Safety climate as a relative concept: Exploring variability and change in a dynamic construction project environment

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Abstract

Purpose - This study uses a longitudinal approach to measure safety climate at construction projects, and explores the relationship between safety climate and the level of project completion in the dynamic construction project environments.

Design/methodology/approach – Multi-wave safety climate surveys were conducted at four processing plant construction projects in New Zealand. Safety climate was measured with a multi-level measurement instrument, which measured construction workers’ perceptions of client’s organisational safety response (COSR), principal contractor’s organisational safety response (PCOSR), supervisors’ safety response (SSR) and co-workers’ safety response (CWSR).

Findings – At the organisational level, the research identifies a general downward change trend in workers’ perceptions of client’s organisational safety response (COSR) and principal contractor’s organizational safety response (PCOSR). At the group level, no clear or consistent change trend is identified between the level of project completion and workers’ perceptions of supervisors’ safety response (SSR) and co-workers’ safety response (CWSR).

Research implications - The research suggests that the construction project management should consistently emphasise the importance of safety, even when they are facing production pressure. The research highlights the opportunity to examine the role of supervisors’ leadership as an antecedent to the group level safety climate and the development of workers’ safety concerns for their co-workers over time.

Originality/value - This research provides the starting point for understanding safety climate in the dynamic and constantly changing construction project environments, in which the relative priorities change, adverse events arise and production pressures fluctuate over time.

Key words: Construction safety; project management; organization

Paper type: Research Paper
Introduction

Safety climate

The contemporary view of workplace safety management emphasizes cultural determinants of safety (Hudson, 2007). The cultural drivers of safety are elements embedded in organisational systems and structures and ways of working (Guldenmund, 2000). If this view is accepted, then it is helpful to focus on aspects of the organisational culture to understand the extent to which safety is integrated into organisational work processes and decision making (Guldenmund, 2000).

However, the cultural influences on safety are complex and multi-layered. At the deepest level, the basic assumptions underpinning organisational life can be seen to influence all aspects of an organisation’s activities, including safety (Schein, 1985). These assumptions are so deeply rooted and often taken-for-granted that they are very difficult to reveal or for people to express. Nevertheless, their influence is manifested in the beliefs and espoused values held by organisational members and behaviours and artefacts created in the work of an organisation. These values and beliefs, as well as behaviours and artefacts, are purported to be rooted in and logically flow from the core basic assumptions, and can be (at least in part) uncovered by measuring employees’ attitudes and perceptions (Guldenmund, 2000). The summary of attitudes and perceptions that employees share about their work environment is described as the safety climate (Zohar, 1980). According to Flin et al. (2000, p. 178), safety climate represents the “surface features of the safety culture discerned from the workforce’s attitudes and perceptions at a given point in time”. It therefore presents a ‘snapshot’ assessment of prevalent cultural influences on safety in an organisation at a particular point in time (Mearns & Flin, 1999). Many organisations that take a cultural approach to safety improvement consequently use safety climate measurement as a diagnostic method to identify problematic areas requiring change (Zhang et al., 2015).

In recent years, there has been a growing interest in the measurement of safety climate in construction as well as other industries. The growth is predicated on the expected links between safety climate and safety-related behaviours and objective performance indicators, such as the occurrence of incidents and/or injuries. Empirical evidence across different industries has provided some support for these links. For example, safety climate was found to be negatively associated with risky behaviour in the rail industry (Morrow et al., 2010) and unsafe behaviour in the chemical manufacturing sector (Bosak et al., 2013). A positive safety climate was reported to be strongly correlated to greater participation in safety-related activities in the health sector (Neal et al., 2000) and lower accident rate in wood-processing companies (Varonen & Mattila, 2000).
In the construction industry, several studies have reported a significant link between safety climate and various aspects of safety performance (see, for example, Lingard et al. (2012; 2010), Siu et al. (2004), Zhou et al. (2008)). Emerging evidence also indicates that safety climate may be considered as a valid leading indicator, i.e. safety climate measured at one point in time predicts the occurrence of accidents or injuries in a future point of time (see, for example, Wallace et al. (2006); Neal & Griffin (2006)).

Safety climate measurement

With the exception of a few notable multi-wave studies, safety climate is still mostly measured using a one-off cross-sectional approach. Given that safety climate is defined as workers’ perceptions of their work environment, it may be expected that these perceptions will vary if there is perceivable change in the work environment. Consistent with this, there is emerging evidence to suggest that safety climate is not stable over time. For example, Tharaldsen et al. (2008) recorded significant increases in mean scores relating to four safety climate dimensions on offshore oil platforms on the Norwegian continental shelf (NCS) between 2001 and 2003. They further revealed that the positive changes observed were related to safety initiatives that occurred in the Norwegian petroleum industry, in which a cultural approach was adopted and a stronger emphasis was placed on safety (Tharaldsen et al., 2008). However, changes in safety climate can also be negative. For example, if production falls behind schedule, managers may change their emphasis and either overtly or inadvertently communicate expectations that workers accelerate the pace of work and/or work longer time, thus potentially decreasing the emphasis they place on workers’ wellbeing (e.g. fatigue and anxiety) relative to other project imperatives (Han et al., 2014). A changed management response to safety, even if quite subtle, can be interpreted by workers and expressed in deteriorated perceptions of the organisational safety climate (Zohar, 2008).

In the dynamic context of construction projects, it seems even less likely that safety climate would remain stable over time than in other more stable work environments. Shen et al. (2015) commented that in the “ill-structured and dynamic construction process”, workers should have a heightened sensitivity to surrounding safety stimuli. The unstable nature of safety climate highlights the need to conduct longitudinal multi-wave safety climate measurement to monitor safety climate change in construction projects and inform the implementation of managerial intervention if necessary.
Safety climate as a multi-level concept

According to Zhang et al. (2015), the majority of safety climate studies in the construction industry used the “organisation” as the unit of analysis. The underlying assumption is that workers share homogenous perceptions of all safety issues. Therefore, many studies have confounded the perceptions of safety responses of different social groups. For example, Sui et al. (2004) combined questions relating to workers’ own safety attitudes with questions relating to colleagues’, managers’, safety officers’ and supervisors’ safety attitudes to create an aggregated safety climate score.

However, there is growing recognition of the importance and influence of safety climate perceptions relating to different levels of managerial response. Zohar (2000) suggested that safety climate should be interpreted as a multilevel construct. This is based on the assumption that formal policies and procedures are established by top management at the organisational level and are executed by supervisors at the subunit level (Zohar, 2000). Thus, workers’ perceptions of safety climate stem from two sources, i.e. formal policies and procedures related to organisational level analysis, and supervisory practice related to group level analysis. Due to supervisors’ discrepant interpretations and local implementations of formal procedures, workers in different sub-groups are likely to form different perceptions of supervisory practices. Adopting Zohar’s multilevel climate conceptualisation, Lingard et al. (2009; 2010) demonstrated that subcontracted work groups in construction projects developed unique safety climates relating to supervisory practices that can be distinguished from shared perceptions of the principal contractor’s organisational safety responses.

Previous studies have also indicated that co-workers’ safety attitude and behaviours exert significant impact on workers’ safety norms and behaviours in different ways (see for example Tucker et al. (2008), Westaby and Lowe (2005), Roy (2003)). Perceptions of co-workers’ safety response can be another source of group safety climate and treated conceptually distinct from perceptions of managerial safety response (Lingard et al., 2011). Similarly, Brondino et al. (2012) claim that safety climate perceptions are constructed through interactions between individuals, not only between workers and supervisors but also between workers and co-workers. Co-workers’ safety response as a separate facet of group safety climate has been empirically supported in recent studies (e.g. Lingard et al. (2011); Brondino et al. (2012); Melia et al. (2008)).

The role of clients of the construction industry in driving positive safety behaviour and performance in the projects they procure has also been noted (Huang & Hinze, 2006). Haslam et al. (2005) identified client requirements as a causal factor imposing originating influence on
construction accidents. This is because clients are initiators of construction projects, and they make decisions about the project budget, timeline, project objectives and performance criteria, which can create pressure and constraints that significantly impact safety in construction process (Lingard et al., 2008). Recent studies have identified various client-led initiatives that positively influence construction project safety performance, including setting contractual safety requirements, monitoring safety performance, reviewing and analysing safety data, funding safety initiatives, participating in on-site safety activities, etc. (Huang & Hinze, 2006; Votano & Sunindijo (2014)). Researchers examining safety climate in construction projects have begun to include perceptions of the clients’ safety response as a distinct aspect of project-level safety climate (see, for example, Zhang et al., 2015; Shen et al. 2015).

Safety climate as a relative concept

Perceptions of climate inform workers about what behaviours are likely to be supported and rewarded in an organisation (Zohar, 1980). Zohar (2010) maintained that the cognitive process to identify such behaviours is sophisticated because the organisational environment is normally complex with many elements, e.g. policies, procedures and practices relating to different organisational aspects. Zohar (2010, p. 1518) further argued that perceptions of climate stem from workers’ overall evaluation of the nature of “relationships between or the relative priorities among” these elements instead of the evaluation of individual elements in isolation. Thus safety climate perceptions are understood to arise from workers’ evaluations of the nature of relationships between policies, procedures, and practices associated with safety and those associated with other (possibly competing) goals (such as production speed and cost). In other words, perceptions of safety climate are likely to be constructed in terms of the relative priorities placed on safety and other organisational goals (Zohar, 2008; Zohar, 2010). Previous research indicates that the relative priority placed on safety by management is likely to change over time in response to changing circumstances. For example, Han et al. (2014) observed that, when facing of progress delays, managers tend to pay more attention to production relative to safety; while if a safety incident or injury occurs, managers may shift their emphasis back onto safety in order to prevent any further incidents or injuries. Also, due to its “relative” nature, even if safety is consistently emphasized by managers, any change in emphasis on other organisational objectives may still reduce the patterns of simplicity and consistency in managerial behaviour that are associated with strong and positive safety climates (Zohar, 2000).

Safety and project lifecycle

Construction projects are dynamic systems, in which the relationships between project goals (e.g. functional performance, quality, time, cost, safety) and project resources (e.g. material, labour,
plans, schedule, and finances) are in constant flux (Love et al., 2002). In the construction project environment, decision-making is highly dynamic in nature and decision-makers change their focus over time (Humphrey et al., 2004). This means the relative priorities that project participants place on safety and other project goals can change across the life of a single project. Humphrey et al. (2004) explored how project decision-makers systematically change their emphasis on project completion and safety as a function of the stage of project completion. On the basis of various psychological theories, Humphrey et al. (2004) hypothesized three relationships between production and safety over time and attempted to test which relationship best fit project decision makers’ behaviour:

- **Negative monotonic.** This describes a scenario in which project participants place a high emphasis on safety and allocate significant resources to safety at the beginning of a project but this emphasis and resource allocation steadily decrease as the project approaches completion. This relationship is based on the psychological theories of cognitive limitations and goal substitution (Kanfer and Ackerman, 1989; Garland and Colon, 1998). These theories suggest that individuals maintain multiple goals but possess limited cognitive resources that can be devoted to fulfilling those goals. Therefore, individuals only focus on prioritised goals at a given point in time through interpreting the contextual environment. The prioritised goals are called “active goals”, which dominantly drive individuals’ behaviours (Markman and Brendl, 2000). As a person works toward achieving active goals, the goal activation increases and the person will have more focus on those active goals. Correspondingly, the other goals will receive decreased attention and be “substituted” by the active goals. In the context of a construction project, as the project progresses, the goal of completing the project becomes more active, which then leads project participants to devote more attention to the completion goal relative to other goals, including safety.

- **Positive monotonic.** This describes the scenario in which project participants place more emphasis on and allocate more resources to safety as the project progresses. This relationship is based on the prospect theory of value function and theories of goal setting (Heath et al. 1999). The underpinning logic is that the psychological value attached to a goal is changed by a person’s proximity to the goal achievement. This can be illustrated by the example that people who fail to achieve their goals when they are very close to achieving these goals suffer from more negative emotional impact than those who fail to achieve their goals when they are distal to achieving the goals (Heath et al. 1999). Alternatively, people who are very close to their goals are willing to exert more effort to achieve the goals than those who are distal to their goals. According to this theory, an
incident or injury occurring at the very end of a construction project would be more distressing to project participants than a similar incident/injury occurring earlier in the life of the project. Therefore, as a project progresses toward completion, this theory would suggest that project participants would pay more attention to safety and become more risk averse.

- **Curvilinear.** This combines the underlying logics from the first two hypothesized relationships. In this scenario, project participants attach high importance to safety at the beginning of a project, but, as the project progresses to its middle stages, participants shift their emphasis towards productivity and progress and the relative level of attention to safety is decreased. However, consistent with the positive monotonic relationship, project participants become more risk averse when the project approaches completion, i.e. they try to avoid any incident/injury when the project is nearly finished. Therefore, their emphasis placed on safety and resources allocated to safety increase again in the latter stages of project completion. This relationship is reflected in a “U” pattern of emphasis on safety over the life of the project.

Using both laboratory simulation and archival field study, Humphrey et al. (2004) found evidence to support the ‘curvilinear’ relationship between safety effort and the level of project completion in construction projects. Specifically, the laboratory simulation showed that the amount of resource allocated to safety was highest at the beginning and end of a project, and lowest near the midpoint of the project. The archival field study demonstrated that the fewest incidents/injuries occurred at the commencement and completion stages of a project but the number of incidents/injuries peaked near the middle of the project. However, no significant relationship was found between project participants’ self-reported emphasis on safety and the level of project completion.

Humphrey et al.’s (2004) study was conducted in a road construction project, i.e., in which all stages of the construction process are similar, and with a laboratory simulation, i.e., using MBA students as participants who responded to pre-designed vignettes with safety implications. It is therefore unclear whether the same curvilinear relationship or any other relationship (e.g. negative monotonic or positive monotonic) can be identified between safety climate and the level of project completion in actual building construction projects, in which the physical construction process varies significantly as work progresses.

It is also noted that the participants in Humphrey et al.’s (2004) study assumed the role of project decision-makers, who decide the project goals and the amount of resources allocated on safety. However, the relationships between safety responses of lower level project participants (e.g.
supervisors, and co-workers) and the level of project completion have not been explored. Previous research indicates that supervisors can act as “gatekeepers” of group level safety environment, i.e. in circumstances where organisational management indicates higher priority of production than safety, supervisors who demonstrate strong and effective leadership can still maintain high safety priority in their workgroups (Zohar and Luria, 2010). Previous research also shows that as workers get to know their co-workers better and develop stronger social ties with their co-workers, they tend to show higher concerns for their co-workers’ safety and wellbeing (Burt et al. 2008), which implies that more positive co-workers’ safety responses may be expected as workers work together for longer time. It is thus anticipated that the change patterns in safety responses of supervisors and co-workers are different from that in safety response of organisational management over the life of a construction project.

The present study therefore examined Humphrey et al. (2004)’s assertions to explore the relationship between safety climate of multiple levels and the level of project completion in four large construction projects.

**Aim of this study**

The research was driven by an aim to examine whether and how safety climate changes over the life of construction projects. Adopting a multilevel approach, we assessed the relationship between the level of project completion and safety climate in terms of workers’ perceptions of:

- the client’s organisational safety response;
- principal contractors’ organisational safety response;
- workgroup supervisors’ safety response; and
- co-workers’ safety response.

**Research Design**

*Safety climate measurement tool*

A multilevel safety climate measurement tool was used to longitudinally assess safety climate in construction projects in the present study. Following the suggestion of Meliá et al. (2008), the measurement tool analyses safety climate from the perspective of safety agents, who perform or take responsibility for safety activity/issue in each safety climate statement. This enables a clear identification of safety effort required from a specific agent for safety improvement. At the client level, the client’s organisational safety response (COSR) was measured by the measure of general management commitment to safety, which was developed for the UK Health and Safety Executive by Davies et al. (1999). An example item is “Client management places a strong
emphasis on workplace health and safety”. At the principal contractor level, the global organisational-level safety climate scale developed by Zohar and Luria (2005) was adapted to assess principal contractors’ organisational safety response (PCOSR). Example items include “Management of the principal contractor reacts quickly to solve the problem when told about safety hazards” and “Management of principal contractor insists on thorough and regular safety audits and inspections”. At the group level, supervisors’ safety response (SSR) was measured by the measure developed by Zohar and Luria (2005), which covers various interactions between supervisors and group members through which supervisors indicate the priority of safety in relation to completing goals. Example items include “My supervisor frequently checks to see if we are all following the safety rules” and “My supervisor is strict about working safely – even when we are tired or stressed”. Co-workers’ safety response (CWSR) was measured by the scale of co-workers’ safety climate (CSC) developed by Brondino et al. (2013), which reflects co-workers’ general safety value and practice. Example items include “My group members care about each other’s safety awareness” and “My group members frequently discuss incident prevention”. The development and validation of the multilevel safety climate measurement tool has been reported in Zhang et al. (2015). All the scales showed adequate reliability and validity, which was demonstrated by the statistical analysis results that they had Cronbach’s alpha values higher than 0.7 and could be distinguished from each other in the factor analysis.

Data collection

Longitudinal safety climate surveys were conducted at four processing plant construction projects (i.e. Project A, B, C and D) commissioned by a manufacturing organisation in New Zealand. Project A was the construction of a new cream cheese processing facility with the construction phase lasted a ten-month period; Project B involved the expansion of an existing mozzarella plant to twice its original capacity and the construction process took an eighteen-month period; Project C involved large scale earthworks allowing for the extension of an existing store and construction of a rail loadout facility, and the construction phase occurred over an eighteen-month period; and Project D was the expansion of milk processing capacity on an operational site involving the building of a number of new plants and upgrades of associated site services and waste water facility, and the construction process took a nineteen-month period. The surveys were conducted from January 2013 to September 2015. Three waves of data collection were undertaken at the four projects. The timing of each survey was suggested by the client company depending on their project schedule and progress.

The surveys were administered using the ‘TurningPoint’ automated response system with ‘KeePad’ hand held devices. Survey questions were projected onto a screen one by one and read
out by a facilitator. Workers were required to press a number on the hand held devices to indicate their responses to the statement in each survey question against a 5-point scale ranging from ‘1 = Strongly Disagree’ to ‘5 = Strongly Agree’. The advantages of using the automated response system in conducting the surveys over the traditional paper-based questionnaire survey include: 1) potential language and literacy problems were overcome as the facilitator read all questions to participants; 2) there was minimum data entry cost as the system automatically recorded all the responses; and 3) there was improved worker engagement during the survey process.

The number of participants involved in each survey for each project is listed in Table 1. The number of participants who attended each survey was largely determined by the number of workers working on site at the time when the survey was conducted. Schulte et al. (2009) suggested that a minimum size of 5 participants is required to reflect the shared perceptions measured by safety climate and to reduce the bias in using aggregated scores. Table 1 indicates that the number of participants for each survey ranged from 16 – 58, thus meeting the criterion for a valid safety climate analysis.

[Insert Table 1 here]

**Data analysis and results**

*Mean safety response scores*

For each individual survey, a mean safety response score was calculated for each safety agent. This was achieved by averaging the mean scores for all items relating to each safety agent. The mean safety response score is an indication of workers’ perceptions of each safety agent’s overall safety effort. Mean safety response scores were calculated for all surveys at each project, including mean scores for client’s organisational safety response (COSR), principal contractors’ organisational safety response (PCOSR), supervisors’ safety response (SSR), and co-workers’ safety response (CWSR). Figure 1 to Figure 4 illustrates the mean safety response scores for all four projects.

*Stages of project completion*

Durations of the four construction projects were different. In order to conduct between-project comparisons, the time at which each survey was conducted was converted into percentage of project completion, which was calculated by:

\[
\text{Percentage of project completion} = \left( \frac{\text{Project duration to the date of survey}}{\text{Total project duration}} \right) \times 100\%
\]
Table 2 lists the stages of project completion at which the surveys were conducted for each project.

[Insert Table 2 here]

*Change trend of safety responses*

The mean safety response scores and the percentages of project completion were then plotted to graphically represent the data, and identify the overall change trends for each safety agent’s response across the four construction projects. One-way analyses of variance (ANOVA) were performed to assess whether the safety response changes between survey sessions were statistically significant for each project.

Then a hierarchical regression analysis was performed to assess whether safety climate changed as a function of project progress for each project, and if yes, whether the changes were linear (either negative or positive monotonic) or curvilinear. These procedures followed those utilised by Humphrey et al. (2004). The mean safety score was firstly regressed on the variable *percentage of project completion* to explore whether there was a linear relationship. If the variance explained ($R^2$), the model significance and coefficient ($\beta$) were all statistically significant, a linear relationship was confirmed. Then the variable squared percentage of project completion was entered into the regression model to explore whether a curvilinear relationship was evident. If the increase in variance ($\Delta R^2$), the model significance and coefficients ($\beta$) were still all statistically significant, it could be concluded that a curvilinear relationship was more appropriate to explain the relationship between the mean safety climate score and the percentage of project completion.

*Client organisational safety response (COSR)*

Figure 1 shows the mean scores for the client’s organisational safety response (COSR) at different stages of project completion at each of the four projects. The data shows that perceptions of COSR generally declined across all projects as the construction work progressed. However, at some projects, notably Project C, this decline was not as dramatic as it was in other projects between 40% and 60% completion. The one-way ANOVA indicated that the downward changes in COSR between surveys were statistically significant for project D ($F (2, 100) = 3.428, p = 0.036$).

The relationship between COSR and the percentage of project completion was then tested using two-step hierarchical regression. The regression analysis revealed a significant relationship between COSR and the percentage of project completion at Project B and Project D.
Specifically, at Project B, when the variable *percentage of project completion* was entered in the first step, a significant negative linear relationship between COSR and the percentage of project completion was observed (see Table 3). However, when the variable *squared percentage of project completion* was entered in the second step, neither the change in $R^2$ ($p = 0.462$), nor the regression model ($F(2, 82) = 2.424, p = 0.095$) was significant. Regarding project D, a significant negative linear relationship between COSR and the percentage of project completion was also revealed in the first step. In the second step, although the regression model was significant ($F(2, 100) = 3.428, p = 0.036$), the increase in $R^2$ was not significant ($p = 0.643$) and the standardized coefficient was not significant either ($\beta = -0.754; t = -0.465, p \text{ ns}$). Therefore, it is concluded that a *negative linear relationship* exists between COSR and the percentage of project completion at both Projects B and D.

[Insert Figure 1 here]

[Insert Table 3 here]

**Principal contractors’ organisational safety response (PCOSR)**

Figure 2 shows the mean scores for principal contractors’ organisational safety response (PCOSR) at different stages of project completion for each of the four projects. The results show that workers’ perceptions of PCOSR also tended to decline across most of the projects as the construction work progressed. At Project A, B, and D, the decline escalated after the second survey (around 36%, 55% and 74% completion respectively). In contrast, at Project C, workers’ perceptions of PCOSR increased after the second survey (approximately 47% completion). One-way ANOVAs showed that the changes in PCOSR between surveys were statistically significant for Project A ($F(2, 99) = 4.553, p = 0.013$), and Project B ($F(2, 82) = 4.107, p = 0.020$).

Regression analysis indicated a significant relationship between PCOSR and the percentage of project completion at Project A and Project B. Table 4 revealed similar results to those found for the client’s organisational safety response, i.e. the relationship and the model were significant when *percentage of project completion* was introduced into the model, while the increase in $R^2$ and the coefficient were not significant when the *squared percentage of project completion* was introduced into the model in the second step. Again, it is concluded that only a *negative linear relationship* exists between PCOSR and the percentage of project completion at Projects A and B.

[Insert Figure 2 here]

[Insert Table 4 here]
Supervisors’ safety response (SSR)

Figure 3 shows the mean scores for the supervisors’ safety response (SSR) at different stages of project completion for each of the four projects. The data shows that perceptions of supervisors’ safety responses declined across Project B as the construction work progressed. However, at Project A and Project C, workers’ perceptions of SSR increased notably after the second survey (at approximately 36% and 47% completion respectively). At Project D, workers’ perceptions of SSR also slightly increased after the second survey (at approximately 74% completion). One-way ANOVA analysis indicated that the change in SSR was not significant for any of the four projects. Also the regression analysis revealed that no significant relationship between SSR and percentage of project completion was found for any of the projects.

[Insert Figure 3 here]

Co-workers’ safety response (CWSR)

Figure 4 shows the mean scores for co-workers’ safety response (CWSR) at different stages of project completion for each of the four projects. The data shows that workers’ perceptions of CWSR declined across Project B as the construction work progressed. However, at Project A and D, perceptions of CWSR responses initially increased and then decreased after the second survey (at approximately 36% and 74% completion respectively). At Project C, positive perceptions of co-workers’ safety responses increased as the project progressed. One-way ANOVA analysis indicates that only the increases in CWSR between surveys at Project C was statistically significant (F (2. 136) = 3.083; p = 0.049). Regression analysis demonstrated that a positive linear relationship was revealed for Project C (see Table 5).

[Insert Figure 4 here]

[Insert Table 5 here]

Discussion

The fluctuating and relative nature of safety climate

The research results demonstrate that safety climate does fluctuate over time in a dynamic construction project environment. The changes in workers’ perceptions of safety responses at various levels of the client, principal contractor and workgroup, were statistically significant in a number of projects in the present study.
It is likely that the changing nature of safety climate in construction project environments is linked to the fact that safety climate reflects workers’ subjective evaluations of the relative priorities placed on safety and other competing goals by managers and others at various levels. In a construction project where multiple goals exist, the relative emphasis placed on these goals may change (even subtly) during the project life due to project-specific circumstances and unforeseen events at different time points. Thus, changes in the emphasis placed on project performance goals (e.g. production speed) may bring about changed perceptions of the relative importance of safety.

The fluctuating nature of safety climate in dynamic construction project environments suggests that multi-wave longitudinal safety climate measurement is more appropriate than cross-sectional safety climate measurement in this industrial context. Longitudinal safety climate measurement over the life of a construction project enables managers to better understand the changes in safety climate that are related to project dynamics. Measurement of safety climate over the life of a construction project can also inform the implementation of managerial interventions when significant negative change is identified. It is also useful in uncovering the effectiveness of intervention strategies through comparing the before-intervention safety climate and post-intervention safety climate (Tharaldsen et al. 2008). In this study, notable improvements were observed for safety responses at Project C between the second survey and the third survey. At this project a significant health, wellbeing and fatigue management initiative was implemented. The client established a program which they named “safety- first, quality-second, time line-third” emphasising the importance they placed on safety as a project objective. The client works with the principal contractor and sub-contractors to negotiate time lines that capped workers’ weekly hours and afforded them a work-life balance. The importance of health and safety was actively communicated by managers to workers during formal meetings and informal site visits and conversations. Qualitative data collected for a different research study at Project C provides some insight into how this project differed from others. For example, one client representative compared his experience at Project C with his experience of other projects as follows: “Usually, the last two weeks [of a project] before start up, people are running in all directions and there’s rubbish all over the floor, there’s electrical cables, you know there’s people stressed. At this project it looked like everything was calm and in control….people were having good quality conversations about how to install things, about how to wire something up, about how to weld.”

One of the contractors engaged on Project C commented: “we’ve had people coming up to us and saying this is the best project that they’ve ever worked on and they’ve been in the industry for 15, 20 years”.
Organisational safety respond change trend

Despite the finding that safety climate changes over the life of construction projects, our research revealed no consistent change pattern observed for either client organisational safety response (COSR) or the principal contractors’ organisational safety response (PCOSR) across the four projects. This is likely explained by the fact that each construction project organisation is unique in nature and climate fluctuations may be driven by idiosyncrasies and local project conditions. The key project factors (e.g. scheduling, budgeting, and availability of resources), managerial values and practices, and the importance placed on safety by project participants may vary from project to project, and even vary within a project over its life course. Given the dynamic and idiosyncratic nature of construction project experiences, it may therefore be unrealistic to expect a standard or consistent pattern of safety climate to emerge across projects.

However, our results did show that COSR and PCOSR generally declined across most of the projects. Moreover, a negative monotonic relationship between COSR and percentage of project completion was identified Project B (between 35% - 79% project completion), and Project D (between 58%- 90% project completion). The negative monotonic relationship was also found between PCOSR and percentage of project completion for project A (between 17% - 61% project completion), and project B (between 35% - 79% project completion). The results are in line with the theory of goal substitution discussed earlier, i.e. as a construction project progresses, other project goals (such as productivity) become more “active” and receive more attention from project management team than the project goal of safety. Previous research shows that as a project progresses to the final stage, completion of the project becomes the primary focus of the project management team (Garland and Conlon, 1998). This can sometimes detract from emphasis placed on other project goals (including safety) that may have been more salient during earlier stages of the project. The negative monotonic relationship revealed in this study suggests the possibility that as those construction projects progressed toward completion, the relative emphasis placed on project goals by project management may have changed with a greater emphasis on ‘getting the job done on time’. It is important that construction project managers consistently emphasize the importance of safety over the life of a construction project, and do not inadvertently reduce the focus on safety when they reinforce the importance of keeping the production pace.

The results discussed here, however, are not consistent with Humphrey’s et al. (2004) finding that a curvilinear relationship exists between project decision makers’ level of safety effort and the stage of project completion. The curvilinear relationship identified in Humphrey et al. (2004) suggested that project decision makers tended to direct their focus from safety to production
when the project progressed from the commencement stage to the middle stage, but increased their emphasis back to safety as the project approached completion. In contrast, the *negative monotonic* relationship suggested by our data (at least in some projects) suggests that project decision makers’ relative safety emphasis steadily decreased over the project lifecycle.

Reasons why our findings differed from those of Humphrey et al. (2004) are not entirely clear but the differences may be partially explained by factors relating to research design and context. First, Humphrey et al. (2004) utilised a laboratory simulation, in which MBA students were asked to respond to pre-designed scenarios with safety implications. In the simulation context, students would not face the actual pressures that project participants experience in a real construction project context. The reliability of data may have been adversely affected by social desirability bias or reflected the students’ ideal management ideology. By contrast, our study was conducted in four real construction project contexts, in which production goals and the likely consequences of failure to meet these goals (e.g. financial loss) produce substantial pressure on project participants. This pressure may influence the relative emphasis placed on production compared to safety objectives as the projects progressed to their completion stage.

Second, Humphrey et al. (2004) selected a highway construction project for their retrospective analysis of project safety performance. The stages of highway construction are very similar and the nature of work for highway construction is highly repetitive over the course of the project. In contrast, we collected our data at building projects in the manufacturing sector. In projects of this type, construction processes vary significantly as work progresses from one stage to the next. It is possible that decision-making in highway construction projects is more repetitive and therefore may be less impacted by project environment changes than those in the construction of complex buildings, particularly process plants in which there is the need to install complicated plant, equipment and services as the project nears completion.

*Group level safety climate changes*

At the group level, there was no significant relationship identified between supervisors’ safety response (SSR) and the level of project completion for those projects. Workers’ perceptions of SSR were relatively stable compared to the perceptions of the client’s organisational safety response (COSR) and principal contractors’ organisational safety response (PCOSR). No significant change in SSR was identified for any of the projects. The relative stability in SSR suggests that workers working at these projects perceived their supervisors to be consistent in terms of safety acts and expectations over the project life courses, even when organisational management reduced their emphasis placed on safety. The research results suggest that supervisors of those construction projects effectively managed the boundary relationship of their
workgroups and the organisational environment, consistently emphasised the importance of safety in their workgroups and implemented safety procedures in a way that is not contingent on production pressure.

It is noticed that in some projects (e.g. project A and D), although both the client organisational safety response (COSR) and the principal contractor organisational safety response (PCOSR) declined between the second survey and the third survey, SSR increased during the same period. The research result confirms Zohar’s (2000) proposition that workers form perceptions of group safety climate relating to supervisory practices that can be differentiated from the shared perception of organisational safety climate. The result is also in line with previous research finding that supervisors’ actions are critical drivers of group level safety climates (Zohar and Luria, 2010). More specifically, given a poor organisational safety climate, strong and effective supervisory leadership can help to maintain a positive group safety climate, even when perceptions of the organisational safety climate may have deteriorated (Zohar and Luria, 2010). Previous research and the present study indicate that there may be great value in better understanding the role played by supervisors’ leadership as an antecedent to group level safety climate and potentially also to group-level performance.

The research results also indicate that there was no consistent change trend identified for co-workers’ safety response (CWSR) across projects. No significant relationship was identified between co-workers’ safety response and percentage of project completion at Project A, B and D. The changes in CWSR over three surveys were also not significant at these three projects. This suggests that workers of these projects perceived their co-workers to be consistent in holding safety values and demonstrating safety practices over the project processes. The consistency revealed in co-workers’ safety response, again, may be attributed to the “gatekeeper” role played by their supervisors in consistently emphasizing safety and maintaining positive group safety climate, despite the deterioration in organisational safety response. The association between supervisors’ safety response and co-workers’ safety response is worthy to be further investigated in future research. A positive monotonic relationship was identified between CWSR and percentage of project completion at Project C. It is also observed that although COSR, PCOSR and SSR declined between the first survey and the second survey at most of the projects, CWSR increased during the same period at Projects A, C and D. The result confirms the assertion that perception of co-workers’ safety response is a separate source of group safety climate and can be conceptually distinguished from perceptions of managerial safety response (Lingard et al. 2011; Brondino et al. 2012). Meanwhile, our results also support the argument that workers’ concerns for the safety and wellbeing of their co-workers may increase as they develop stronger social ties and greater knowledge about their co-workers (Burt, et al. 2008). However, the reason that
CWSR slightly decreased after the second survey at Projects A and C is not clear. Further research into the development of group safety climates over time, and the relationships between project events, higher level (i.e. client and principal contractor) management activity and group-level climates is warranted.

Benchmarking safety climate

The present study also presents a significant opportunity for client organisations, such as the manufacturing organisation that participated in our research, to benchmark safety climate over the life course of their construction projects. Longitudinal safety climate measurement enables a construction project management team to compare safety climate scores recorded at different stages of project completion and identify opportunities for improvement. Construction project management teams could also compare their safety climate scores with benchmark scores from other projects at similar stages of project completion. Safety benchmarking can be helpful to project management teams to understand their weaknesses and strengths relative to other project experiences (Fuller, 1999), and to strive to improve the safety climate in their projects, particularly in the context of disruptive or challenging project events.

Previous research has adopted benchmarking approaches related to safety climate in other industrial sectors. For example, Mearns et al. (2001) longitudinally measured safety climate on nine UK offshore installations in consecutive years, and then benchmarked the installations on key safety climate components. Internally, the benchmarking allowed the installations to compare their safety climate profile with the previous year’s data and identify any significant changes. Externally, the benchmarking enabled an installation to monitor their position relative to other installations in terms of safety climate. “Best performers” were identified through the benchmarking exercise and the managers of the poorer performing installations were encouraged to learn from the “best performers” to improve their safety climates (Mearns et al., 2001). There is the potential to adopt a similar approach in construction, in which client organisations operating in comparable industry sectors could compare their safety climate scores with external benchmark scores from other organisations. This would enable the client organisations to better understand their safety management performance in a wider industrial context and could foster inter-organisational learning and performance improvement.

Conclusion and limitations

This study longitudinally assessed safety climate and also explored the relationship between safety climate and the stage of project completion in construction project environments. The research results indicate that, when measured at different levels, safety climate does fluctuate
over the life course of a construction project. The changing nature of safety climate can be explained by the fact that safety climate reflects workers’ evaluations of the relative priorities placed on safety and other completing goals by project participants of different levels, and the relative priorities change over the life of a project probably in response to constantly changing, complex and uncertain project environments.

At the organisational level, this study identified a general downward change trend for workers’ perceptions of client’s organisational safety response (COSR) and principal contractor’s organisational safety response (PCSR). Further, a negative monotonic relationship was found between the level of project completion and workers’ perceptions in terms of COSR and PCSR at several of the construction projects under study. The research suggests that it is important for construction project management to place a high priority on safety consistently over the life of a construction project, and consciously avoid inadvertently reducing the emphasis on safety, even when they are under pressure to keep production on schedule.

At the group level, workers’ perceptions of supervisor’s safety response (SSR) and co-workers’ safety response (CWSR) were relatively stable. There was no clear or consistent relationship identified between the level of project completion and workers’ perceptions in SSR and CWSR. However, the research highlights the potential role of supervisors in maintaining a positive group safety climate in adverse circumstances where organisational management may (even inadvertently) emphasise production efficiency more strongly than safety. More research should be undertaken to examine the role of supervisors’ leadership as an antecedent to group level safety climate, as well as safety performance. Further, the fluctuations in CWSR suggest it may be valuable to investigate the development of workers’ safety concerns for their co-workers over time and also the cross-level relationships between management activities and the group level climate.

This paper advanced our understanding of safety climate in the dynamic construction project environment by examining patterns of safety climate in relation to project completion stages. Most research adopts a cross-sectional approach and fails to acknowledge that construction projects are dynamic, constantly changing work environments in which priorities change, adverse events arise and production pressures fluctuate over time. There is therefore a greater need in this industry context to understand safety climate changes over time, particularly in relation to project events. Our research provides the starting point for understanding safety climate changes over the life course of construction projects.

However, our study had a number of limitations which must be acknowledged. First, the stage of project completion at which the surveys were conducted was not consistent across projects.
reduced the ability to make direct between project comparisons of the level of safety climate. However, our general purpose in this study was to analyse trends or patterns of change over time. In order to make more direct comparisons between projects’ safety climate performance, the timing of future surveys should be carefully controlled so that they are conducted at equivalent stage of project completion. Second, and perhaps more importantly, although multi-wave longitudinal safety climate measurement is suggested for construction projects, the appropriate time intervals between measurements were not explored in this research. The sensitivity of measurement to change in response to project events or managerial behaviour over time needs to be more robustly assessed. For example, it is unclear whether a change in managerial emphasis is detectable in a shift in safety climate immediately, or whether there is a time lag between changing management activity and a change in the safety climate. If a time lag exists, the time sensitivity and durability of these impacts need further exploration, particularly in dynamic work environments such as construction. The time-sensitivity of climate fluctuations is particularly important if safety climate is to be used as a diagnostic tool to inform and enable timely management interventions. Third, the multi-wave safety climate measurement only captured the changes in safety climate but did not inform why the changes had occurred. This study did not investigate the actual management acts or project events that had an impact on safety climate, except for Project C where qualitative data was collected for a different research project. To fully understand the dynamics between safety climate and project environment, qualitative project information should also be captured to explain the causes for any observed changes in safety climate. The information can be collected though qualitative research methods such as interviews, field observations, and participating in the survey result debriefing sessions. The information will also inform what managerial behaviours and acts should be promoted or avoided in order to maintain a positive safety climate. Future studies are recommended to adopt a mix-method research design to collect both quantitative and qualitative data so as to provide a holistic picture about the status of safety climate and the underlying reasons for any significant change. Fourth, only four construction projects were used for data collection in this research. The safety climate change patterns identified from this research may not be able to be generalised to the broad industry. Future studies are suggested to be conducted with similar research design to further explore the dynamics of safety climate. Given the idiosyncratic nature of construction projects, it would also be interesting for future research to explore the relationships between safety climate change patterns and various project characteristics such as construction client’s involvement in safety, resource allocation for safety, project scheduling and budgeting. Lastly, the study only focused on safety issues of construction workers. Future studies can also include the health and wellbeing issues of construction workers in the climate assessment.
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