Assessing Safety Climate in Construction: A Case Study in Hong Kong

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The objective of this research is to determine what constitutes measurement of a safety climate that would enhance safety culture and positively impact safety performance on construction projects. A safety climate questionnaire survey was conducted on the construction sites of a leading construction company and its subcontractors in Hong Kong. In total, 1,500 hard-copy questionnaires were distributed and the response rate was excellent resulting in 1,120 valid questionnaires being collected from 22 construction projects. By means of factor analysis, seven underlying safety climate factors were extracted accounting for 59.5% of the variance in perceived safety climate. Multiple regression analysis identified three significant contributors to safety performance including 'management commitment and employee involvement, 'satisfaction with resources and training' and 'inappropriate safety procedure and work pressure.' The findings indicate that the relationship between safety performance and 'inappropriate safety procedure and work pressure' is inversely correlated indicating poor safety performance. The safety performance of Chinese and foreign employees is also compared in this research. The results indicate that safety climate can be used as an effective measure of assessing and improving site safety for projects under construction. This research provides useful information for project managers and safety practitioners who desire to improve safety climate and safety performance at construction sites in any culture.

Key Words: Safety; Construction sites; Factor analysis; Multiple regressions; Safety climate; Safety performance

Introduction

In recent years, there has been a movement away from safety measures that are based on retrospective data or lagging indicators such as accident rates and compensation costs. Because these traditional approaches measure historical safety events, the terms 'reactive, downstream, or lagging indicators' are used in construction (Choudhry et al., 2006a; Hinze, 2005; Mohamed, 2002). Accident costs tend to be reactive or after the event and relatively infrequent. This focus on safety results (Cohen, 2002) often means that the success of safety is measured by levels of system failure. Many modern approaches advocate a shift to using 'proactive measures, upstream, or leading indicators such as measurement of safety climate (Flin et al., 2000; Mohamed, 2002). The safety climate approach relies and focuses on current safety activities to establish the success of the safety management system rather than relying and focusing on system failures (Cooper & Phillips, 2004).

Research is essential in identifying the principle contributors to site safety performance and investigating how safety climate affects construction site safety. In 2004, the Tsinghua-Gammon Construction Safety Research Center was invited to carry out research at the construction projects of a leading construction firm in the Hong Kong construction industry, hereinafter called, the "company." The concept of 'safety culture' is highly valued within the company and management believes that a positive safety climate is required for improving safety performance at its construction projects. As part of the company's plan, a safety climate survey was conducted in 2005. The main objective of the research was to suggest recommendations for improving site safety at projects currently under construction. Specifically, the following objectives are considered for this research:

1. To conduct a safety climate survey on construction sites that examine employees' perceptions as a predictive tool to demonstrate how safety is operational within the organization;
2. To identify the structural factors of safety climate that help project management teams improve the safety climate on construction sites;
3. To analyze the data statistically to identify the significant factors affecting safety climate, and to evaluate the relationship between safety climate and perceptual safety performance;
4. To compare safety performance of Chinese and non-Chinese employees working on construction sites;
5. To suggest ways to improve the existing safety climate for improving safety performance on the company's construction projects.

Studies to date (e.g. Mohamed, 2002; Fang et al., 2006a) that have focused on the relationship between safety climate and safety performance are limited, and their findings are inconclusive. This current research on the relationship features the comparison of safety performance of Chinese nationals and foreign employees working on construction projects, making this unique research among safety climate studies to date. Further, this work was carried out to encourage, coordinate, and participate in construction research.

Research Method

A questionnaire was prepared for this study that took place at 22 construction projects of a Hong Kong based construction company (the "company") with annual revenues of approximately US $1billion and employing more than 2,000 full-time staff. A safety climate questionnaire survey was conducted in this company in 2002 wherein Fang et al. (2006a), extracted 15 factors from 87 questionnaire items. Nonetheless, there are 2 problems in Fang et al.'s factor structure. One is that there are too many factors in the structure, thus failing to emphasize the significant factors; the other is that all 87 questions make a large questionnaire, where respondents may feel unwilling to finish it, or may complete it in a careless manner. Most previous studies (e.g., Williamson et al., 1997, with 27 items; and Glendon & Litherland, 2001, with 32 items) reported less than 40 questions in their questionnaires, and found less than 10 factors. Following this strategy, the researchers of Tsinghua-Gammon Construction Safety Research Center (Fang et al., 2006b) have reduced the original 87 questionnaire items into 31 questions. This 31-item safety climate questionnaire was adopted for this research to investigate the safety climate on construction sites. The first 24 items were taken from the 71-item questionnaire of the Health and Safety Climate Survey Tool (Health and Safety Executive [HSE], 1997); then 7 additional items were included to make the questionnaire suitable in accordance with the safety management systems operational in Hong Kong.

A cover letter and survey instructions were prepared to ensure that all employees understood that their responses would be anonymous. The questionnaires were prepared in both English and Chinese languages. The questionnaire in its final form consisted of 35 statements and consisted of three parts (details of the English or Chinese questionnaires may be obtained by consulting the Tsinghua-Gammon Construction Safety Research Center). The first part of the questionnaire related to the respondents' general information. The questions included respondent's project name, name of the company, and asked, "Are you Chinese or non-Chinese?" Further questions included job information inquiring whether the respondent is, "a worker or clerical staff, a supervisor, or a manager." The second part consisted of 31 safety climate items which asked the participants to endorse the statements using a five-point Likert-type scale (from 1 = "strongly disagree"; to 5 = "strongly agree"). The third part consisted of four questions. Two questions measured respondents' perception on safety performance for the surveyed projects. The other two questions measured respondents' perception of safe work behavior. Respondents were asked to indicate, on average, the percentage of time they and their co-workers follow all of the safety procedures for the job they perform.

Sample

A questionnaire survey was carried out targeting all employees working on the 22 construction sites. In total, 1,500 hard-copy questionnaires were distributed. Company Safety Managers agreed to distribute the questionnaire on their sites with the help of their safety supervisors. The response rate was excellent, with 1,294 questionnaires collected from the 22 construction sites. The breakdown of the received questionnaires is presented in Table 1. To prevent a distortion of the results from the data set, a few questionnaires were discarded, and considered invalid if they contained too many missing values, or were completed by unclassified categories, such as clerical staff. The sample size for the data analysis was thus reduced from 1,294 to 1120.

Table 1

Breakdown of the received questionnaires

Location	Questionnaire distributed	Questionnaire received	Response rate	Invalid questionnaire	Final sample
Hong Kong	1,500	1,294	86.3%	174	1,120 (M = 49, S= 197, W = 874)

Legend: M = Manager; S = Supervisor; W = Worker

The collected quantitative data was analyzed by advanced statistical techniques, such as factor analysis (FA) and multiple regressions, to evaluate the essential factors affecting safety climate and its impact on safety performance. Factor analysis is by far the most commonly used method to identify the dimensions of safety climate (e.g. Gadd, 2002; Glendon & Litherland, 2001).

Results of Research

For factor analysis, a principal component analysis (PCA) of factor extraction with varimax rotation on the 31 questions (N= 1,120) was carried out through the SPSS 13.0 factor program. According to George and Mallery (2006 p.256), the KMO value (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) should be greater than the acceptable threshold of 0.5. In this study, the KMO-value was equal to 0.912, which is well above the acceptable threshold, indicating that the data was appropriate for factor analysis. Barlett's test for sphericity was carried out and the value of the test statistic for sphericity was large (chi-square value = 13689.165) with the associated significance level being small (p-value = 0.000). A significance value < 0.05 indicates that the data does not produce an identity matrix or differ significantly from identity (George & Mallery, 2006). The overall Cronbach's Alpha value is 0.833, indicating that there is good internal consistency reliability between factors as a value of 0.70 or above is acceptable (Cooper & Phillip, 2004; George & Mallery, 2006 p. 231). Since the requirements of KMO measure, Barlett's test of sphericity, and Cronbach's Alpha values were all achieved, the factor analysis for this research can proceed with confidence. A total of 7 factors were extracted from the 31 safety climate items and from the 1,120 valid responses, accounting for 59.5% of the variance (see Table 2), which is comparable to other related research studies, for example Fang et al. (2006a) at 47.6%. Table 2 contains the details of factor loading which indicates the strength of relationship between a particular variable (denoted by C01, C02 … C31) and a particular factor.

Meaning of Underlying Safety Climate Factors

Factor 1, Inappropriate safety procedure and work pressure, consists of 8 statements mainly concerned with the safety system, procedures, and work pressures on-site. This factor gives a bleak picture of improper operational procedures related to construction tasks that *some jobs are difficult to execute safely* (C02); *Safety procedures are difficult to follow* (C09); and *some safety procedures do not reflect how the job is done here* (C08). Respondents view that *productivity has an edge over safety issues on construction projects* (C06). It appears that meeting deadlines has always been one of management's priorities on-site which instills work pressure to take risks to complete the job. Employees perceive that *accident investigations are used to identify who is to blame* (03) rather than learning or improving on-site safety. Also, respondents perceive that *suggestions to improve health and safety are seldom acted upon* (C04). This factor indicates an area of opportunity for improvements in safety management practices.

Factor 2, Management commitment and employee involvement, consists of 7 statements that are related to management attitudes and actions towards safety. This factor includes 2 statements which relate to the respondents' satisfaction with the current *safety inspections and accident investigation* (C27, C26). Respondents feel satisfied with *the job-specific safety training* (C25). Additionally, the respondents view that the organization has *a good preparedness for emergency* (C28). Also, this factor explains the commitment for improving safety performance within teams that *it is important to work safely if I am to be respected by others in the team* (C24). The degree of workers' involvement in establishing a safety system is also contained in factor (C21, C23). At present, the company takes account the needs of employees in the safety process. *The company shows interest in my views on health and safety* (C21). *All people who work in my team are fully committed to health and safety* (C23).

Factor 3, Satisfaction with resources and training, consists of 7 statements measuring the effectiveness of safety resources and training. This factor shows the respondents' confidence that *there are enough people available to do the job safely* (C17); and that *everyone can get the equipment which is needed to perform the job safely* (C16). The respondents view safety as the organization's commitment that *the company really cares for the safety of the people who work here* (C18). Employees believe that *sufficient resources are available for safety and health* (C20) and true priority is given to safety. This factor explores participants' views about training, and the level of understanding which they perceive they have achieved. For example, *I am clear about what my responsibilities are for health and safety* (C11). The respondents perceive that safety systems are reviewed and promoted by the organization (C05 and C12).

Table 2

Factor structure by principal factors extraction and varimax rotation

No.	Item	Factor loading
Factor 1: Inappropriate safety procedure and work pressure; Eigenvalue 7.752; % of Variance 25.005 ; Cumulative % 25.005		
C02	Some jobs here are difficult to do safely.	0.754
C09	Some health and safety procedures / instructions / rules are difficult to follow.	0.717
C08	Some health and safety procedures / instructions / rules do not reflect how the job is now done.	0.707
C06	Productivity is usually seen as more important than health and safety by management.	0.680
C19	Sometimes it is necessary to take risks to get the job done.	0.676
C03	Accident investigations are mainly used to identify who is to blame.	0.601
C04	Suggestions to improve health and safety are seldom acted upon.	0.600
C10	The permit to work system is over the top given the real risks of some of the jobs it is used for.	0.481
Factor 2: Management commitment and employee involvement; Eigenvalue 4.547; % of Variance 14.668 ; Cumulative % 39.673		
C27	I think management here does enough to follow up safety inspections / accident investigations.	0.759
C26	Safety inspection here is very helpful to improve the health and safety of workers.	0.758
C25	Most of the job-specific safety trainings I received are effective.	0.724
C28	There is good preparedness for emergency here.	0.652
C24	It is important for me to work safely if I am to be respected by others in my team.	0.570
C21	The company shows interest in my views on health and safety.	0.550
C23	All the people who work in my team are fully committed to health and safety.	0.486
Factor 3: Satisfaction with resources and training; Eigenvalue 1.580; % of Variance 5.096 ; Cumulative % 44.769		
C17	There are always enough people available to get the job done according to the health and safety procedures/instructions/rules.	0.729
C16	People can always get the equipment which is needed to work to the health and safety procedures/instructions/rules.	0.723
C18	The company really cares about the health and safety of the people who work here.	0.715
C20	Sufficient resources are available for health and safety here.	0.681
C11	I am clear about what my responsibilities are for health and safety.	0.544
C12	The company encourages suggestions on how to improve health and safety.	0.528
C05	I feel involved when health and safety procedures / instructions / rules are developed or reviewed.	0.514
Factor 4: Appraisal of hazard and reporting; Eigenvalue 1.390; % of Variance 4.484 ; Cumulative % 49.252		
C30	Health and safety is not my problem – it is up to management and others.	0.791
C31	People are just unlucky that suffer an accident.	0.687
C01	Accidents and incidents which happen here are always reported.	-0.562
C29	Safety publications and posters have little influence on the awareness and behavior of people here.	0.523
Factor 5: Personal risk appreciation; Eigenvalue 1.148; % of Variance 3.703 ; Cumulative % 52.955		
C13	Some of the workforce pays little attention to health and safety.	0.745
C15	Not all the health and safety procedures / instructions / rules are strictly followed here.	0.619
Factor 6: Competence; Eigenvalue 1.023; % of Variance 3.299 ; Cumulative % 56.254		
C07	People here always work safely even when they are not being supervised.	0.796
C14	People here always wear their health and safety protective equipment when they are supposed to.	0.491
Factor 7: Co-worker's influence; Eigenvalue 1.005; % of Variance 3.241 ; Cumulative % 59.496		
C22	My workmates would react strongly against people who break health and safety procedures / instructions / rules.	0.712

Factor 4, Appraisal of hazard and reporting, consists of 4 statements exploring the extent to which workers perceive risks and behave unsafely at work. The finding of this factor indicates that on-site safety has been compromised since employees view that *health and safety is not their problem* (C30) and that *people are just unlucky that suffer an accident* (C31). The negative sign with the statement shows that those respondents who are mostly workers perceive that *hazards are not always properly reported* (C01). Also workers view that *safety publication or posters have little effect on changing behavior of employees* (C29). This factor emphasizes that safety is unlikely to improve if it is not taken seriously by everyone on-site.

Factor 5, Personal risk appreciation, consists of 2 statements and indicates that some of the *workforce pays little attention to health and safety on-site* (C13). The finding highlights the importance of implementing up-dated safety procedures as employees perceive that *not all rules, regulations and procedures are followed strictly on-site* (C15).

Factor 6, Competence, contains 2 statements demonstrating the competence of respondents. *People work safely even when they are not being supervised* (C07) evaluates the effectiveness of their supervisors. *People always wear their personal protective equipment when they supposed to* (C14). This finding leads to the conclusion that trained employees have a good understanding about safety awareness and the use of personal protective equipment (PPE).

Factor 7, Co-worker's influence, is a single-statement factor which examines the respondents' view on co-worker's influence. *My workmates react strongly against people who break safety procedures* (C22) demonstrating that co-workers support safety and health on-site.

Model of Safety Climate and Safety Performance

Multiple linear regression analysis was used in this research to study the relationships between safety performance (dependent variable) and safety climate factors (independent variables). A stepwise variable selection was adopted as it is the most frequently used method for model building (George & Mallery, 2006; Norusis, 2005) to identify the critical success factors. The stepping method criteria selected the p value = 0.05 for a variable to enter the regression equation and p value = 0.10 to remove an entered variable (George & Mallery, 2006; Norusis, 2005). Seven underlying safety climate factors extracted by factor analysis were used as independent variables in evaluating the relationship with perceived safety performance (dependent variable question C32). Table 3 shows the un-standardized and standardized regression coefficients (ß), adjusted R^2, R^2 change, t-value, and significance level for the sample. Factors 4, 5, 6, and 7 were excluded from the regression model because they failed the entrance criteria of stepwise variable selection described above. Factors 2, 3, and 1 were significantly different from p=0.000 to p=0.044.

Figure 1 exhibits the frequency distribution of the safety performance measure for all respondents of the sample. The x-axis represents the number of respondents, and the y-axis represents the safety performance scores entered by the respondents ranging from 1 to 5. The results show that only 3.2% respondents rated a score of 1 or 2, while a score of 3 (average) was rated by 35.5%, score of 4 (good) by 47.7%, and score of 5 (excellent) was rated by 13.6%

respondents respectively. This means that 61.3% respondents consider that the safety performance of their project is very good.

Table 3

Results of stepwise multiple regression

Independent Variable (safety climate factor)	Un-standardized Coefficients (ß)	Standardized Coefficients (ß)	Adjusted R^2	Adjusted R^2 Change	t-value	Significance
y-intercept (i.e. constant)	3.701	-	-	-	184.406	0.000
Factor 2: Management commitment, communication and employee involvement	0.309	0.397	0.157	0.158	15.411	0.000
Factor 3: Satisfaction with resources and training	0.244	0.313	0.254	0.098	12.132	0.000
Factor 1: Inappropriate safety procedures and work pressure	-0.040	-0.052	0.256	0.003	-2.016	0.044

Note: Dependent Variable – Please evaluate the overall safety performance

Hence, the Multiple Linear Regression equation (*see Equation 1*) for safety performance is:

$$\text{Safety performance} = 3.701 + 0.309(F2) + 0.244(F3) - 0.040(F1) \quad (1)$$

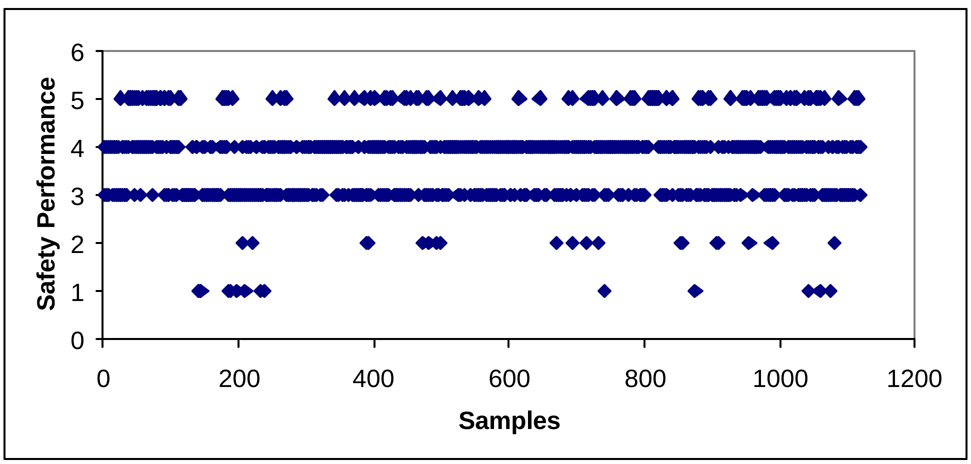

Figure 1: Frequency distribution diagram for the sample (N = 1,120)

Safety Performance of Chinese and Non-Chinese Employees

The term “non-Chinese” indicates people who are not Chinese nationals but are employed by the company on the construction project. Only the results of questions C33, C34, and C35 are presented here, and the outcome may be of interest to those multi-national companies who are employing workers from various countries. The respondents were asked to indicate *your level of* *agreement against any one of these, i.e., 10%, 30%, 50%, 70%, or 90%, by evaluating the safety and health management of your site* (C33). The results are presented in Table 4. The results show that Chinese respondents perceive safety management is slightly better at 63.77%, as compared with non-Chinese (62.26%) respondents.

Table 4

Comparison of safety performance between Chinese and non-Chinese respondent

Description	Chinese	Non-Chinese	All
Respondents	1,089	31	1,120
Results	63.77%	62.26%	63.73%

Respondents were asked to indicate on a scale of 0 (zero) to 100%, the percentage of time: (1) *I follow all of the safety procedures for the jobs that I perform*; and (2) *My coworkers follow all of the safety procedures for the jobs that they perform*. Interesting results were obtained from both questions (C34 and C35) and are presented in Table 5. The results show that safe work behaviors of non-Chinese employees are higher (78.39%) compared with the Chinese respondents (73.06%) on construction sites. Nonetheless, if the results are compared between C34 and C35, i.e., between the respondent and co-workers, similar trends can be seen among Chinese and non-Chinese (see Table 5).

Table 5

Comparison of safe work behavior of Chinese and non-Chinese respondent

Description	Safe Work Behavior of Respondents		
	Chinese	Non-Chinese	All
Respondents	1,089	31	1,120
I follow all of the safety procedures for the jobs that I perform (Q34)	73.06%	78.39%	73.21%
My coworkers follow all of the safety procedures for the jobs that they perform (Q35)	63.98%	65.32%	64.02%

Discussion

Factor analysis explored the determinants of safety climate for the construction sites. Inappropriate safety procedure and work pressure (Factor 1) was identified as an important problem which demonstrated that improper safety procedures need to be revised periodically to ensure they reflect current operation on-site. Also, work pressure for production needs to be managed without compromising safety. The results indicated that management commitment and employee involvement (Factor 2) made significant contributions to safety climate. A growing number of safety climate studies indicate that employee perception regarding management commitment to safety is a core ingredient in shaping a positive safety climate (e.g., Flin et al., 2000; Zohar, 1980). The results of Factor 3 (satisfaction to resources and training) suggest that this component has an influence on positive safety climate. This is not surprising, since trained and satisfied employees having access to safety resources providing a safe work environment exhibit positive safety climate. Factor 4 (appraisal of hazard and reporting) indicates that employees' ability to detect potential hazard has an important role in affecting the safety performance. Employees' attitude towards safety or personal risk appreciation (Factor 5) is one of the important indices of safety climate as found by Cox & Cox (1991). A high level of competence (Factor 6) in employees can help in creating a positive safety climate. Attending to the last identified factor, Factor 7 (co-worker's influence) the degree of confidence, trust, and support for safety that workers extend while interacting with each other, will provide a safer work environment on-site. The factor structure that was generated by factor analysis is probably the most appropriate; as the 7 underlying factors are obtained from a 1,120-valid-questionnaire received from the 22 construction sites.

Safety Performance among Chinese and Non-Chinese Employees

Results show that the Chinese employee's perceived safety was better managed than the foreign employees perceived. In addition, results show that exhibiting safe work behaviors is perceived higher among foreign employees as compared with Chinese employees.

Link between Safety Climate, Safety Performance, and Factors Affecting Safety Performance

The results of the Multiple Regression Analysis identified the critical safety climate factors affecting perceptual safety performance on construction sites. There are three factors in the regression equation, where the values of two regression coefficients, Factors (F2) and (F3), are positive, while negative value exists for Factor (F1). This implies that the relationship between safety performance and Factor (F1) is inversely correlated, resulting in poorer safety performance. The statements in this factor are "*Some jobs here are difficult to do safely* (C02)," "*Some health and safety procedures are difficult to follow* (C09)," "*Some health and safety procedures do not reflect how the job is now done here* (C08)," "*Productivity is usually seen as more important than health and safety by management* (C06)," and "*Accident investigations are mainly used to identify who is to blame* (C03)." These statements imply that inappropriate safety procedures should be up-dated, should be technically correct, and be clear and understandable to employees. In addition, workers should be provided a pressure-free environment to implement safety procedures. These results support the use of safety-climate measures as constructive diagnostic tools in finding employees' perceptions about how safety is being implemented on their construction sites.

Conclusion

From factor analysis, seven principal components were established constituting the measurement of safety climate that would positively impact safety performance on construction sites. They are: (1) inappropriate safety procedure and work pressure, (2) management commitment and employee involvement, (3) satisfaction with resources and training, (4) appraisal of hazard and reporting, (5) personal risk appreciation, (6) competence, and (7) co-workers' influence. These factors have been regressed with the perceived safety performance scores to establish the causal relationship between safety climate and safety performance. Three factors were identified as significant in explaining the safety performance in Hong Kong from the Multiple Regression results which include "Management commitment and employee involvement," "Satisfaction with resources and training," and "inappropriate safety procedures and work pressure." The regression results showed that 'management commitment and employee involvement' was the most significant factor relating to safety performance. The availability of safety resources and providing training to employees is the second most important factor for establishing positive safety climate on construction sites. Some interesting results obtained in this study included that better safety management was perceived by Chinese employees compared to foreign employees. Also, the results indicated that exhibiting safe work behavior among foreign employees was higher compared with Chinese employees. Although the findings of this study are limited to 22 construction projects, the methodology is useful for research at other construction sites in other regions or countries.

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