A LONGITUDINAL ANALYSIS OF SAFETY CLIMATE IN THE DYNAMIC CONSTRUCTION PROJECT ENVIRONMENT

Rita Peihua Zhang[1] and Helen Lingard

School of Property, Construction and Project Management, RMIT University, GPO Box 2476, Melbourne VIC 3001, Australia.

This study longitudinally measured safety climate at construction projects, and explored the overall safety climate change patterns. Safety climate was measured with a multi-level safety climate measurement instrument. At the organizational level, the instrument measured workers' perceptions of client organization's safety response (COSR) and principal contractor's organizational safety response (PCOSR). At the workgroup level, the instrument measured workers' perceptions of supervisors' safety response (SSR) and co-workers' safety response (CWSR). Three waves of data collection were undertaken at four processing plant construction projects in New Zealand. The research results indicate that workers' perceptions of client organization's safety response and principal contractor's organizational safety response generally declined across all projects over the three surveys, and the declines were statistically significant at several projects. The changes in workers' perceptions of supervisors' safety response were insignificant for all projects. Moreover, a significant increase was observed for workers' perceptions of co-workers' safety response at one project. The research suggests that the construction project management should consistently emphasize the importance of safety, even when they are facing production pressure. The research also highlights the potential role played by supervisors in managing boundary relationships between their workgroups and the organizational environment, and maintaining a positive safety climate in their workgroups.

Keywords: safety climate, longitudinal, multi-levels, construction project.

INTRODUCTION

Safety climate was first defined as 'a summary of molar perceptions that employees share about their work environments' by Zohar (1980, p.96). Later Neal and Griffin (2006, p.947) defined safety climate as 'individual perceptions of policies, procedures, and practices relating to safety in the workplace'. The concepts safety climate and safety culture have been theoretically differentiated in previous research (see for example, Glendon and Stanton, 2000; Guldenmund, 2000). Guldenmund (2000) argues that it is more appropriate to define safety culture as the aspects of organizational culture that have impact on safety-related attitudes and behaviours. This is because the core underlying assumptions that characterize an organizational culture shape the whole operation of the organization, including how safety is prioritised and enacted. It is generally accepted that safety climate represents the surface features of cultural influences on safety, which can be discerned from

[1] rita.zhang@rmit.edu.au

Zhang, R P and Lingard, H (2016) A Longitudinal Analysis of Safety Climate in the Dynamic Construction Project Environment. *In*: P W Chan and C J Neilson (Eds.) *Proceedings of the 32nd Annual ARCOM Conference,* 5-7 September 2016, Manchester, UK, Association of Researchers in Construction Management, Vol 1, 529-538.

workforce's attitudes and perceptions at a given point in time. Alternatively, safety climate is a 'snapshot' assessment of cultural influence on safety that prevails in an organization at a particular point in time (Mearns and Flin, 1999).

Recently, there has been a growing interest in the measurement of safety climate across various industries. Safety climate measurement has been recommended as a useful diagnostic tool for organizations, which aim to foster organizational cultures supporting safety, to identify problematic areas for improvements (Zhang *et al.,* 2015). The growing interest in the measurement of safety climate across industries is also predicted by the expected links between safety climate and safety related behaviors and performance indicators, e.g. risky behaviour in the rail industry (Morrow *et al.,* 2010), voluntary safety participation in the health sector (Neal *et al.,* 2000), and accident rate in the construction industry (Siu *et al.,* 2004).

Safety climate as a multilevel concept

The majority of safety climate studies in the construction industry used the 'organisation' as the unit of analysis, assuming that workers share homogenous perceptions of all safety issues organization-wide (Zhang *et al.,* 2015). 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 is a multilevel construct, and that workers' perceptions of safety climate can stem from two sources, i.e. formal policies and procedures related to organizational 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. Lingard *et al.,* (2009; 2010) tested Zohar's multilevel safety climate proposition in the construction industry, and 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 organizational safety responses. Later, Lingard *et al.,* (2011) extended Zohar's idea of group level safety climate to embrace the role of co-workers' safety attitude and behaviorur in influencing safety in workgroups. They empirically illustrated that co-workers' safety response does represent a separate facet of group safety climate.

Recent studies that examine safety climate in construction projects have started to include perceptions of the client's safety response as a separate aspect of project-level safety climate (see for example, Zhang *et al.,* 2015; Shen *et al.,* 2015). 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 constrains that significantly impact safety in construction process (Lingard *et al.,* 2008). Their acts and expectations in relation to safety play a critical role in shaping safety climate in construction projects. 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 analyzing safety data, funding safety initiatives, participating in on-site safety activities, etc. (Huang and Hinze, 2006; Votano and Sunindijo, 2014).

The unstable nature of safety climate

The majority of existing safety climate studies measured safety climate using a cross-sectional approach, assuming that safety climate remains stable over time. However, given that safety climate is defined as workers' perceptions of their work environment, the perceptions are likely to vary if there is perceivable change in the work environment. Consistent with this, evidence is emerging to suggest that safety climate is not stable but changes over time. For example, Tharaldsen *et al.,* (2008) reported significant increases in mean scores of four safety climate dimensions on offshore oil platforms on the Norwegian continental shelf (NCS) between 2001 and 2003. The positive changes were believed to be associated with safety initiatives that occurred in the Norwegian petroleum industry.

Research also indicates that in circumstances where completing goals (e.g. safety, speed and cost) exist, changes in the relative priorities placed on these goals subsequently leads to changes in workers' perceptions of safety climate (Zohar 2010; Zohar 2008). In line with this, it is unlikely that safety climate would remain stable over time in the context of construction projects, where decision-making is highly dynamic in nature and decision-makers change their focus in response to contingent and emergent events (Humphrey *et al.,* 2004). The relative emphasis that project participants place on safety and other project goals can change across the life of a single project (Humphrey *et al.,* 2004). A changed response to safety, even if quite subtle, can be interpreted by workers and expressed in changed perceptions ofthe safety climate. The unstable nature of safety climate highlights the need to conduct longitudinal multi-wave safety climate measurement to monitor change in construction projects and inform the implementation of intervention if necessary.

RESEARCH AIM

The study attempts to longitudinally analyze safety climate in the dynamic construction project environment. With a multilevel approach, this study explored changes in the pattern of safety climate at four construction projects in terms of workers' perceptions of: 1): the client organization's safety response; 2) the principal contractor's organizational safety response; 3) workgroup supervisors' safety response; and 4) co-workers' safety responses.

RESEARCH METHOD

Safety climate measurement instrument

A multilevel safety climate measurement tool was used to longitudinally assess safety climate at participating construction projects. 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 (Meliá *et al.,* 2008). The agent analysis of safety climate would enable a clear identification of safety effort required from a specific agent for safety improvement. At the client level, the client organization's 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). At the principal contractor level, the global organizational level safety climate scale developed by Zohar and Luria (2005) was adapted to assess the principal contractor's organizational safety response (PCOSR). At the group level, supervisor's safety response (SSR) was measured by the scale 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 competing goals. Co-workers' safety response (CWSR) was measured by the scale of co-workers' safety climate developed by Brondino *et al.,* (2011), which reflects co-workers' general safety values and practices. The development and validation of the multilevel safety climate measurement tool has been reported in Zhang *et al.,* (2015).

Data collection

Longitudinal safety climate surveys were conducted at four processing plant construction projects commissioned by a manufacturing organization in New Zealand. The surveys were conducted from January 2013 to August 2015. Three waves of data collection were undertaken at projects A, B, C and D.

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 number of participants involved in each survey for each project is listed in Table 1.

Table 1: Number of participants who completed each survey by project and wave

Project ID	Survey Session	No. of Participants
Project A	Survey1	21
	Survey2	36
	Survey3	45
Project B	Survey1	16
	Survey2	25
	Survey3	44
Project C	Survey1	31
	Survey2	50
	Survey3	58
Project D	Survey1	31
	Survey2	31
	Survey3	41

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 of all questions 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 organization's safety response (COSR), principal contractor's organizational safety response (PCOSR), supervisor's safety response (SSR), and co-workers' safety response (CWSR). Figure 1 - 4 illustrate the mean safety response scores for all surveys conducted at the four projects.

Stages of project completion

The time at which each survey was conducted was converted into the percentage of project completion, which was calculated by:

Percentage of project completion = (Project duration to the date of survey / Total project duration) x 100%

Table 2 lists the stages of project completion at which the surveys were conducted for each project.

Table 2: The stages of project completion at which the surveys were conducted[2]

Project ID	Project duration	Survey 1		Survey 2		Survey 3	
		Survey date	% of completion	Survey date	% of completion	Survey date	% of completion
A	Jan 2013 – Oct 2013	19 Feb 2013	16.80%	18 Apr 2013	36.00%	04 Jul 2013	61.30%
B	Jun 2013 – Nov 2014	10 Dec 2013	35.11%	25 Mar 2014	54.50%	06 Aug 2014	78.83%
C	Mar 2014 – Aug 2015	27 Jun 2014	21.67%	12 Nov 2014	46.67%	05 Mar 2015	67.56%
D	Mar 2014 – Sep 2015	29 Jan 2015	57.89%	30 Apr 2015	73.68%	05 Aug 2015	90.32%

Longitudinal safety climate assessment for each project

The mean safety response scores and the stages of project completion were then plotted to graphically illustrate the longitudinal safety climate assessment for each project, which were shown in Figure 1 - 4. One-way analysis of variance (ANOVA) was performed to assess whether the safety climate changes at each level over the three survey phases were statistically significant for each project. The significant changes were reported in the following descriptions.

At Project A, workers' perceptions of principal contractor's organizational safety response (PCOSR) generally declined over the three surveys. The decline was statistically significant ($F (2, 99) = 4.553$; $p = 0.013$). Workers' perceptions of the client organization's safety response (COSR) and co-workers' safety response (CWSR) slightly increased after the 1st survey (at approximately 15% completion), but then declined after the 2nd survey (at approximately 35% completion). Although workers' perceptions of supervisors' safety response (SSR) slightly decreased after the 1st survey, the perceptions increased between the 2nd and 3rd surveys while the perceptions of safety responses at the other levels all declined during the same period.

At Project B, workers' perceptions of the client organization's safety response (COSR), supervisors' safety response (SSR), and co-workers' safety response (CWSR) deteriorated over the three surveys (at approximately 35% completion, 55% completion and 80% completion respectively). Workers' perceptions of the principal

[2] Note: The calculation was based on the assumption that each project was commenced on the first day of the starting month and finished on the last day of the completing month. For example, the duration for project A is 10 months. The first survey for project A was conducted on 19 Feb 2013, and therefore the duration to the date of survey was approximately 1.68 months. Then the percentage of project completion was calculated as 16.8%.

contractor's safety response (PCOSR) remained similar between the 1st survey and the 2nd survey, but then dramatically declined after the 2nd survey. The change in PCOSR was statistically significant ($F(2, 82) = 4.107$; $p = 0.020$).

At Project C, workers' perceptions of the principal contractor's safety response (PCOSR) and supervisors' safety response (SSR) slightly declined after the 1st survey (at approximately 20% completion), but then increased between the 2nd survey (at approximately 45% completion) and the 3rd survey (at approximately 70% completion).

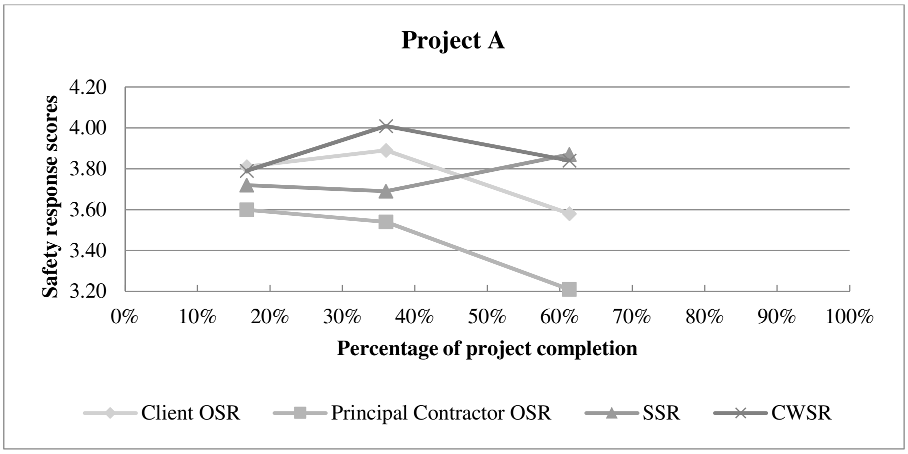

Figure 1: Longitudinal safety climate assessment for Project A

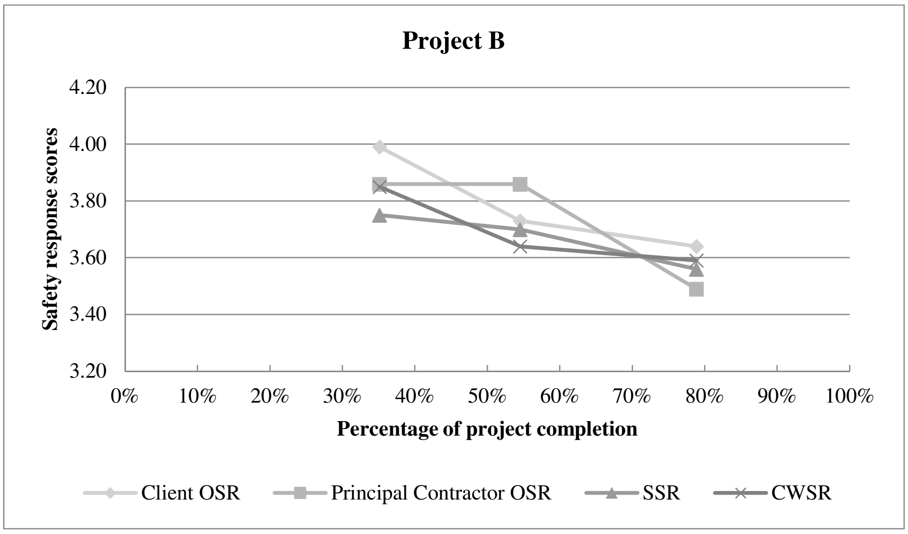

Figure 2: Longitudinal safety climate assessment for Project B

Workers' perceptions of the client organization's safety response (COSR) slightly declined over the three surveys, while workers' perceptions of co-workers' safety response (CWSR) increased over the three surveys. The increase in CWSR was statistically significant ($F(2, 136) = 3.083$; $p = 0.049$).

At project D, workers' perceptions of the client organization's safety response (COSR) and the principal contractor's organizational safety response (PCOSR) decreased over the three surveys as the construction project progressed (at approximately 60% completion, 75% completion and 90% completion respectively). The decrease in COSR was statistically significant ($F(2, 100) = 3.428$; $p = 0.036$). Workers' perceptions of supervisors' safety response (SSR) deteriorated between the 1st survey and the 2nd survey, but then slightly increased between the 2nd survey and the 3rd survey.

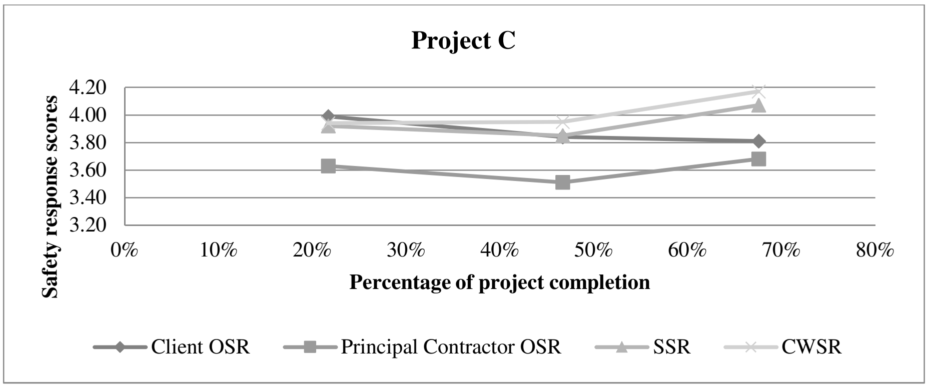

Figure 3: Longitudinal safety climate assessment for Project C

Workers' perceptions of co-workers' safety response (CWSR) increased after the 1st survey, but then declined after the 2nd survey.

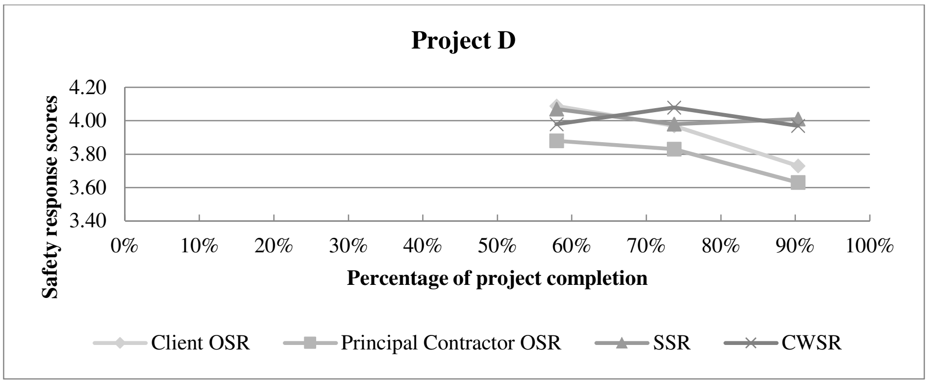

Figure 4: Longitudinal safety climate assessment for Project D

DISCUSSION

Longitudinal safety climate measurement in construction project environments

The research indicates that safety climate does significantly change at certain levels in dynamic construction project environments. The significant changes observed in this research suggest that multi-wave longitudinal safety climate measurement is more appropriate than cross-sectional safety climate measurement in the construction industry. Longitudinal safety climate measurement over the life of a construction project helps the project management team to monitor the change in safety climate, and informs the implementation of managerial interventions when a significant negative change is identified. For example, at Project C, notable improvements were observed for safety responses between the 2nd survey and the 3rd survey. These improvements may be attributed to the implementation of a health, wellbeing and fatigue management initiative. The client established a program named 'safety-first, quality-second, time line-third' to emphasize the importance they placed on safety as a project objective. As the research suggests, the safety climate improved following the implementation of this program.

Generally declined safety responses at organizational levels

The research results show that workers' perceptions of the client organization's safety response (CORS) generally declined over the three surveys across all the projects, while the principal contractor's organizational safety response (PCOSR) generally declined at Project A, Project B and Project D. The decline in COSRS at Project D and the decline in PCOSR at Project A and Project B were statistically significant. In addition, the declines in CORS and PCOSR between the 2nd and the 3rd surveys at those projects were more obvious than those between the 1st and the 2nd surveys. Previous research suggests that as a project progresses to the final stage, completion of the project becomes the primary focus of the project team (Garland and Conlon, 1998). This can sometimes detract from emphasis placed on other project objectives (including safety) which may have been more salient during earlier stages of the project. It is possible that as those construction projects progressed toward completion, the relative emphasis placed on competing 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 on schedule.

Relatively stable safety responses at the group level

The results show that workers' perceptions of supervisors' safety response (SSR) were relatively stable with the changes in SSR being insignificant for all the four 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 course. Supervisors were perceived not to reduce the emphasis placed on safety even at the later stages of the projects when production pressures were normally high. It is noticed that, at Project A and Project E, although both the client organization's safety response (COSR) and the principal contractor's organizational safety response (PCOSR) declined between the 2nd survey and the 3rd survey, supervisors' safety response (SSR) increased during the same period. The result is consistent with previous research findings that supervisors can act as ‘gatekeepers’ of group level safety climate, i.e. in circumstances where organizational management indicates higher priority of production than safety, supervisors whose leadership is strong and effective are expected to better manage boundary relationships between their groups and the organizational environment, thereby maintaining high safety priorities in their own groups (Zohar and Luria, 2010). The research suggests the potential to further examine the role played by supervisors' leadership as an antecedent to group level safety climate.

Despite slight fluctuations, no significant change was observed for workers' perceptions of co-workers' safety response (CWSR) over the three survey phases at Project A, B and D. 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. At Project C, CWSR increased over three phases of surveys and the increase was statistically significant. This is in line with the claim 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 over time (Burt, *et al.,* 2008). Although the safety responses at the organizational levels generally declined across all the projects, CWSR remained stable or even increased as the projects progressed. This outcome, again, may be attributed to the 'gatekeeper' role played by supervisors' in maintaining positive group safety climate despite the deterioration in organisational safety responses.

CONCLUSIONS

The present research provides evidence that in the dynamic construction project environment, the relative priority placed on safety by the project management tends to decrease over the life course of construction projects. It is likely that as a construction project progresses, adverse events arise and production pressure increases, leading the project management to direct their focus away from safety to production. 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. The research also highlights the potential role played by supervisors in managing a positive safety climate in their workgroups. There may be great value in better understanding the role played by supervisors' leadership as an antecedent to group level safety climate and ultimately to group-level performance. The research also suggests the opportunities to further study cross-level relationships between managerial activities and locally experienced safety climates.

REFERENCES

Brondino, M, Pasini, M, and da Silva, S C A (2011) Development and validation of an integrated organizational safety climate questionnaire with multilevel confirmatory factor analysis. *Quality and Quantity*, **47**(4), 2191-2223.

Burt, C D B, Sepie, B and McFadden, G (2008) The development of a considerate and responsible safety attitude in work teams. *Safety Science*, In Press, Corrected Proof (1), 79-91.

Davies, F, Spencer, R and Dooley, K (1999) *Summary Guide to Safety Climate Tools: Offshore Technology Report*: London: Health and Safety Executive.

Garland, H and Conlon, D E (1998) Too close to quit: The role of project completion in maintaining commitment. *Journal of Applied Social Psychology*, **28**(22), 2025-2048.

Glendon, A I and Stanton, N A (2000) Perspectives on safety culture. *Safety Science*, **34**(1-3), 193-214.

Guldenmund, F W (2000) The nature of safety culture: A review of theory and research. Safety Science, **34**(1-3), 215-257.

Huang, X and Hinze, J (2006) Owner's Role in Construction Safety. *Journal of Construction Engineering and Management*, **132**(2), 164-173.

Humphrey, S E, Moon, H, Conlon, D E and Hofmann, D A (2004) Decision-making and behavior fluidity: How focus on completion and emphasis on safety changes over the course of projects. *Organizational Behavior and Human Decision Processes*, **93**(1), 14-27.

Lingard, H, Blismas, N.G, Cooke, T and Jellie, D (2008) *The Model Client: Promoting Safe Construction*, The Office of the Federal Safety Commissioner Australian Government: Canberra ISBN 978-0-642-32687-4.

Lingard, H, Cooke, T and Blismas, N (2009) Group-level safety climate in the Australian construction industry: Within-group homogeneity and between-group differences in road construction and maintenance. *Construction Management and Economics*, **27**(4), 419–432.

Lingard, H C, Cooke, T and Blismas, N (2010) Safety climate in conditions of construction subcontracting: A multi-level analysis. *Construction Management and Economics*, **28**(8), 813-825.

Lingard, H, Cooke, T and Blismas, N (2011) Co-workers' response to occupational health and safety: An overlooked dimension of group-level safety climate in the construction industry. *Engineering, Construction and Architectural Management*, **18**(2), 159-175.

Mearns, K and Flin, R (1999) Assessing the state of organizational safety: Culture or climate? *Current Psychology*, **18**(1), 5-17.

Meliá, J L, Mearns, K, Silva, S A and Lima, M L (2008) Safety climate responses and the perceived risk of accidents in the construction industry. *Safety Science*, **46**(6), 949-958.

Morrow, S L, McGonagle, A K, Dove-Steinkamp, M L, Walker Jr, C T, Marmet, M and Barnes-Farrell, J L (2010) Relationships between psychological safety climate facets and safety behavior in the rail industry: A dominance analysis. *Accident Analysis and Prevention*, **42**(5), 1460-1467.

Neal, A and Griffin, M.A (2006) A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. *Journal of Applied Psychology*, **91**(4), 946–53.

Neal, A, Griffin, M A and Hart, P M (2000) The impact of organizational climate on safety climate and individual behavior. *Safety Science*, **34**(1), 99-109.

Shen, Y, Koh, T Y, Rowlinson, S and Bridge, A J (2015) Empirical Investigation of Factors Contributing to the Psychological Safety Climate on Construction Sites. *Journal of Construction Engineering and Management*, **141**(11), 04015038.

Siu, O.-l, Phillips, D R and Leung, T.-w (2004) Safety climate and safety performance among construction workers in Hong Kong: The role of psychological strains as mediators. *Accident Analysis and Prevention*. **36**(3), 359-366

Tharaldsen, J, Olsen, E and Rundmo, T (2008) A longitudinal study of safety climate on the Norwegian continental shelf. *Safety Science*, **46**(3), 427-439

Votano, S and Sunindijo, R Y (2014) Client safety roles in small and medium construction projects in Australia. *Journal of Construction Engineering and Management*, **140**(9), 04014045

Zhang, R P, Lingard, H and Nevin, S (2015) Development and validation of a multilevel safety climate measurement tool in the construction industry. *Construction Management and Economics*, **33**(10)1-22.

Zohar, D (1980) Safety climate in industrial organizations: theoretical and applied implications Journal of applied psychology, 65(1), 96-102.

Zohar, D (2000) A group-level model of safety climate: Testing the effect of group climate on micro accidents in manufacturing jobs. *Journal of Applied Psychology*, **85**(4), 587-596

Zohar, D (2008) Safety climate and beyond: A multi-level multi-climate framework. *Safety Science*, **46**(3), 376-387

Zohar, D (2010) Thirty years of safety climate research: Reflections and future directions Accident Analysis and Prevention, **42**(5), 1517-1522

Zohar, D and Luria, G (2005) A multilevel model of safety climate: Cross-level relationships between organization and group-level climates. *Journal of Applied Psychology*, **90**(4), 616

Zohar, D and Luria, G (2010) Group leaders as gatekeepers: Testing safety climate variations across levels of analysis. *Applied Psychology*, **59**(4), 647-673.