Measuring Safety Climate of a Construction Company

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Abstract: Safety climate can benefit contractors, specialty contractors, and owners of industries by providing them with the knowledge of attitudes and perceptions that can help to consistently achieve better safety performance. The objective of this research was to determine safety climate that would enhance safety culture and positively impact perceived 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. Approximately, 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, two underlying safety climate factors were extracted, accounting for 43.9% of the total variance. Multiple regression analysis confirmed that these climate factors, "management commitment and employee involvement" and "inappropriate safety procedure and work practices" were significant predictors of workers' perceptions of safety performance. The findings indicated that the relationship between perceived safety performance and "inappropriate safety procedure and work practices" was inversely correlated. The results suggest that safety climate can be used as an effective measure of assessing and improving site safety for projects under construction. The findings of this study and the methodology might be useful for research at other construction sites in other regions and countries. This work provides useful information for project managers and safety practitioners who desire to improve safety climate and safety performance on construction sites.

DOI: 10.1061/(ASCE)CO.1943-7862.0000063

CE Database subject headings: Safety; Construction sites; Regression analysis; Construction companies; Contractors.

Introduction

It is documented that construction has the highest rate of accidents among all industries (Hinze 1997; Sawacha et al. 1999; Choudhry et al. 2008) and the construction industry of Hong Kong is no exception. In the 1980s and early 1990s, the safety record of the construction industry in Hong Kong was poor. The annual accident rate in 1991 was 364 per 1,000 workers, which was 25 times greater than that of Japan and Singapore (Lingard and Rowlinson 1994). Nevertheless, a number of initiatives have been put in place in promoting safety and health in the workplace in the form of legislation, law enforcement, safety promotion, and training, reducing the accident rate in Hong Kong to 59.9 per 1,000 workers in 2005 (Choudhry et al. 2008). In addition, the number of fatalities in the Hong Kong construction industry (HKCI) was 17 in 2004; the lowest figure ever recorded [Labor Department (LD) 2005]. Although, the accident rate in the construction industry of Hong Kong has declined, it is still high when compared with other developed countries. The Construction Industry Review Committee commissioned by the Government of Hong Kong Special Administrative Region reported that there is an urgent need to cultivate a safety culture within the construction industry at all levels [Construction Industry Review Committee (CIRC) 2001].

Research is essential in identifying the principal contributors to site safety performance and investigating how safety climate affects site safety on construction projects. In 2005, the Tsinghua-Gammon Construction Safety Research Center was invited to carry out research at the construction projects of Gammon Construction Limited hereinafter called the company. The company is a well-established construction firm and a market leader in the HKCI. The company has implemented good safety, health and environment management systems on all of its construction sites. The company's accident rate is lower than that of the HKCI (Choudhry et al. 2008). The company's safety management system is based on Occupational Health and Safety Assessment Series 18001 and Factories and Industrial Undertakings Ordinance (Chapters 59 and 509). The concept of "safety culture" (Choudhry et al. 2007a) is highly valued within the company and management believes that a positive safety climate is required for improving safety performance on its construction projects. Also, management aims to include safety as the company's core value, one that every manager, supervisor, and employee should embrace. As part of the company's long-term plan, a safety climate survey was conducted in 2002 and the results were published in Fang et al. (2006). The present survey was conducted in 2005 as part of the follow-up survey. The main objective of this research was to suggest recommendations for improving site safety for the company's projects. A key focus of this safety climate survey was to ensure the accountability of management in demonstrating their leadership and support for safety. The results of the survey

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Note. This manuscript was submitted on June 25, 2008; approved on March 3, 2009; published online on August 14, 2009. Discussion period open until February 1, 2010; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 135, No. 9, September 1, 2009. ©ASCE, ISSN 0733-9364/2009/9-890–899/$25.00.

were submitted to the company and are reported in this publication. Specifically, the following objectives are considered for this work:

1. To conduct a safety climate survey on construction sites that examine employees' perceptions as a predictive tool to demonstrate how safety is perceived within the organization;
2. To identify the structural factors of safety climate that help project management teams to improve the safety climate on construction sites;
3. To analyze the data statistically to evaluate the relationship between safety climate and perceived safety performance within the company; and
4. To suggest ways to improve the existing safety climate in the company's construction projects.

Studies to date (e.g., Zohar 1980; Mohamed 2002) have focused on identifying a set of safety climate factors. Some researchers have attempted to link safety climate with safety performance. For example, in a longitudinal study of Swedish construction workers, Pousette et al. (2008) report safety climate predicted self-reported safety behaviors 7 months later (after controlling for previous safety behavior). Attempts to link safety climate with objective accident data have had mixed results (Clarke 2006). By measuring safety climate perceptions and evaluating the perceived safety performance of employees working on construction projects this research makes a unique contribution to safety climate studies to date. Furthermore, past studies (e.g., Zohar 1980; Lee and Harrison 2000; Cooper and Phillips 2004) were conducted in western cultures and this study was carried out in the Chinese culture providing an insight into the generalizability of the safety climate concept beyond western cultures.

Literature Review

Zohar (1980) introduced the concept of safety climate and defined it as "a summary of molar perceptions that employees share about their work environment." The term safety climate, which has been derived from organizational climate, refers to perceptions of policies, procedures, and practices relating to safety in the work place. Glendon and Stanton (2000) demonstrate that organizational climate refers to the perceived quality of an organization's internal environment. Flin et al. (2000) defined safety climate as the shared perceptions about safety values, norms, beliefs, practices, and procedures.

In past research, safety climate was considered to be a subcomponent of safety culture (Cooper 2000; Glendon and Stanton 2000; Neal et al. 2000; Choudhry et al. 2007a) and a reflection of actual safety culture (Lee and Harrison 2000; Flin et al. 2000; O'Toole 2002; Fang et al. 2006). The distinction between culture and climate remains a source of some debate and confusion in the safety field (Guldenmund 2000) but, for the most part, safety climate highlights the perceptions held by employees regarding the significance of safety in their jobsite (Choudhry et al. 2007b). Mohamed (2003) suggested that safety culture is concerned with the determinants for the ability to manage safety (top-down organizational attribute approach); whereas, safety climate is concerned with the workers' perceptions of the role safety plays in the workplace (bottom-up perceptual approach). Mohamed (2003) further stated that the safety climate is largely a product of safety culture and the two terms should not be viewed as alternatives. Different writers interpreted safety climate differently. While there is no single accepted definition in construction, Choudhry et al. (2007b) provided the definition that *safety climate reflects employees' perceptions about the organizations' safety management system including policies, practices, and procedures that show how safety is implemented in construction sites environments*.

Safety climate measures vary significantly, for example there is substantial variation in questionnaire content, style, statistical analysis, sample size, and sample composition (managers, supervisors, workers, industry, or country). Typically, factor analysis (FA) is employed to identify an underlying structure for questionnaire items, which range from 9 (DeDobbeleer and Beland 1991) to 120 (Lee and Harrison 2000) and the resulting factor structures vary from 2 to 28, respectively. A cluster of obtained factors is interpreted to be as scales, factors, or dimensions of safety climate. Investigating safety climate is not new in the nuclear industry (Lee and Harrison 2000) or steel, food processing, chemical and textile industry (Zohar 1980). More recently, some studies have begun to explore the safety climate concept in construction [see, for example, Gillen et al. (2002) and Pousette et al. (2008)]. Notwithstanding this, no agreed factor structure for safety climate in the construction context has been established.

Management commitment is a central element of safety climate (Zohar 1980). Management plays an important role in organizing and implementing safety policies on construction sites. O'Toole (2002) proposed that there is a connection between management's approach to safety and employees' perception of how important safety is to the management team. In an empirical study in construction, Mohamed (2002) presented a model of safety climate determinants and found that there was a significant relationship or positive association between perceptions of the safety climate and self-reported safe work behavior. Neal et al. (2000) also linked safety climate to self-reported safety compliance and participation. Neal et al. (2000) distinguished safety compliance, which involves adhering to safety procedures and carrying out work in a safe manner from safety participation, which involves helping coworkers, promoting the safety program within the workplace, demonstrating initiatives, and putting efforts into safety for improving the safety performance. Consequently, an individual must know how to perform work safely and have the skill to be able to do it to comply with safety rules, regulations, and procedures.

Dimensions of Safety Climate

Zohar (1980) attempted to define organizational characteristics that would distinguish between high versus low accident rate companies. During interviews, a questionnaire of 40 questions was administered in 20 Israeli industrial organizations with 400 respondents (Zohar 1980). According to Zohar, safety climate consists of the following eight dimensions: successful safety training; management commitment to safety; status of safety officer; status of the safety committee; level of risk at workplace; effects of safe conduct on promotion; effect of safe conduct on social status; and effects of required work pace on safety. Brown and Holmes (1986) attempted to validate Zohar's safety climate model on 10 American manufacturing and production companies with 425 workers' response with the same questionnaire. They reduced the original eight-factor climate model to three factors: management attitudes, management actions, and employee level of risk. DeDobbeleer and Beland (1991) tested Brown and Holmes's safety climate model among workers employed on construction sites. They found strong correlations between management concerns and reduced the model to two factors: management commitment and workers' involvement.

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Keil (2002) reported that the Health and Safety Executive (HSE) published a health and safety climate survey tool in 1997. In the HSE climate survey tool [Health and Safety Executive (HSE) 1999] 10 safety climate factors were posited, including organizational commitment and communication, line management commitment, supervisor's role, personal role, workmates' influence, competence, risk taking behavior and contributory influences, obstacles to safe behavior, permit to work, and reporting of accidents and near misses. After exploring 18 safety climate reports from 1980 to 1998, Flin et al. (2000) reported the "big five" themes of safety climate to be management, safety system, risk, work pressure, and competence.

Glendon and Litherland (2001) examined the safety climate in a road construction organization and found six factors. The factors include communication and support, adequacy of procedures, work pressure, personal protective equipment, relationships, and safety rules. Mohamed (2002) has identified 10 dimensions of safety climate in construction site environments. These 10 dimensions are management commitment, communication, safety rules and procedures, supportive environment, supervisory environment, workers' involvement, personal risk appreciation, appraisal of work hazards, work pressure, and competence. Fang et al. (2006) found 15 factors, however, only 10 were considered as the important dimensions of safety climate in a study conducted in the construction industry of Hong Kong. These 10 dimensions were safety attitudes and management commitment, safety consultation and safety training, supervisor's role and workmates' role, risk taking behavior, safety resources, appraisal of safety procedure and work risk, improper safety procedure, worker's involvement, workmate's influence, and competence.

Safety Climate and Demographic Factors

Many studies have collected personal information about the respondents, such as age, gender, marital status, education level, working experience in the industry, and other personal information. These demographic factors can influence safety climate and consequently influence individual safety behavior (Hinze 1997). Siu et al. (2003) investigated age difference in safety attitudes and safety performance in Hong Kong construction workers with data from 374 Chinese construction workers from 27 construction sites. The study found that the older workers exhibited more positive attitudes toward safety.

Fang et al. (2006) used logistic regression to explore the relationship between safety climate and personal characteristics. Statistically, eight personal characteristics namely age, marital status, the presence of dependent family members, education level, safety knowledge, drinking habits, direct or indirect employer, and breaking safety procedures or not, were found to be related to safety climate perceptions. Five variables, including gender, work experience with the company, work experience in the construction industry, whether injured or not, and smoking habits were found to have no influence on perceptions of safety climate. Cooper and Phillips (2004) suggested that differences in types of work activity and other site situational conditions are much more important in climate research than personal demographical variables, such as age, job experience, or accident involvement. This finding makes sense since safety climate measures tend to investigate employees perceptions about how on-site safety operates, which is theoretically and conceptually distinct from employees' personal characteristics. Nonetheless, empirical justification for using personal demographics as a validation technique is required if safety climate research is to progress (Cooper and Phillips 2004).

Safety Climate and Safety Performance

Researchers have struggled over the past decade to find empirical evidence to demonstrate actual links between safety climate, individual safety behavior, and safety performance. Neal et al. (2000) examined the impact of organizational climate on safety climate and individual behaviors on a sample consisting of 525 employees from 32 work groups in a large Australian hospital. They concluded that organizational climate exerted a significant impact on safety climate and the effect of safety climate on perceived safety performance was mediated by safety knowledge and motivation. In construction, Glendon and Litherland (2001) investigated the relationship between safety climate and individual safety behavior within a road construction organization but the research failed to find any relationship between safety climate and the behavioral observation measure of safety performance. Mohamed (2002) developed a research model based on the hypothesis that safe work behaviors were the consequences of the existing safety climate in construction site environments.

Broadly, safety performance measurement techniques can be categorized into statistical measures, behavioral measures, periodic safety audits, and a balanced scorecard approach. The behavioral approach, safety audits, and balanced scorecard require a relatively long period of time to set up and are not easy to measure by the use of a questionnaire survey (Chan et al. 2005). Measurement of workers' perceptions of safety performance requires respondents to judge the safety of their own construction sites. The reliability of workers' perceptions of safety performance of a construction project can present a problem in small samples because different respondents from the same construction site may have different perceptions of safety performance. However, this problem can be overcome by using a large sample size as a prerequisite for maintaining statistical validity.

Research Method

From the literature review, an understanding was developed about the concepts of safety climate, perceptions of safety performance, and safety climate surveys. Potential safety attributes affecting safety performance at the company's construction sites were identified. Based on the previous research by Fang et al. (2006) carried out in 2002 by adopting the HSE questionnaire, the present questionnaire was modified for measuring safety climate. The HSE climate survey tool was first published in December 1997 [Health and Safety Executive (HSE) 2002] and the tool appeared to be more appropriate than others, which were developed specifically for the oil and gas industry.

Questionnaire

Data were collected on 22 construction projects of a large construction company based in Hong Kong. The company has annual revenues of approximately $1 billion and employs more than 2,500 full-time staff. Fang et al. (2006) extracted 15 factors from 87 questionnaire items by performing a principal component FA to construct the safety climate factor structure of the company. Nonetheless, this factor structure was fragmented and the survey

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deemed to be too long. The length of the survey was threat to data completeness and reliability. In the present study, the number of questionnaire items was reduced.

Generally, safety climate questionnaires were used to capture employee perceptions of management commitment to safety, or to identify areas of safety that require improvement. Most previous studies [e.g., Williamson et al. (1997) with 27 items and Glendon and 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 have reduced the original 87 questionnaire items (Fang et al. 2006) 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 seven additional items were included to make the questionnaire suitable in accordance with the safety management systems operating in Hong Kong. A pilot study was carried out to check reliability, validity, and usefulness of the questionnaire. The questionnaire was presented to 10 project managers, 20 safety managers, and 20 workers. The questionnaire was also presented in a workshop to get feedback of 20 respondents. The questionnaire was examined for content validity, structural validity, and offensiveness of the language. They were asked to comment on if there are any overlapping statements/items in the questionnaire. Their feedback was used to refine the questionnaire and to delete any unacceptable wording. Thus, the questionnaires described and measured what it was supposed to. Additionally, the questionnaire was purposely designed to seek views of managers, supervisors, and workers on key aspects of safety climate on construction sites.

The questionnaires were prepared both in English and Chinese versions. The questionnaire in its final form consisted of 42 statements about safety issues at the organizational, group, and individual levels and consisted of four parts. The first part of the questionnaire related to the respondents' general information. The questions included respondent's project name, name of the company, and ethnicity. Further questions included the respondent's job information, i.e., is he/she a worker, a clerical staff, 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 (1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, and 5=strongly agree). The third part measured respondents' perception of safety performance for the surveyed projects. The fourth part of the questionnaire included eight questions on personal information, including demographic information, such as age, gender, marital status, number of family members to support, education level, employer, work experience with the company and in the industry. This part of the questionnaire was designed to investigate the personal characteristics of the respondents.

Sample

Twenty-two construction projects in Hong Kong were selected for the target sample. Overseas projects of the company were excluded from the survey. The company management wanted that maximum employees would be surveyed. The company thought that they would learn about safety issues by participating in the survey. Approximately 1,500 hard copy questionnaires were distributed randomly to a population of around 2,950 individuals working on the projects. The sought confidence level was 95%

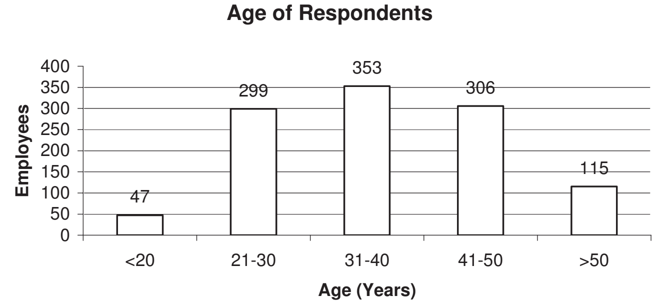

Fig. 1. Age of participants for the sample

and confidence interval was 2.5. To keep the error small, the worst case percentage, i.e., 50% was sought. Following Bernard (1994) and CRS (2009), a sample of 1,011 respondents was enough. The response rate was excellent (86.3%) and 1,294 questionnaires were collected from the 22 construction sites. The questionnaires, which were completed by ticking the same option in all questions or completed by unclassified categories, such as clerical staff, were discarded and considered invalid to prevent a distortion of the results from the data set. The sample size for the data analysis was thus reduced from 1,294 to 1,120 hereinafter called the sample.

Krejcie and Morgan (1970) reported that at 5% confidence interval, the sample size should be 278 for a population of 1,000; 322 for a population of 2,000; and 341 for a population of 3,000. The sample is very large as compared to the population, which satisfies the statistical expectations. It is a random sample where each individual have the same chance as every other individual of being selected.

For this study, a cover letter and survey instructions were prepared to ensure all employees understood that their responses would be anonymous. There was no requirement for the respondents to put their name on the questionnaire. The respondents were requested to return their responses in the sealed boxes. The questionnaires were distributed with the help of the safety supervisors. In the beginning, the supervisors were provided half-day training for conducting the survey. The writers were also present on site for conducting and monitoring the survey. To check and avoid the problem of bias, it was decided to interview at least one employee working on each project of the company and 22 interviews were conducted to investigate compliance with the methodology.

Of the 1,120 respondents, 4.2% were younger than 20 years, 26.7% were between 21 and 30 years old, 31.5% were between 31 and 40 years, 27.3% were between 41 and 50 years old, and the rest 10.3% were older than 50 years (see Fig. 1). Genderwise, 97.3% participants were male and only 2.7% were female. Of all the respondents, 67.1% were married and 32.9% were single. When asked how many family members are supported by the respondent, 17.6% respondents responded none, 36.5% are supporting one to two family members, 33.4% are supporting three to four dependent family members, 8.9% are supporting five or six family members, and 3.6% are supporting seven or more family members. Of all the respondents, 9.1% had an advanced degree, 10.6% were college graduates, 42.8% had a secondary education, 24.9% had a primary education, and 12.6% did not have a primary education. The majority of respondents (54.9%) were subcontractor employees, 6.6% were employed by a joint venture, and 38.5% were directly employed by the company. Approximately 36% of the sample had worked for their present employer

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for more than 6 years and 44.3% had worked between 1 and 5 years, and the rest (19.7%) had less than 1 year working experience with the present employer. In terms of construction industry experience, 15.4% of the sample had less than 3 years working experience, 38.7% had 3–10 years working experience, and rest (45.9%) had more than 10 years working experience.

The collected quantitative data were further analyzed by statistical techniques, such as FA and multiple regression to evaluate the essential factors affecting safety climate and its impact on safety performance. The FA is by far the most commonly used method to identify the dimensions of safety climate (Gadd 2002). Principal components analysis (PCA) was used to identify the underlying factors, which is regarded as a useful tool for determining the interdependence of variables. In this method, variables are grouped by their correlations with each other and therefore demonstrably measuring the same underlying component or factor. Varimax rotation was selected to assist in the interpretation of the factor structure.

Results of Research

Factor Analysis

The FA technique was used to identify the underlying cluster of factors, which affected safety climate. The FA was conducted by using the SPSS for Windows 15.0 software package (SPSS Inc. Corporate Headquarters, Chicago). A PCA with Varimax rotation on the 31 questions ($N=1,120$) was conducted. According to George and Mallery (2006), p. 256, the Kaiser-Meyer-Olkin (KMO) value (measure of sampling adequacy) should be greater than the acceptable threshold of 0.5 and a value greater than 0.6 is mediocre, >0.7 is middling, >0.8 is meritorious, and >0.9 is marvelous for a FA to proceed. In this study, the KMO value was equal to 0.905, which is well above the acceptable threshold indicating that the data were appropriate for FA. Barlett's test for sphericity was used to test the hypothesis that the correlation matrix was an identity matrix. In this case, the value of the test statistic for sphericity is large (chi-square value$=13,033.730$) and the associated significance level is small (p value$=0.000$), indicating that the population correlation matrix is not an identity matrix as a FA would be meaningless with an identity matrix (George and Mallery 2006). A significance value <0.05 indicates that the data do not produce an identity matrix or differ significantly from identity. Since the requirements of KMO measure and Barlett's test of sphericity were achieved, the FA for this research could proceed.

A total of six components or factors having eigenvalues of 1 or more were extracted from the 31 item questionnaire. These accounted for 52.4% of the variance. The eigenvalues for each of these six components were 6.872, 4.313, 1.547, 1.327, 1.136, and 1.055, explaining 22.2, 13.9, 5, 4.3, 3.7, and 3.4% of the variance, respectively. These factors were based on the criteria that the eigenvalue for each factor should be greater than 1 (George and Mallery 2006, p. 248). However, when the scree plot was inspected, there was quite a clear break between the second and the third component. Pallant (2007) recommended retaining (extracting) only two factors in this case. It was recognized that most of the items loaded quite strongly (above 0.4) on the first two components and very few items loaded on Components 3–6. This suggested that a two-factor solution is more appropriate. Consequently, a forced two-factor solution was tested (Cattell 1966; Pallant 2007, p. 192).

Table 1. List of Removed Items with Low Communality Values (Less Than 0.30)

Number	Item	Extraction
C01	Accidents and incidents which happen here are always reported.	0.143
C05	I feel involved when health and safety procedures/instructions/rules are developed or reviewed.	0.219
C07	People here always work safely even when they are not being supervised.	0.133
C10	The permit to work system is over the top given the real risks of some of the jobs it is used for.	0.283
C11	I am clear about what my responsibilities are for health and safety.	0.258
C13	Some of the workforce pays little attention to health and safety.	0.150
C14	People here always wear their health and safety protective equipment when they are supposed to.	0.294
C22	My workmates would react strongly against people who break health and safety procedures/instructions/rules.	0.122
C28	There is good preparedness for emergency here.	0.178

In the two-factor solution, only 36.1% of the variance were explained, compared with over 52% explained by the six-factor solution. Items with low communalities (e.g., less than 0.3) and displaying low factor loadings in the rotated component matrix were removed (Pallant 2007, p. 196). Thus, items C1, C5, C7, C10, C11, C13, C14, C22, and C28 (see Table 1) showed low communality values of 0.143, 0.219, 0.133, 0.283, 0.258, 0.150, 0.294, 0.122, and 0.178 The removal of problem items is useful if one is interested to improve the scale after a survey.

Finally, the 22 items of safety climate scale were subjected to principal components PCA. Prior to performing the final PCA, the suitability of the data for FA was assessed. The KMO value was 0.902, exceeding the recommended value of 0.6; and Bartlett's Test of Sphericity reached statistical significance which was large (chi-square value$=10,247.249$ with small p value$=0.000$), supporting the factorability of the correlation matrix. Using the scree test in Cattell (1966) and following the Pallant (2007, p. 196) approach, it was decided to retain two components for further investigation. The two-factor solution (see Table 2) explained a total of 43.9% of the variance, with Factor 1 contributing 27.62% and Factor 2 contributing 16.28%. The results are comparable to other related research studies (O'Toole 2002) and Fang et al. (2006) for which the value were 47.26 and 47.6%, respectively. To aid the interpretation of these two factors, varimax rotation was performed. The 22 safety climate influencing variables/statements were included in one of these two underlying factors. Table 2 contains the detail of factor loadings, which indicates the strength of relationship between a particular variable (denoted by C02–C31) and a particular factor. The scree plot is shown in Fig. 2, which confirms that a two-factor model is appropriate for the research model.

Meaning of Underlying Safety Climate Factors

Table 2 lists the grouped safety climate items in descending order of significance. A new underlying factor was labeled in accor-

Table 2. Factor Structure by Principal Factors Extraction and Varimax Rotation

Number	Item	Factor loading
Factor 1: Management commitment and employee involvement; eigenvalue 6.077; % of variance 27.623; cumulative % 27.623		
C20	Sufficient resources are available for health and safety here.	0.745
C18	The company really cares about the health and safety of the people who work here.	0.722
C27	I think management here does enough to follow up safety inspections/accident investigations.	0.703
C21	The company shows interest in my views on health and safety.	0.688
C16	People can always get the equipment which is needed to work to the health and safety procedures/instructions/rules.	0.679
C26	Safety inspection here is very helpful to improve the health and safety of workers.	0.657
C24	It is important for me to work safely if I be respected by others in my team.	0.636
C17	There are always enough people available to get the job done according to the health and safety procedures/instructions/rules.	0.634
C25	Most of the job-specific safety trainings I received are effective.	0.613
C12	The company encourages suggestions on how to improve health and safety.	0.592
C23	All the people who work in my team are fully committed to health and safety.	0.576
Factor 2: Inappropriate safety procedure and work practices; eigenvalue 3.581; % of variance 16.278; cumulative % 43.901		
C06	Productivity is usually seen as more important than health and safety by management.	0.726
C19	Sometimes it is necessary to take risks to get the job done.	0.713
C30	Health and safety is not my problem—it is up to management and others.	0.668
C31	People are just unlucky to suffer an accident.	0.659
C08	Some health and safety procedures/instructions/rules do not reflect how the job is now done.	0.657
C04	Suggestions to improve health and safety are seldom acted upon.	0.654
C09	Some health and safety procedures/instructions/rules are difficult to follow.	0.650
C03	Accident investigations are mainly used to identify who is to blame.	0.642
C29	Safety publications and posters have little influence on the awareness and behavior of people here.	0.626
C02	Some jobs here are difficult to do safely.	0.563
C15	Not all the health and safety procedures/instructions/rules are strictly followed here.	0.538

dance with the set of individual factors it comprised. It is important to mention that the suggested factor label is entirely subjective and other researchers may use a different label. In case of doubt about the true meaning of a given factor label, it is always possible to refer to the full set of items. Nonetheless, the meanings of the two labeled underlying factors are interpreted as follows.

Factor 1: Management Commitment and Employee Involvement

Factor 1 consists of 11 statements that are related to management commitment, involvement and actions toward safety as well as employee involvement. Employees believe that *sufficient resources are available for safety and health* (C20), meaning true priority is given to safety. The respondents view safety as the organization's commitment that *the company really cares for the safety of the people who work here* (C18). The factor shows the respondents' satisfaction with the current *safety inspections and accident investigation* (C27). At present, the company takes account of employees in the safety process. *The company shows interest in my views on health and safety* (C21) factor shows worker's involvement in establishing a safety system. The employees view that *everyone can get the equipment that is needed to perform the job safely* (C16). The employees view that *safety inspections are helpful to improve their health and safety* (C26), which showed their trust with the safety systems. The factor relates to the importance placed upon safety by other members of one's work team, as it follows that *it is important to work safely if I am to be respected by others on the team* (C24). The respondents show their confidence that *there are enough people available to do the job safely* (C17). Respondents feel satisfied with *the job-specific safety training* (C25). The respondents' perceive that *the company encourages suggestions on how to improve health and safety* (C12). Employees indicate their commitment that *all people who work on my team are fully committed to health and safety* (C23).

Factor 2: Inappropriate Safety Procedure and Work Practices

Factor 2 again consists of 11 statements mainly concerning the safety system, procedures and work practices within the company. Respondents view that *productivity has an edge over safety issues on construction projects* (C06). The respondents perceive that *it is necessary to take risks to get the job done*. The findings indicate that safety has been compromised on-site as employees view that *health and safety is not his/her problem* (C30) and *people are just unlucky to suffer an accident* (C31). Respondents view that *some safety procedures do not reflect how the job is done on-site* (C08). Respondents perceive that *suggestions to improve health and safety are seldom acted upon* (C04). Respondents view that *some safety procedures are difficult to follow* (C09) and thus needed to be improved. Employees perceive that *accident investigations are used to identify who is to blame* (C03) rather than learning or improving on-site safety. Employees view that *safety publication or posters have little effect on changing behavior of employees* (C29). Factor 2 gives a bleak picture of improper operational procedures related to construction tasks that *some jobs are difficult to execute safely* (C02). The finding highlights the importance of implementing updated safety procedures as employees perceive that *not all rules, regulations and procedures are followed strictly on-site* (C15).

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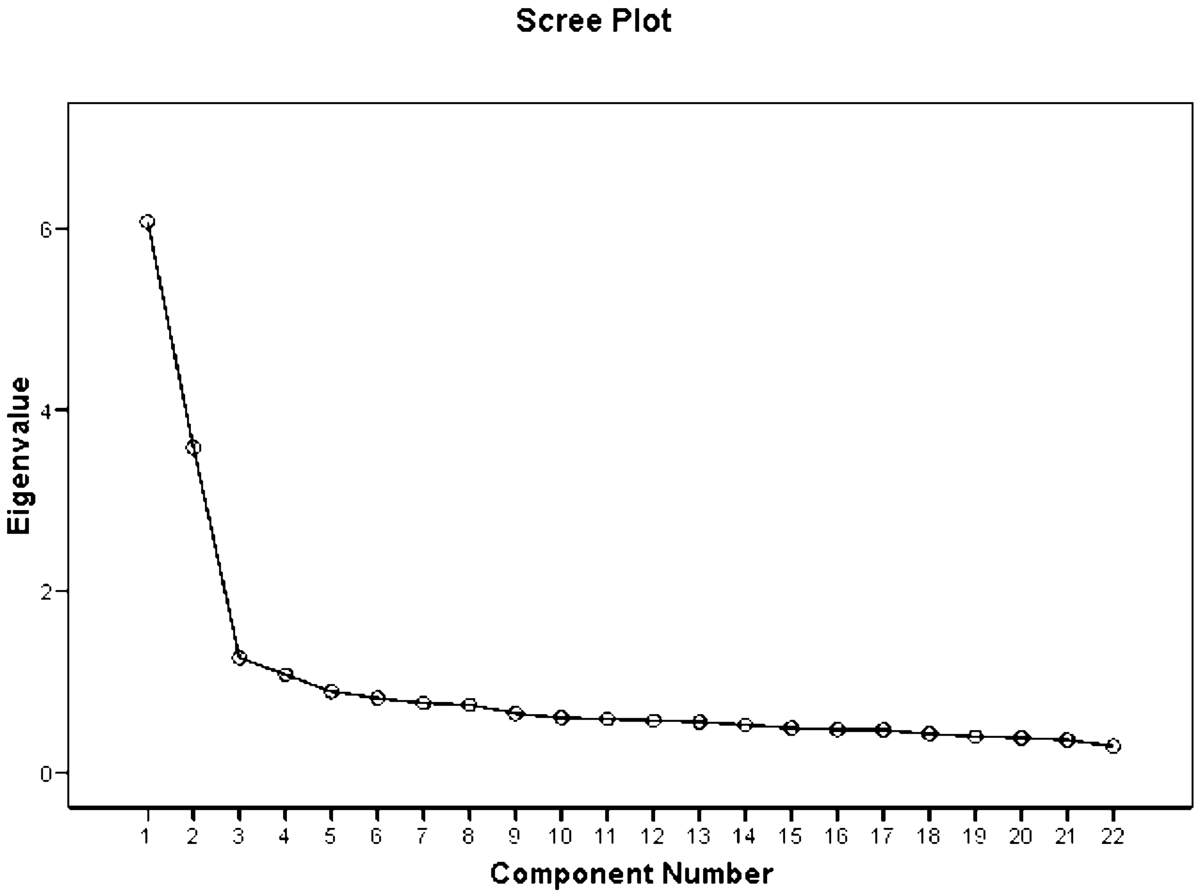

Fig. 2. Scree plot of the 22 variables influencing safety climate

Model of Safety Climate and Safety Performance

Multiple linear regression analysis was used in this research to study the relationships between perceived 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 (Norusis 2005; George and Mallery 2006) 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 (Norusis 2005; George and Mallery 2006). The model gives an equation, which contains a constant (intercept) and partial regression coefficients for each of the critical success factors.

The two underlying safety climate factors extracted by FA from the 22 variables were used as independent variables in evaluating the relationship with workers perceptions of safety performance (dependent variable question C32). Table 3 shows the unstandardized and standardized regression coefficients (β), adjusted R^2, R^2 change, t value and significance level for the sample. "Management commitment and employee involvement (Factor 1)" and "inappropriate safety procedure and work practices (Factor 2)" were significantly different at $p \leqslant 0.000$. The β values indicate the relative influence of the entered variables, that is F1 has the greatest influence on perceived safety performance ($\beta=0.385$) followed by F2 ($\beta=-0.107$) and the direction of influence for F1 is positive while direction of F2 is negative. An R-square change value of 0.205 indicates that 20.5% of the variance in the perceived safety performance is explained by F1, followed by 1.6% by F2. Hence the multiple linear regression equation for safety performance is

$$\text{Perceived safety performance} = 3.661 + 0.385(\text{F1}) - 0.107(\text{F2}) \tag{1}$$

Fig. 3 exhibits the frequency distribution of the perceived safety performance measure for all respondents of the sample. The x-axis represents the number of respondent and y-axis represents the perceived safety performance scores entered by the respondents ranging from 1 to 5. The result shows that only 3.2%

Table 3. Results of Stepwise Multiple Regression

Independent variable (safety climate factor)	Unstandardized coefficients (β)	Standardized coefficients (β)	Adj. R^2	R^2 change	t value	Sig.
y intercept (i.e., constant)	3.661	—	—	—	175.548	0.000
Factor 1: management commitment and employee involvement	0.385	0.453	0.205	0.205	18.441	0.000
Factor 2: inappropriate safety procedures and work practices	−0.107	−0.126	0.220	0.016	−5.125	0.00

Note: Dependent variable—please evaluate the overall safety performance.

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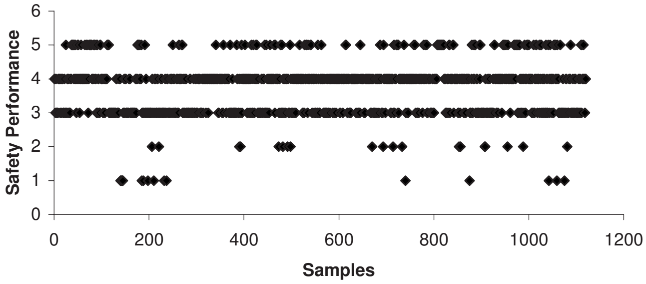

Fig. 3. Frequency distribution diagram for the sample ($N=1,120$)

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

Discussion

The FA explored the structure of safety climate perceptions from data collected at the 22 construction sites. The results revealed two underlying dimensions, i.e., "management commitment and employee involvement" (Factor 1) and "inappropriate safety procedure and work practices" (Factor 2). The latter dimension was identified as an important problem, which demonstrated that improper safety practices on-site (and poor compliance with procedures) need to be revised periodically to ensure they reflect current safe work methods.

A growing number of safety climate studies show that employee perception regarding management commitment to safety is a core ingredient in shaping a positive safety climate (e.g., Zohar 1980; DeDobbeleer and Beland 1991; Flin et al. 2000; Mohamed 2002). This analysis was also supported by employees who, during their interviews with the investigators, described the way safety was operational on-site. The results of these interviews suggested that employees perceived a positive change in management's approach toward safety. The importance of "management commitment and employee involvement (Factor 1)" fits with the idea that a positive safety climate is more likely to exist on construction sites that support and value its employees and where there is sufficient resources and open or effective exchange of information. The result of Factor 1 further suggests that this is not surprising, as trained and satisfied employees having commitment to safety provided a safe work environment, exhibiting a positive safety climate. Factor 2's "inappropriate safety procedure and work practices," indicate that work practices for production need to be managed without compromising safety. Factor 2 indicates an area of opportunity for improvements in the safety management practices.

Safety Climate and Comparison

As previously mentioned, a study on safety climate factor structure was conducted by Fang et al. (2006) in Hong Kong in 2002 wherein 15 factors were extracted but only the first 10 factors were listed. The survey for this research was conducted in 2005 with 31 items in Hong Kong as the follow-up survey but nine items were dropped from the FA to show how the measurement scale can be further improved. From the FA, two principal components were established, which constitute the measurement of safety climate for this work. The factorial structure obtained by Fang et al. (2006) was not replicated in the present study because of modifications to the safety climate questionnaire used in this research. In this research, the two problems in Fang et al. (2006) factor structure were addressed by analyzing the modified scale. One is that there were too many factors (total of 15) in the structure, failing to emphasize the significant factors; the other is that all 87 questions make a large questionnaire that respondent felt unwilling to complete or would have completed in a careless manner.

Comparing factors with that of the previous research in construction industry, Mohamed (2002) derived ten-factor structure, namely, "commitment," "communication," "safety rules and procedures," "supportive environment," "supervisory environment," "workers' involvement," "personal risk appreciation," "appraisal of work hazards," "work pressure," and "competence." Though similarities exist with the present two-factor structure, however, Mohamed (2002) derived dimensions of safety climate from an extensive literature review rather than through FA. So, the results of this work are in line with Coyle et al. (1995) that the same safety climate factors would not apply to all organizations. The writers postulate that some safety climate factors might be stable across constructions sites.

Inconsistencies in factor structures existed because of the variety of questionnaires, samples, and methodologies used by different researchers. Because organizations differ in management style and safety regulations, therefore different safety perceptions resulted, which are then, reflected in different factor structures. The problem can be severe when researchers are looking for universal sets of safety climate factors while reviewing past studies. Safety climate factor structure can vary due to the method of questionnaire development that reflects issues pertinent to a particular organization. Also, the phrasing of questions vary as some surveys reflected perceptions of current working environment (e.g., Mohamed 2002), while others ask general questions about safety (e.g., Glendon and Litherland 2001). The method of extracting factors is also important; whether one is retaining all factors having eigenvalues more than 1.0 or inspecting the scree plot, examining the communality values and observing how many items loaded to a particular factor when there are to be three or more items loading on each factor (Pallant 2007). Then the factor structure relies extensively on the researcher's discretion for labeling them. The writers postulate that labeling or seeking common factors is not important but what is essential is to provide feedback to the management team or the organization where the survey was conducted. As long as the purpose is to measure or improve safety climate for projects under construction, the FA is a unique method that helps in identifying the problem area quantitatively.

Finally, safety climate is about "perception" (not attitudes, values, or beliefs) and more specifically, it is about perception of management commitment to safety as demonstrated by a pioneer researcher (Zohar 2002; Zohar and Luria 2004). This is the current view about safety climate and the factor structure of this research supports these findings when Factor 1 contributed more toward perceived safety performance [see Eq. (1)].

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

The results of multiple regression analysis identified the critical safety climate factors affecting respondents' perceptions of safety performance on construction sites. The results showed that the

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two factors, i.e., "management commitment and employee involvement (Factor 1)" and "inappropriate safety procedures and work practices (Factor 2)" were significant contributors to perceptual safety performance on the construction sites [see Eq. (1)]. "Management commitment and employee involvement" was found to be the most significant factor affecting perceptual safety performance on construction sites particularly in a positive direction. The finding was consistent with Jaselskis et al. (1996) that management's commitment and involvement in safety was the most important factor for a satisfactory safety level. This factor also emphasized the importance of employees' involvement and safety resources available for safety on the construction sites. The second significant factor—"inappropriate safety procedure and work practices"—negatively affects perceptual safety performance, which requires the company to revise safety procedure to cope with the current operations of on-site tasks. The company must raise the awareness among workers about safety hazards and urge them to take responsibility for their personal safety as well as manage production pressure. Sawacha et al. (1999) found that productivity bonus pay could lead workers to achieve higher production through performing unsafely.

We have seen that there are two factors in the regression equation and the value of one regression coefficient for factors (F1) is positive, while negative value exists for Factor F2. This implies that the relationship between safety performance and Factor F2 is inversely correlated, which resulted in poorer safety performance. All statements in Factor 2 required that inappropriate safety procedure must be updated, technically correct, and clear and understandable to employees. The research provided evidence that by FA, deficiencies in safety management procedures and systems of an organization can be identified by conducting a safety climate questionnaires survey. It appeared that safety climate provided an important diagnostic tool for under construction projects. The survey can provide an aid for focusing safety improvement efforts as well as in determining the impact of safety campaigns, e.g., safety training or safety procedures. Nonetheless, to identify the problem areas, safety needs to be measured regularly. For example, if it is found that a safety procedure was a problem then that procedure must be updated.

Finally, the results support the use of safety climate measures as constructive diagnostic tools in exploring employee's perceptions about safety being implemented on their construction sites. Although the company's safety management systems are mature, there is still a long way to go before a zero-accident rate or actual good safety performance is achieved.

Demographic Factors and Safety Climate

Fang et al. (2006) reported a statistical analysis between personal characteristics of respondents and safety climate. This personal characteristics analysis was not the emphasis of this work but is being used as a follow-up study. Nevertheless, interviews conducted on construction sites provided support to summarize the demographic factors and how they influenced safety climate on construction sites. Safety climate surveys exerted positive effects upon perceptions of older workers, who are married, and have more family members to support yet have little impact upon those who are in the youngest age, single, or have no family member to support. The results are consistent with the research of Fang et al. (2006) that the three factors are related to the social responsibility of employees. In the Chinese cultural context, a young single person likes to work on-site without using a safety harness and independent lifeline but his attitude toward safety changes once he/she is married or has family members to support.

Interviewees explained that workers with educational levels below primary had less perception of the safety climate. Also, to train them was difficult as they could not read issued safety material or documents. These employees now are the focus of special attention of the company to improve safety climate on construction sites. Respondents revealed that subcontractors' employees had a less positive safety climate as compared to the direct employees of the company. This issue needs attention by providing equal training to subcontractors' employees as the company now considers safety its overall core value.

Limitations and Future Directions

Based on a number of constraints there are some useful aspects that are outside the scope of the current research, and are now emphasized for further investigation. The data collected was self-reported as is the case with research surveys. It is suggested that a database may be developed to compare safety climate scores across organizations, departments, working levels, age, and employees' experience. Researchers may try to develop industry specific common factors by using some common questionnaires and analysis methods rather than fulfilling the demand of the sponsoring organization(s). Based on the data collected from the company's construction sites, the results measured safety climate of the firm. Nonetheless, it appears that safety climate, its impact on accidents happening, involvement of employees, and their behaviors are important areas, which can be further explored.

Conclusion

In recent years, there has been a movement away from "lagging" measures of safety toward "leading" or predictive assessments of safety climate within organizations. This work determines what constituted the measurement of safety climate that would enhance safety culture and positively impact safety performance on construction sites. From FA, two principal components were established and they are namely: (1) management commitment and employee involvement and (2) inappropriate safety procedure and work practices. These two factors are regarded as the most embracing attributes for this research in construction site environments. These factors have been regressed with the perceived safety performance scores to establish the causal relationship between safety climate and perceived safety performance. During the multiple regression analysis, the two underlying factors were used as independent variables in evaluating the relationship with perceived safety performance. All two factors were identified as significant in explaining the perceived safety performance in Hong Kong from the multiple regression results. The regression results showed that "management commitment and employee involvement" was the most significant factor relating to perceived safety performance because it contributed the most for establishing positive safety climate on construction sites. The regression results found problems in the construction safety and statistically identified one important setback of "inappropriate safety procedure and work practices" on construction sites. Consequently, safety procedures must be regularly reviewed with employees' particularly frontline workers to improve safety performance.

The study concluded that management may be warned of potential safety system failures by measuring safety climate and can assess how safety is functioning in construction site environments. This research supports the use of safety climate measures as an important diagnostic tool in construction. Thus, rather than basing safety actions on measures of past failures, a shift in

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thinking is needed that focuses on those actions leading to good safety performance by measuring employees' perceptions to examine the way safety is in operation on construction sites. The findings of this study may be useful in creating safer sites that help to foster a positive safety climate through enhanced safety management, implementation, and awareness on construction sites in any culture.

Acknowledgments

Financial support from Higher Education Commission, Pakistan is gratefully appreciated to undertake this research. Acknowledgments are addressed to Gammon Construction Limited, Hong Kong and its employees, including subcontractors, for supporting and participating in this research.

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