 0.000$, RMSEA = 0.036 95% CI = 0.029–0.044, CFI = 0.957, TLI = 0.951,

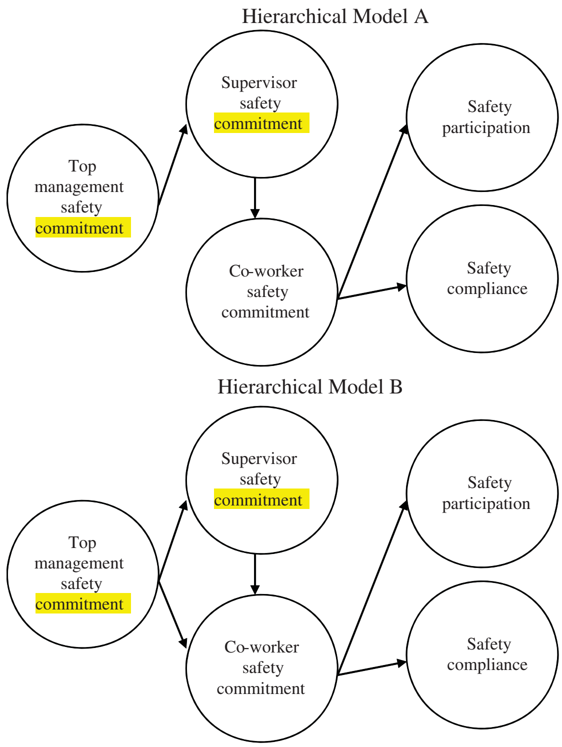


Fig. 2. Hierarchical models compared to hypothesized model in Fig. 1.

SRMR = 0.048. However, since 1) the second order supervisor safety commitment factor was hypothesized to mediate the relationship between the second order top management safety commitment and co-worker safety commitment factors, and 2) the co-worker safety commitment factor was hypothesized to mediate the relationships between the second order top management safety commitment and second order supervisor safety commitment factors and both safety behavior factors, the hypothesized model was compared to two competing hierarchical models (see Fig. 2). Compared to the hypothesized model in Fig. 1, hierarchical model A did not result in significantly better fit ($\chi^2 = 15.68$ (5), $p < 0.01$), but hierarchical model B did result in better fit ($\chi^2 = 4.79$ (4), $p > 0.05$). This indicates that the direct paths

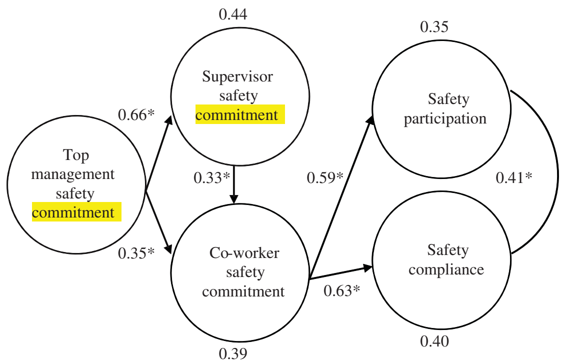


Fig. 3. Final structural model with significant standardized path estimates. *Note.* *Significant ($p < 0.001$). Only paths significant at $p < 0.001$ are shown. Values beside latent variables represent variance accounted for.

Table 2
Mediation effects in the final structural equation model

| | Estimate (S.E.) | 95% CI |
|---|---|---|
| *Effects on Safety Participation* | | |
| Effects from TMSC to SP | | |
| TMSC → SSC → CSC → SP | 0.130 (0.049) | 0.033–0.226 |
| TMSC → CSC → SP | 0.208 (0.057) | 0.061–0.356 |
| *Total indirect effect* | *0.338 (0.057)* | *0.227–0.449* |
| *Effects on Safety Compliance* | | |
| Effects from TMSC to SC | | |
| TMSC → SSC → CSC → SC | 0.139 (0.054) | 0.034–0.245 |
| TMSC → CSC → SC | 0.224 (0.076) | 0.076–0.373 |
| *Total indirect effect* | *0.364 (0.055)* | *0.256–0.472* |

*Note.* TMSC: Higher order top management safety commitment, SSC: Higher order supervisor safety commitment, CSC: Co-worker safety commitment, SP: Safety participation, SC: Safety compliance.

of both second order management safety commitment factors on both safety behavior factors did not improve the fit of the model. The final model with all significant standardized parameter path estimates and $r^2$ values is illustrated in Fig. 3.

The strength of the mediation effects can be seen in Table 2. The second order supervisor safety commitment factor and co-worker safety commitment factor both significantly mediated the relationship between the second order top management safety commitment and both types of safety behaviors.

The present study hypothesized that the model in Fig. 1 proposed by Melia et al. [25] and Brondino et al. [26] would also be appropriate among US construction workers. Our results only found partial support for this model. Hypothesis H1 was supported, because we found that top management safety commitment was significantly associated with supervisor safety commitment. Both top management safety commitment and supervisor safety commitment were significantly correlated with both types of safety behaviors. However, the final SEM model did not indicate a direct path between them, which fails to support hypothesis H2. The relationship between co-worker safety commitment and both types of safety behaviors was significant in the final SEM model, which supports hypothesis H3. Finally, hypothesis H4 was supported, because 1) no direct paths between the two management safety commitment factors and the two safety behaviors were significant and 2) the mediation effects in Table 2 were all significant.

## 4. Discussion

The present study was one of the first to test a concept of safety climate that focuses on perceptions of how individuals at each company level (top management, supervisors and co-workers) respond to safety and how these perceptions affect personal safety behaviors. These relationships were initially proposed by Melia et al. [22] and Brondino et al. [23] as an extension of Zohar's [29] multi-level concept of safety climate. After evaluating this model in the US construction industry, we found similar results. Specifically, we found that co-worker's safety commitment may be an important factor that explains the mechanism by which safety behaviors are affected by top management and supervisor safety commitment. Our comparable results in the present study strengthen the evidence for a concept of safety climate that focuses on "who" performs actions (i.e., management and co-workers) rather than relying solely on "what" actions were performed (e.g., safety training).

Melia et al. [25] tested this concept of safety climate among four cohorts, two general cohorts from the United Kingdom and Spain and two construction cohorts from Hong Kong and Spain, using multiple regression. Brondino et al. [23] tested the concept in the Italian manufacturing industry using multi-level SEM. In both Melia et al.'s [22] and Brondino et al.'s [23] studies, top management's safety response had a direct effect on safety behaviors. Yet, in the present study they did not (H2). Supervisor's safety response affected some sample's safety behaviors in Melia et al.'s [22] study (English general and Chinese construction cohorts), but they did not affect them in Brondino et al.'s [23] or the present study's cohort (H2). In both the previous and the present studies (H3), co-worker safety response had a significant direct relationship with safety behaviors. Additionally, Brondino et al.'s [23] and the present study (H4) found significant mediation effects among the safety climate, co-worker safety commitment and safety behavior factors. Melia et al. [22] did not test mediation in their study. Ultimately, these studies support the inclusion of perceptions of top management and supervisors in the measurement of safety climate and in the prediction of safety behaviors. It also supports the inclusion of co-workers commitment to safety as a mediating variable.

While previous research found a direct relationship between both levels of management safety commitment and safety outcomes [15, 25, 26, 29], the present study indicates that the relationship is mediated by co-worker's safety commitment. These findings broaden our understanding of how management's response to safety influences safety behaviors. It indicates that it is important to account for co-worker safety commitment alongside the top management and supervisor safety commitment. It's inclusion helps to explain how top management and supervisor's safety response to safety influences safety behaviors. It is through positive perceptions of co-workers commitment to safety that top management and supervisors can influence safety behaviors. In other words, workers must perceive that their co-workers are committed to safety in order for management to positively influence safety behaviors on the job. In practice, co-worker's response to safety should be seen as just as important in generating a safe work environment as management's response to safety. Building a commitment to safety among co-workers should be emphasized in educational programs such as toolbox talks.

Perhaps the reason that co-worker safety commitment had such a great influence on safety behaviors in this study is because the majority of the workers in the study belonged to unions. Unions provide workers training [48], they find job sites for them to work on, and negotiate wages and safety standards. Unions also provide a sense of belonging and brotherhood [49]. Thus, union workers may feel closer to and responsible for the safety of their co-workers (who are also members of the same union). Additionally, workers are influenced by their co-workers commitment to safety and the pressure to conform to group norms of whether or not to be a "tough guy" [50]. Thus, the present study lends support for the necessity to understand the influence of co-workers, not just management, in safety behavior investigations [34].

### *4.1. Future directions and limitations*

#### *4.1.1. Relationships to be addressed*

The concept of safety climate could be strengthened by the inclusion of other potential explanatory variables. Since the present study found that co-worker safety commitment was important, it is possible that team member exchange (TMX) might be important in the safety climate and safety behavior relationship. TMX represents worker's relationship with their work group as a whole. Under high quality TMX, workers assist each other and share their ideas and feedback [51]. Future research should consider TMX in the context of this safety climate concept and the potential causal or reciprocal relationship with leader factors that previous research linked with safety climate (i.e. transformational leadership style and leader member exchange) [52–54].

Reverse causation should be addressed through a longitudinal design. Reverse causation suggests that the outcome may actually occur before its predictor. Reverse causation can be ruled out with longitudinal study designs, as they help to distinguish which variables truly influence other variables over time. In the present study, it is unclear if the management safety climate factors predict the co-worker safety commitment over time. Nor is it clear if one safety climate factor predicts safety behaviors better than the others over time. Furthermore, a longitudinal design may indicate that workers who perform more safety behaviors may influence perceptions of co-worker's commitment to safety or that a feedback loop exists between them. Within the context of the aforementioned additional leadership and team member variables to be included in the model, there may be reciprocal relationships between variables or paths that may work in an unexpected direction.

Finally, the model could be improved by testing its validity among and between other construction companies in different US geographical regions as well as other countries, trades, union and non-union contractors, and size of company (i.e., number of workers). Including fixed effects such as these in the model will allow commonalities between workers and companies to be addressed. For example, questions remain about how company size may affect safety climate perceptions. Larger companies have more resources for safety policies, procedures and practices, thus higher levels of safety climate perceptions may exist among larger companies. Yet, the majority of contractors in the US and Europe are small in size (i.e., 9 workers or less) [2, 55].

A large-scale multilevel study of safety climate perceptions among different contractors could answer this question, and offer potential avenues for safety climate intervention research.

#### 4.1.2. Safety climate interventions

The present study supports the use of proactive work place interventions to improve health and safety. Efforts to improve safety climate on the job include transformational leadership training [53] and feedback methods to increase safety specific communication between supervisors and workers [32, 56]. Our study supports the use of these kinds of interventions. Yet, it also supports team based interventions, as suggested by Brondino et al. [26]. Such interventions could improve the relationship between management and workers as well as among workers themselves. Specifically, interactive and engaging training among work teams may be an effective means of increasing safety knowledge and performance [57]. Team based interventions may help build social rapport amongst work crews [58] and build communication networks amongst all organizational levels [59]. Participatory ergonomics is an example of one such intervention [60]. Consideration for work teams could also be given during on the job training via mentoring [61, 62].

#### 4.1.3. Limitations

Some of the present study's limitations were addressed in the previous section 4.1.1. (i.e., cross-sectional design, omitted variables, omitted fixed effects, and common method variance). The present study also only represents one region of the US and a few construction trades, and thus may not be generalizable to the entire US construction industry. Finally, a main tenant of safety climate is that perceptions of it are *shared*, but the present study could not determine *sharedness* among work groups due to a lack of crew-membership information. Thus, the present study only addressed psychological safety climate.

## 5. Conclusions

The irremediable construction safety culture depicted in Applebaum's [1] ethnography is slowly transitioning into a culture that rejects the fallacy that accidents just happen and cannot be prevented. There is growing empirical evidence that as safety climate improves injuries and fatalities are reduced. This evidence is strongest when safety climate is measured via perceptions of management commitment to safety [63]. In other words, when management is committed to safety, job sites are safer. Indeed, Lingard et al. [33] aptly stated that there is a "cascading influence . . . [of] management commitment to safety [that] filters down through organizational hierarchies" (pg. 239).

Similar to prior research, we hypothesized that construction worker's safety climate perceptions of top management and supervisor commitment to safety would affect their personal safety behaviors. However, it was hypothesized that worker's perceptions of their co-workers commitment to safety would play an important intervening role in the relationship between the management focused safety climate factors and safety behaviors. Our results indicate that top management, supervisor, and co-workers commitment to safety positively impact safety behaviors on the job. More specifically, workers must perceive that their co-workers are committed to safety in order for top management and supervisors to influence safety behaviors on the job. Our results support workplace health and safety interventions targeted towards not only leadership, but also work teams.

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## Conflict of interest

None to declare.

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## Appendix A

Table A.1
Confirmatory factor analysis results

| Factor | Item | Estimate | S.E. | *P*-Value | Inter-item reliability (α) |
|---|---|---|---|---|---|
| SP | V1 | 0.686 | 0.051 | $P < 0.01$ | 0.828 |
| | V4 | 0.809 | 0.033 | $P < 0.01$ | |
| | V5 | 0.873 | 0.029 | $P < 0.01$ | |
| SC | V2 | 0.851 | 0.027 | $P < 0.01$ | 0.840 |
| | V3 | 0.848 | 0.031 | $P < 0.01$ | |
| | V6 | 0.714 | 0.042 | $P < 0.01$ | |
| TMP | V7 | 0.716 | 0.045 | $P < 0.01$ | 0.844 |
| | V14 | 0.715 | 0.038 | $P < 0.01$ | |
| | V15 | 0.860 | 0.024 | $P < 0.01$ | |
| | V16 | 0.814 | 0.028 | $P < 0.01$ | |
| TME | V9 | 0.755 | 0.034 | $P < 0.01$ | 0.812 |
| | V10 | 0.817 | 0.036 | $P < 0.01$ | |
| | V12 | 0.772 | 0.036 | $P < 0.01$ | |
| TMJ | V8 | 0.784 | 0.039 | $P < 0.01$ | 0.717 |
| | V13 | 0.727 | 0.056 | $P < 0.01$ | |
| SUPP | V17 | 0.704 | 0.074 | $P < 0.01$ | 0.846 |
| | V19 | 0.823 | 0.043 | $P < 0.01$ | |
| | V20 | 0.752 | 0.078 | $P < 0.01$ | |
| | V21 | 0.759 | 0.094 | $P < 0.01$ | |
| | V28 | 0.274 | 0.113 | $P < 0.01$ | |
| SUPE | V24 | 0.882 | 0.031 | $P < 0.01$ | 0.801 |
| | V25 | 0.805 | 0.035 | $P < 0.01$ | |
| | V26 | 0.574 | 0.060 | $P < 0.01$ | |
| | V28 | 0.503 | 0.098 | $P < 0.01$ | |
| SUPJ | V18 | 0.653 | 0.076 | $P < 0.01$ | 0.679 |
| | V23 | 0.779 | 0.062 | $P < 0.01$ | |
| CSC | V29 | 0.808 | 0.034 | $P < 0.01$ | 0.850 |
| | V30 | 0.731 | 0.037 | $P < 0.01$ | |
| | V33 | 0.702 | 0.081 | $P < 0.01$ | |
| | V34 | 0.683 | 0.064 | $P < 0.01$ | |
| TMSC | TMP | 0.927 | 0.032 | $P < 0.01$ | |
| | TME | 0.979 | 0.023 | $P < 0.01$ | |
| | TMJ | 0.920 | 0.039 | $P < 0.01$ | |
| SSC | SUPP | 0.625 | 0.075 | $P < 0.01$ | |
| | SUPE | 0.974 | 0.034 | $P < 0.01$ | |
| | SUPJ | 0.946 | 0.054 | $P < 0.01$ | |

*Note.* TMSC: Higher order top management, TMP: Top management safety commitment; TME: Top management safety empowerment; TMJ: Top management safety justice; SSC: Higher order supervisor, SUP: Supervisor safety commitment; SUPE: Supervisor safety empowerment; SUPJ: Supervisor safety justice; CSC: Co-worker safety commitment, SP: Safety participation, SC: Safety compliance.