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

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Abstract: Because of the characteristics of decentralization and mobility in the construction industry, safety culture is crucially important. A comprehensive safety climate questionnaire survey was conducted with all sites and employees of a leading construction company and its subcontractors in Hong Kong. In total, 4,719 records were returned from 54 sites. By means of factor analysis, a 15-factor structure that defines the dimensions of the safety climate has been extracted. Compared with previous research studies, the roles and influences of fellow workers, and safety resources on the safety climate are emphasized. The results also confirm the feasibility of exploring common factors of the safety climate in the construction industry. Through further analysis, logistic regression was used to explore the relationship between the safety climate and personal characteristics. Statistically significant relationships were found between safety climate and personal characteristics, including gender, marital status, education level, number of family members to support, safety knowledge, drinking habits, direct employer, and individual safety behavior. This research is a case study and the results are derived from the data of one company, but the methodology of this research may be useful as a model for further research, and the findings may provide useful information for construction managers and safety practitioners in the construction industry to improve their safety culture.

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Introduction

In recent years the concept of safety culture has attracted considerable attention, especially in the dangerous industries, such as the nuclear industry and offshore oil industry (Cox and Cheyne 2000; Lee and Harrison 2000). The construction industry is regarded as a dangerous industry due to two characteristics: decentralization and mobility. The meaning of decentralization is that the employees are separated by sites and although regulations and plans are available, they still have to make decisions by themselves when facing specific problems. Mobility implies that employees in the construction industry move among companies, sites, and positions more frequently than those in other traditional industries (Fang et al. 2001). Because of these two characteristics, while the promotion of safety management and working conditions is achieved in a manner that is used by several industries to continuously improve safety performance, they are inadequate in the construction industry. This is due to decentralization and the mobility of the workforce. One of the reasons is that in the construction industry, safety performance is more relevant to human factors. It is especially important for a construction company to improve its safety culture to achieve better safety performance (Mearns et al. 2003; Xie 2003). A positive safety culture means the safety attitudes and values of the company are totally accepted by its employees.

Gammon is a well-established construction company and a market leader in the Hong Kong construction industry. Gammon commits to continuous improvement through regular review and benchmarking of its occupational safety and health management system against the latest technology and development in the industry. Over the past 10 years an excellent safety performance, one-third the accident rate of the average in Hong Kong construction industry, has been achieved by the great efforts made by the top management and all employees. However, further improvement in safety performance has not appeared as expected recently, although safety is regarded as one of the core values of the company. Top management recognized that the common method cannot be applicable due to decentralization and mobility in the construction industry and that the safety culture will play a more important role if higher goals of safety performance are to be achieved. They consider it to be the right time to have an overview of the organizational safety culture so as to provide a basis for the development of a future safety management strategy. Furthermore, in the Hong Kong construction industry, outsourcing and subcontracting are two major characteristics. Many workers do not have a fixed employer, and they join different sites only in a certain period. It is valuable to take Gammon as a case to study the safety culture in the Hong Kong construction industry.

In response to this demand, research was launched with the following objectives: (1) to conduct a safety climate survey in Gammon to examine employee values, attitudes, perceptions, competencies, and patterns of behavior that reflect the safety climate of the company; (2) to achieve a factor structure as to the

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dimensions of the safety climate of Gammon to help it improve the safety climate; (3) to examine the safety climate among different subgroups of employees of Gammon to reveal the characteristics of the safety climate in the company and to help it improve the safety climate with limited resources; and (4) to explore the relationship between the safety climate and individual safety behavior in the construction industry.

Literature Review

The concepts of safety culture and safety climate originated from organizational culture and are not well defined although they have been widely used for more than 20 years. Adrian and Barrie (1993) and Guldenmund (2000) provided the previous definitions of the safety culture and safety climate, respectively. Generally, safety culture is a set of prevailing indicators, beliefs, and values that the organization owns in safety, while Guldenmund (2000) defined safety climate as a summary concept describing the employees' beliefs about all the safety issues. Safety climate is usually regarded as being more superficial than safety culture in that it involves the current position of a company (Glendon and Stanton 2000). Other researchers have described safety climate as an indicator of the overall safety culture of an organization (Gadd 2002). In essence, safety climate, which can be measured through quantitative methods, is a "snapshot" of safety culture.

Dimensions of Safety Climate

Dimensions of safety climate are the major features or levels of safety climate (Glendon and Stanton 2000). A number of attempts have been made to construct the dimensions of safety climate. The quantitative research of safety culture and safety climate was begun by Zohar (1980) in "Safety climate in industrial organizations: Theoretical and applied implications." Based on questionnaires completed by 400 employees in 20 industrial organizations, Zohar extracted eight factors as safety climate dimensions through factor analysis, including the importance of safety training, effects of required work pace on safety, status of safety committee, status of safety officer, effects of safe conduct on promotion, level of risk at the work place, management attitudes to safety, and the effect of safe conduct on social status. Brown and Holmes (Glendon and Litherland 2001) attempted to validate Zohar's safety climate model on a sample of 425 American production workers with the same questionnaire. They reduced the original eight-factor climate model to three factors: management attitudes, management actions, and level of risk. They also related their measures of safety climate to actual safety performance, and differences in safety perceptions were detected between the accident and nonaccident groups. In 1997, the Health and Safety Executive of the United Kingdom (HSE) developed and published a Health and Safety Climate Survey Tool (HSCST), which has been purchased by over 500 organizations across a range of industry sectors (Keil 2002). In the survey tool, the dimensions of safety climate were constructed with 10 factors: organizational commitment and communication, line management commitment, supervisor's role, personal role, fellow worker influence, competence, risk taking behavior and some contributory influences, some obstacles to safe behavior, permit-to-work, and reporting of accidents and near misses (HSE 1997a).

Dimensions of safety climate differ from industry to industry, and from district to district. McDonald and Ryan (Gadd 2002) concluded that the factors that influence safety climate within one industry may not be valid in another. Coyle et al. (1995) suggested that no universal set of safety climate factors existed. However, many researchers have attempted to find the common dimensions of the safety climate.

Williamson et al. (1997) examined seven reports measuring safety climate and concluded that eight factors could be discerned: four measuring attitudes and four perceptions. Dedobbeleer and Beland (1998) reviewed ten safety climate instruments and argued that only two factors, management commitment and worker involvement, had been properly replicated across studies. Flin et al. (2000) reviewed 18 safety climate reports published from 1980 to 1998 to identify the common features of safety climate. It was found that in these reports the frequently used themes for describing the dimensions of safety climate were management, safety system, risk, work pressure, competence, and procedures. The actual item components of each theme varied and were likely to be industry or even company specific. A similar study was done by Guldenmund (2000). Based on 15 safety climate reports, Guldenmund concluded the commonly used dimensions of safety climate were: management, risk, safety arrangements, procedures, training, and work pressure. In the construction industry, Glendon and Litherland (2001) investigated the safety climate in a road construction organization and found through factor analysis that there were six factors: communication and support, adequacy of procedures, work pressure, personal protective equipment, relationships, and safety rules. Sherif (2002) identified 10 dimensions to describe the safety climate in construction site environments.

Personal Characteristics and Safety Climate

Personal characteristics include demographic information, such as age, gender, marital status and education level, and other personal information. These personal characteristics may influence safety climate and consequently influence the individual safety behavior (Hinze 1997). However, there has been little research that systematically examines the relationship between these personal characteristics and safety climate.

Lee (Mearns and Flin 1999) assessed risk perceptions and attitudes to safety among 5,295 employees at a large British nuclear reprocessing plant using a questionnaire of 172 items. Major differences were found in the attitudes and perceptions of different occupational groups, according to supervisor status, type of shift worked, gender, age, and experience. Lee also found that these differences in safety perception and attitudes were clearly linked with prior accident involvement. Glendon and Litherland (2001) developed the safety climate six-factor structure of a road construction organization and the multivariate analysis of variance was performed to compare the factor structures of two subgroups: construction workers and maintenance workers. Differences in the safety climate of job subgroups were found on only two of the factors: relationships and safety rules. Siu et al. (2003) examined age differences in safety attitude and safety performance with data from 374 Chinese construction workers employed on 27 construction sites in Hong Kong. The intercorrelations among age, tenure, and safety attitudes were examined and it was found that older workers exhibited more positive attitudes to safety. If age and tenure were controlled, some attitude scales were predictors of safety performance. Garcia et al. (2004) developed a safety climate index (SCI) (scale 0–100) to measure the safety climate in

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the pottery industry in Castellon, Spain and found no differences in SCI scores according to age, gender, education, children at large, seniority at work, or type of employment.

Safety Climate and Individual Safety Behavior

In the past decade, in order to confirm the hypothesis that the measurement of safety performance can be partly done through the measurement and evaluation of safety climate, researchers have attempted to explore the relationships among safety climate, individual safety behavior, and safety performance. Some positive results have been found.

The relationship described in the behavior-attitude model by Eagly and Chaiken (1993) described the way in which the employee's attitude, which is one dimension of safety climate, influenced the individual behavior to explain the influence of safety climate on safety of individual behavior. Neal et al. (2000) pointed out that several research studies emphasized the relationship between safety climate and safety performance and have reported that positive results had been found. A key assumption of this research was that the relationship between safety climate and system safety was at least partially mediated by individual safety behavior. However, relatively little previous research had investigated the mechanisms by which safety climate affects safety behavior. To solve this problem, Neal investigated 525 employees from 32 work groups in a large Australian hospital and developed a model to explain the influence of organizational climate and safety climate on individual safety behavior using structural equation modeling.

In the construction industry, Glendon and Litherland (2001) discussed the relationship between safety climate and individual behavior based on a survey in a road construction organization, but the research failed to find any relationship between safety climate and the individual behavior. Sherif's (2002) research findings, using structural equation modeling, supported the hypothesis that safe work behaviors were consequences of existing safety climates in construction site environments. Mitropoulos et al. (2005) focused on actual production behaviors and proposed a new system model of construction accident causation. Reducing task unpredictability and improving error management capabilities were the two alternative strategies proposed by Mitropoulos et al. (2005).

Several studies have shown that safety climate has a significant influence on individual safety behavior, and that there is a close relationship between individual safety behavior and safety performance (Tarrants 1980; Sawacha et al. 1999). Consequently, the influence of safety climate on individual safety behavior transfers to safety performance. Thus, improving safety climate is an effective way to promote safe performance.

Methodology

Since safety climate is "a summary concept describing the employees beliefs about all the safety issues" (Guldenmund 2000), questionnaire surveys of employees have been widely used to describe safety climate. Based on these prior successes with this approach, this was also selected as the mode of data collection in this study.

With an annual turnover of around US$1 billion and about 2,000 full-time staff, Gammon offers a complete construction service for a wide range of project types, including commercial and residential properties, industrial facilities, M&E and rail, ports, roads, bridges, tunnels, and water and wastewater plant. Its service extends over the full project life cycle from initial site survey and design through construction to commissioning and ongoing maintenance. One of Gammon's latest completed projects is "Hong Kong–Shenzhen Western Corridor" project, whose contract value is US$280.6 million and construction period is from August 2003 to October 2005.

A comprehensive questionnaire survey was conducted with all sites and employees of Gammon and its subcontractors in Hong Kong in October 2002, to collect the views, attitudes, and beliefs of safety issues inside the company. Occupational Safety & Health Council of Hong Kong (OSHC) and (Tsinghua–Gammon) Construction Safety Research Center (CSRC) were involved in conducting this survey and in the data analysis. Factor analysis and logistic regression method were used to conduct the data analysis. Based on the results of data analysis, the relationships among safety climate, personal characteristics, and individual safety behavior were discussed. After that, some suggestions for improving safety climate in Gammon were brought out. All employees of Gammon and all employees of subcontractors working on the sites of Gammon were asked to complete the safety climate questionnaire. Furthermore, the safety officers of every site were required to complete an added site information form, in which basic information of the site, such as contract sum, site area, current construction activities, nature of project, site safety records (reportable occupational injuries, first-aid cases, fatalities, etc), safety awards of year 2002, and various kinds of safety audit scores were involved.

The 110-item safety climate questionnaire was composed of two parts. The first part (see Appendix I) included 87 questions on safety climate. It was purposely designed to seek the view of managers, supervisors, and workers on key aspects of safety climate within their organizations. It was developed based on the safety climate survey questionnaire of Health and Safety Climate Survey Tool of HSE, United Kingdom and the safety management system in Hong Kong. The questionnaire of HSE contained 71 items and covered the five safety management elements in the Safety Management Model of HSE (HSE 1997b). In 1995, the Hong Kong government developed a safety management system based on a complete examination of industrial safety in Hong Kong. Fourteen safety management elements were included in the system: safety policy, organizational structure, safety training, in-house safety rules, program of inspection, program to identify hazards or risks, investigation of accidents or incidents, emergency preparedness, evaluation selection and control of subcontractors, safety committees, evaluation of job hazards, promotion safety and health awareness, program for accident control, and program to protect workers (OSHB 2002). The 71 items of the HSE survey questionnaire were all incorporated in the safety climate questionnaire and combined with 16 additional items to cover the 14 safety management elements. The respondents could rate their responses to the 87 items on a five-point Likert scale, from strongly disagree to strongly agree. The second part of the questionnaire included 23 questions on personal information, including demographic information, such as age, gender, marital status, education level, and other personal characteristics, such as direct employer and relevant safety knowledge. This part of the questionnaire was designed to explore the relationship between safety climate and personal characteristics. The respondents also needed to tick the most appropriate options for the 23 additional questions.

A pilot study was conducted before the formal questionnaire survey was administered. Forty randomly selected workers and all

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the safety management personnel from two sites of Gammon were involved in the pilot study. According to the responses, all 110 items were retained with minor revisions being made to the narration and the format of the questionnaire. The survey was then considered finalized and ready to be administered on all Gammon projects.

Attentions of The Safety climate Survey for Gammon was delivered to all of the safety officers in the company. Questionnaires were prepared in three versions (English, Mandarin, and Cantonese) and survey instructions were prepared to make sure all employees could understand that their responses were anonymous. A total of 4,719 questionnaires (3,410 were from workers, 193 from clerk staffs, 681 from supervisors, 112 from managers, and 323 from undisclosed positions) were collected from 54 Gammon sites in Hong Kong.

Factor analysis and logistic regression were used in the subsequent statistical analysis. Factor analysis can be used to reduce a larger number of variables to a smaller number of latent factors (Garson 2004a). It is the typical method while identifying the dimensions of safety climate (Gadd 2002). Binary logistic regression is a form of regression which is used when the dependent is a dichotomy and the independents are of any type (Garson 2004b). The logistic regression model is shown in the following formula. In the logistic model, P value is equivalent to the probability that the safety climate is good, while X_i is the factors affecting safety climate (Wang and Guo 2001).

$$\ln \frac{P}{1-P} = B_0X_0 + B_1X_1 + B_2X_2 + \cdots + B_kX_k = \sum B_iX_i \quad (1)$$

Results

Factor Analysis

There were two types of abnormal cases out of 4,719. The first were those in which the respondents thought it was difficult to understand the questionnaire well (it was one of the items in the questionnaire); and the second was those that ticked the same option in all questions. The two types of returned questionnaires were dropped from the dataset. Thus the sample size for the analysis is reduced from 4,719 to 4,127.

Table 1. Name and Corresponding Items of First 10 Factors

Factors	Corresponding items	Name
1	13, 20, 27, 28, 33, 36, 50, 51, 55, 61, 66, 79, 82, 83, 84, 85, 86	Safety attitude and management commitment
2	46, 72, 73, 74, 75, 76, 77, 78, 80, 81	Safety consultation and safety training
3	2, 5, 8, 9, 10, 16, 17, 30, 39, 60	Supervisor's role and workmate's role
4	21, 32, 40, 45, 47, 53, 56, 63, 67	Risk taking behavior
5	24, 41, 42, 43, 54, 65	Safety resources
6	15, 23, 29, 34, 48, 64, 87	Appraisal of safety procedure and work risk
7	7, 12, 25, 26	Improper safety procedure
8	14, 19, 31, 49, 57, 58, 62	Worker's involvement
9	68, 69, 70, 71	Workmate's influence
10	18, 35, 38, 44	Competence

Table 2. Descriptive Statistics of FS_ALL

	N	Minimum	Maximum	Mean	Standard deviation
FS_ALL	4 127	−16.15	15.38	0.00	3.87

A principal components factor analysis, followed by a varimax rotation, was conducted on the first 87 questions in the questionnaire from the reduced dataset (N=4,127), with the use of the *Statistical Package for the Social Sciences (SPSS)* V11.0. The Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) value was equivalent to 0.971, indicating that the data were appropriate for the analysis (Kim 1985b). Finally, 15 factors were extracted from the 87 questions and the explained total variance was 47.6%, comparable to other related research studies (O'Toole 2002). Previous research results suggested that, in general, the maximum loading of each question among factors in the factor loading matrix was kept to explain factors' meanings. Those loadings greater than 0.40 were preferred (Hair et al. 1995; Glendon and Litherland 2001). The factor loading matrix was shown in Appendix II.

Since the last five factors had few questions with high loadings, according to Thurstone's rule of thumb (Kim 1985a), their significances were left out of the explanation. The names and the corresponding codes of the items of the first ten factors are shown in Table 1.

Logit Model of Personal Characteristics and Safety Climate

In addition to the 87 questions on safety climate, questions were designed to collect personal information, such as age, gender, marital status, education level, and other personal characteristics. For this information, logistic regression was used to explore the relationship between safety climate and the personal characteristics.

Dependent Variable

Glendon and Litherland (2001) and Siu et al. (2003) used a single factor as the dependent variable when the relationship between some personal characteristics and safety climate was examined. That is, they examined the relationship between every factor or dimension of safety climate and personal characteristics. Because of the uncertainty and variability of the dimensions of safety climate, it is intended to define a single compositive indicator, instead of 15 factors, as the dependent variable. In this research, the indicator variable is obtained by summing up 15 standardized factor scores which are automatically computed by factor analysis. The single compositive indicator variable is named as FS_ALL and its descriptive statistics are shown in Table 2.

Since the binary logistic regression requests that the dependent variable should be dichotomous, the variable FS_ALL was changed from a continuous variable into a new dichotomous variable named FAC_ALL (see Table 3). A FAC_ALL value of 1

Table 3. FAC_ALL

FS_ALL	N	Percent (%)	FAC_ALL
−16.15–0.00	2,025	49.1	0
0.00–15.38	2,102	50.9	1

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Table 4. Mean Factor Scores of Two Groups

FAC_ALL	0	1
FAC 1	−0.2358	0.2271
FAC 2	−0.2543	0.2450
FAC 3	−0.2585	0.2490
FAC 4	−0.2184	0.2104
FAC 5	−0.1853	0.1785
FAC 6	−0.2167	0.2087
FAC 7	−0.2165	0.2086
FAC 8	−0.1987	0.1914
FAC 9	−0.2053	0.1977
FAC 10	−0.2575	0.2481
FAC 11	−0.2022	0.1948
FAC 12	−0.1999	0.1925
FAC 13	−0.1497	0.1443
FAC 14	−0.2156	0.2077
FAC 15	−0.1635	0.1575

meant the safety climate was good while a FAC_ALL of 0 described a poor safety climate. The p value describes the probability that FAC_ALL was equivalent to 1.

The mean factor scores of group "FAC_ALL=1" are significantly higher than those of group "FAC_ALL=0" with every factor, which is tested by one-way analysis of variance ($p<0.001$) (see Table 4). It, to some extent, confirms the reasonability of using one indicator as the dependent variable instead of 15 indicators.

Initial Selection of Independent Variables

Based on the information in the second part of the safety climate questionnaire, 13 variables were originally selected, of which 12 were personal factors and the last one, BREAK, was a safety behavior variable (see Table 5).

The initial selection of the independent variables started with the investigation of the binary relation between each independent and dependent variable. Bivariate cross table analysis was conducted on the ordinal and categorical variables and the dichotomic dependent variable. The test significance level of likelihood ratio was set up as 0.05 (Wang and Guo 2001). The result of the initial selection is shown in Table 6.

The variables out of selection could be regarded as the variables that were not crucial for the dependent variable. In other words, they were not helpful in explaining the variance of safety climate.

Development of Model

Based on the initial selection, 10 independent variables entered the model. The independent variables and dependent variable are shown in Table 7 and the final logit model is shown in Table 8.

The significance test for model chi square was far less than 0.05 (Model chi-square=395.5, $n=19$, $p<0.001$), which meant the model was acceptable (Wang and Guo 2001). Eight variables, which predicted 63.4% of good/bad safety climate, were involved in the final model. They were AGE, MARRIED, SUPPORT, EDU, SK, DRINK, EMPLOYER, and BREAK. Five of the original 13 variables were dropped out of the model. The five dropped variables, which did not have a significant influence on safety climate, were GENDER, COMPANY, INDUS, INJURY, and SMOKE.

Discussion

Comparison of Safety Climate Factor Structure with Previous Research

The present research presented a safety climate factor structure based on the data collected within a single firm, Gammon. Comparison of the factor structure with that of previous research, especially with the factors of safety climate in the construction industry was conducted. The obvious differences between this factor structure and that of Glendon and Litherland (2001) could be explained with some confidence. In the first place, there were only 32 items in the questionnaire of Glendon and Litherland, which was far less than the 87 safety climate questions in the questionnaire of this research, and thus it was reasonable to extract a six-factor structure through factor analysis. However, according to careful examination of the two factor structure, it was found that almost all of the safety climate factors of Glendon and Litherland were involved in the factor structure of this research. When compared with Sherif's (2002) 10-factor structure, very strong similarities were found (see Table 9). Because Sherif's dimensions of safety climate were derived from an extensive literature review rather than through the factor analysis method, they could be regarded as representative dimensions. It was reasonable to draw the conclusion that the factor structure of this research was, to some extent, consistent with the common factor structure in the construction industry, which proved the feasibility of building common dimensions of safety climate within an industry. The main difference with Sherif's (2002) dimensions of safety climate was that safety resource was extracted as a factor, which emphasized the importance of providing enough safety resources, such as human resource and equipment, in constructing a good safety climate.

Comparisons were also conducted with several reviews of the area (Flin et al. 2000; Guldenmund 2000; Gadd 2002). It can be found that the role and influence of fellow workers has been specially emphasized in this research, compared with the previous research. Actually, Sherif (2002) also mentioned co-worker as one factor of a supportive safety environment, which was one dimension of the 10-factor structure of safety climate. This shows the importance of fellow workers in the safety climate of the construction industry, which may be one of the features that distinguish construction industry from other industries. In the construction industry, the workers are accustomed to working together and thus their risk perceptions and safety attitudes may interact.

The results of this research reveal that although it is difficult to establish common dimensions in safety climate among different industries, as shown in the previous research, it is still feasible to explore common factors in the same industry, at least, in the construction industry.

Relationship between Personal Characteristics and Safety Climate

A meeting with seven safety managers from Gammon was held to discuss the relationship between these personal characteristics and safety climate and how to combine the results into effectively improving the safety climate in the company. Their opinions and suggestions are included in the following discussions.

The employees who are older, married, or with more family members to support have more positive perceptions of the safety climate than those employees who are younger, single, or with

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Table 5. Originally Selected Categorical Variables

Number	Variables	Meaning	Options
1	AGE	Age of employee	1. Younger than 20 2. 21–30 3. 31–40 4. 41–50 5. Older than 50
2	GENDER	Gender of employee	1. Male 2. Female
3	MARRIED	Married or not	1. Single 2. Married
4	SUPPORT	How many family members to support	1. None 2. 1–2 3. 3–4 4. 5–6 5. 7 or more
5	EDU	Education level	1. Below primary 2. Primary 3. Secondary 4. Certificate/diploma 5. College or higher
6	EMPLOYER	Direct employer	1. Gammon Skanska limited 2. Gammon joint venture 3. Subcontractor
7	COMPANY	How long have worked for the company	1. Less than 1 years 2. 1–5 years 3. 6–10 years 4. 11–15 years 5. more than 15 years
8	INDUS	How long have worked in the industry	1. Less than 3 years 2. 3–10 years 3. 11–15 years 4. 16–20 years 5. more than 20 years
9	SMOKE	Smoking habit	1. Smoke even at work 2. Smoke, but not at work Don't smoke
10	DRINK	Drinking habit	1. Drink even at work 2. Drink, but not at leisure time 3. Don't drink
11	SK	Safety knowledge	1. Bad 2. Good
12	INJURY	Whether having injury at work	1. No 2. Yes
13	BREAK	Whether breaking safety procedures at work	1. No. 2. Yes

less family members to support. The results are consistent with the research of Siu et al. (2003) in terms of the characteristic of age. The three factors are essentially related to the social responsibilities of employees. The results implied that with increased social responsibilities, the propensity of risk taking may decline and people tend to work more safely and thus have a better perception of their work environment as well as better safety attitudes and beliefs. This trend may stem from the recognition of one's own mortality that may accompany the maturing process. For example, a young, single man may feel comfortable working on site without wearing a safety helmet, but his attitude may change once he becomes a husband or father or having family members to support. He may not view the nature of the risk itself any differently, but he will assess the consequences of a mishap differently.

Education level is also an important influencing factor for safety climate. Employees with education levels below primary school have far less positive perceptions of the safety climate than

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Table 6. Results of Initial Selection

Cross tables analysis			
Number	Variable	Significance	Whether selected
1	AGE	0.000[a]	Y
2	GENDER	0.348	N
3	MARRIED	0.000[a]	Y
4	SUPPORT	0.000[a]	Y
5	EDU	0.000[a]	Y
6	EMPLOYER	0.000[a]	Y
7	COMPANY	0.575	N
8	INDUS	0.000[a]	Y
9	SMOKE	0.000[a]	Y
10	DRINK	0.000[a]	Y
11	SK	0.000[a]	Y
12	INJURY	0.712	N
13	BREAK	0.000[a]	Y

[a]Statistically significant at 0.05 level.

others (see Table 8). It is recommended that an education level of primary school or higher may be one of the criterion used for recruiting, or that those employees with education levels below primary school should be the focus of safety training.

Safety knowledge is another influencing factor for safety climate. Employees with good safety knowledge have a more positive safety climate than those with poor safety knowledge. Actually the two variables, education level and safety knowledge, emphasize the importance of education and training within a company. It may be difficult for management to control the personal characteristics mentioned above, but safety knowledge can be controlled and promoted through education and training in the company.

Employees who drink alcohol at work have a less positive safety climate than those who do not. The primary concern with regard to drinking at work is that the mental condition of a worker may be altered. Such an altered mental stage generally results in impaired judgment, which may increase the chance of an injury,

Table 7. Dependent Variable and Independent Variables

Variables		Categories	
	The dependent variable: FAC_ALL	1 means good safety climate 0 means bad safety climate	Dummy variables
1	Age	1. <20	
		2. 20–30	AGE(2)
		3. 31–40	AGE(3)
		4. 41–50	AGE(4)
		5. >50	AGE(5)
2	Marital status	1. single	
		2. Married	MARRIED(2)
3	Family members supported	1. None	
		2. 1–2	SUPPORT(2)
		3. 3–4	SUPPORT(3)
		4. 5–6	SUPPORT(4)
		5. >6	SUPPORT(5)
4	Education level	1. Below primary	
		2. Primary	EDU(2)
		3. Secondary	EDU(3)
		4. Certificate/diploma	EDU(4)
		5. College or higher	EDU(5)
5	Employer	1. Direct employee	
		2. Joint venture	EMPLOY(2)
		3. Subcontractor	EMPLOY(3)
6	How long have worked in the industry	1. <3 years	
		2. 3–10 years	INDUS(2)
		3. 11–15 years	INDUS(3)
		4. 16–20 years	INDUS(4)
		5 >20 years	INDUS(5)
7	Smoking habit	1. Smoke even at work	
		2. Smoke, but not at work	SMOKE(2)
		3. Do not smoke	SMOKE(3)
8	Drinking habit	1. Drink even at work	
		2. Drink, but not at work	DRINK(2)
		3. Do not drink	DRINK(3)
9	Safety knowledge	1. Bad	
		2. Good	SK(2)
10	Whether seldom breaking safety procedures at work	1. No	
		2. Yes	BREAK(2)

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Table 8. Results of Logit Model

Variables	Coefficient	EXP(Co.)	SE	Wald	Significance
Constant	−2.388	0.092	0.343	48.381	0.000
AGE	—	—	—	—	0.000[a]
AGE(2)	0.156	1.168	0.248	0.393	0.531
AGE(3)	0.424	1.528	0.255	2.764	0.096
AGE(4)	0.725	2.064	0.259	7.827	0.005
AGE(5)	1.094	2.986	0.272	16.225	0.000
MARRIED(2)	0.139	1.149	0.106	1.714	0.090[a]
SUPPORT	—	—	—	—	0.013[a]
SUPPORT(2)	−0.144	0.866	0.125	1.337	0.248
SUPPORT(3)	0.102	1.107	0.132	0.591	0.442
SUPPORT(4)	0.173	1.189	0.166	1.088	0.297
SUPPORT(5)	0.225	1.253	0.218	1.067	0.302
EDU	—	—	—	—	0.000[a]
EDU(2)	0.118	1.125	0.103	1.299	0.254
EDU(3)	0.331	1.392	0.110	9.027	0.003
EDU(4)	0.156	1.169	0.163	0.919	0.338
EDU(5)	0.407	1.502	0.160	6.465	0.011
EMPLOY	—	—	—	—	0.000[a]
EMPLOY(2)	−0.845	0.429	0.188	20.181	0.000
EMPLOY(3)	−0.510	0.600	0.077	44.211	0.000
DRINK	—	—	—	—	0.000[a]
DRINK(2)	0.772	2.163	0.198	15.221	0.000
DRINK(3)	1.133	3.105	0.193	34.361	0.000
SK(2)	0.535	1.707	0.078	47.282	0.000[a]
BREAK(2)	0.586	1.796	0.104	31.850	0.000[a]

[a]Statistically significant at 5% level.

whether to the drinker or to fellow workers. An employee with a bad habit of drinking alcohol at work tends to neglect the safety of self as well as fellow workers. This increases the chances of developing other bad work habits. This result suggests that forbidding drinking alcohol at work may be necessary for improving the safety climate in the company.

The employees of subcontractors or joint ventures generally have a less positive view of the safety climate than direct employees of Gammon. It indicates that the extensive use of subcontracting on Gammon sites (six layers on average) may lead to problems of lack of control on site and reduced levels of worker commitment. Since subcontracting does not provide any career prospects nor continuity of workload for the average construction worker, it is expected that the level of commitment shown by workers to their companies, and even to their colleagues, is low. On the other hand, since about 40% of all respondents are employees of subcontractors, this result, to some extent, shows the situation of the safety climate in the construction industry in Hong Kong. It is recommended that the safety climate of subcontractors should be assessed before a contract is signed. After the subcontract is signed, the safety retraining of the employees of the subcontractor is also absolutely necessary.

Five personal characteristic variables: GENDER, COMPANY, INDUS, INJURY, and SMOKE have been ticked out from the model. The reasons are attempted to be explained as follows: (1) Since 95% of respondents are male, it is difficult to find the statistically significant correlations between GENDER variables and safety climate. (2) Generally, people tend to think that the longer a person works in a company or one industry, the better his safety climate is. But it is not found in this study. More exploratory research is recommended at this point. (3) Statistics showed that about one fourth of respondents reported that they have had injury accidents before. People tend to think that the workers who usually work more safely will suffer fewer injuries and thus may have a better perception of their workplace safety. However, no link between injury records and safety climate has been found in this analysis. (4)About half of the workers smoke, among which there are 33% of respondents even smoking at work. But no significant influence of smoking on safety climate was found in this research. This could be explained as smoking may not damage the mental status as badly as drinking.

Table 9. Comparison of Factor Structure with Sherif's

This research's safety climate factor structure		Sherif M.'s safety climate factor structure
1	Safety attitude and management commitment	Personal risk appreciation; commitment
2	Safety consultation and safety training	Competence
3	Supervisor's role and workmate's role	Supervisory environment
4	Risk taking behavior	Safety work behavior
5	Safety resources	—
6	Appraisal of safety procedure and work risk	Appraisal of work hazards
7	Improper safety procedure	Safety rules and procedures
8	Worker's involvement	Worker's involvement
9	Workmate's influence	Supportive environment
10	Competence	Competence

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Relationship between Safety Climate and Individual Safety Behavior

It was found that the employees who seldom violate safety regulations have a more positive safety climate, which partly confirms the positive relationship between safety climate and individual safety behavior. A good safety climate has an active influence on behavior. On the other hand, this indicates that employees who usually work more safely have a better perception of their workplace safety. Thus, by encouraging positive safety behavior and reducing negative behavior, the safety climate of the company can be improved.

A limitation of the result is that the indicator used to measure individual safety behavior is subjective, using self-reported assessments. The corresponding question was "I have seldom broken safety procedures/instructions/rules while working here: Yes or No." Although, Glendon and Litherland (2001) used more objective indicators to measure behavior by randomly sampling employee behavior such as manual handling and personal protective equipment practice and trained observers were used to evaluate the proportion of unsafe working behaviors, no relationship between safety climate and safety behavior was found in their research.

Future Work

The developed model demonstrates the relationship between personal characteristics and safety climate. Regarding the relationships among these personal characteristics themselves and which one of them contributes most to safety climate, no answer can be found in the model. The reason is that in the logit model, the categorical variables were used to describe the personal characteristics. There is no statistical method to standardize the coefficients (see Table 8). So the relative importance could not be obtained by directly contrasting the unstandardized coefficients. Future work needs to be conducted in this area.

As mentioned before, during the safety climate survey, some basic information of sites was also collected through the site information forms that were completed by the safety officers. This information was not included in the analysis due to the multilevel problem of transforming data. The writers are trying to find an appropriate method to combine the two parts of questionnaire into one model to explore the direct relationship between safety climate and sites safety performance.

Conclusions

The safety climate questionnaire survey of Gammon has been successfully utilized, with 4,719 employees from 54 sites completing the questionnaire. Factor analysis extracted a 15-factor structure as the dimensions of safety climate with the help of *SPSS11.0*. Comparing the dimensions with the previous research, it was found that the roles and influences of fellow workers and safety resources on safety climate are emphasized. The results also confirm the feasibility of exploring common factors within the same industry, at least in the construction industry.

In the subsequent analysis based on factor structure, logistic regression was used to explore the relationship between safety climate and personal characteristics. Statistically significant relationships were found between safety climate and some personal characteristics and individual safety behavior. First, the employees who are older, married, or with more dependent family members have a more positive perception of the safety climate than those who are younger, single, or with fewer family members to support. The results imply that with increased social responsibilities, people will have a better perception of their work environment as well as better safety attitudes and beliefs. Second, the education level and safety knowledge level are also important for safety climate. The employees with an education level below primary school have a far less positive perception of the safety climate than others. Similarly, a better safety climate was reported by employees with good safety knowledge than those with poor safety knowledge. They both emphasize the importance of education and training within a company. Third, employees who drink alcohol at work have a less positive safety climate than those who do not. This result suggests that forbidding drinking at work may be necessary for improving the safety climate in the company. Fourth, the employees of subcontractors or joint ventures generally have a less positive safety climate than direct employees of Gammon. It indicates that the extensive use of subcontracting on sites may lead to problems of lack of control on site and lower levels of worker commitment. It is recommended that the safety climate of subcontractors should be considered in the assessment before a contract is signed with them. Finally, the employees who seldom break any safety regulations have a more positive safety climate. It confirms the assumption that a good safety climate has a positive influence on behavior. On the other hand, employees who usually work more safely will have a better perception of their workplace safety.

In conclusion, the results assess the situation of safety climate in Gammon, reveal some features of safety culture and safety management in the company, and measure the influence of some personal characteristics on safety climate and the relationship between safety climate and safety behavior. The results may be helpful for Gammon to improve its safety culture and safety performance. This research is a case study and the results come from the data of one company—Gammon, but the methodology of this research might be useful for a similar survey conducted with several different construction firms. We have to mention that since all the responses were self reported by subjects, the exaggerations by the subjects may affect the accuracy of the outcomes, especially in the analysis of some behavior-related variables involved. However, the findings and suggestions still provide useful information for managers of construction and safety practitioners in cultivating a safety culture in the construction industry.

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Appendix I. Safety Climate Survey Questionnaire (Part I)

1. Some health and safety procedures/instructions/rules do not need to be followed to get the job done safely
2. People who work here often have to take risks when they are at work
3. Supervisors are good at detecting unsafe behavior
4. My job is boring and repetitive
5. There are good communications here between management and workers about health and safety issues
6. Accidents which happen here are always reported
7. Some jobs here are difficult to do safely
8. Supervisors here are not very effective at ensuring health and safety
9. Accident investigations are mainly used to identify who is to blame
10. Suggestions to improve health and safety are seldom acted upon
11. Near misses are always reported
12. Some health and safety procedures /instructions/rules are not really practical
13. There is little advantage for me keeping strictly to the health and safety procedures/instructions/rules
14. I feel involved when health and safety procedures/instructions/rules are developed or reviewed
15. I fully understand the health and safety risks associated with the work for which I am responsible
16. Productivity is usually seen as more important than health and safety by management
17. Management sometimes turn a blind eye to health and safety procedures/instructions/rules being broken
18. Management always act quickly over health and safety concerns
19. I am always informed of the outcome of safety committee meetings which address health and safety
20. Management only bother to look at health and safety after there has been an accident
21. People here do not remember much of the health and safety training which applies to their job
22. The permit to work system is always strictly applied and followed
23. People here always work safely even when they are not being supervised
24. Senior management take health and safety seriously
25. Some health and safety procedures/instructions/rules do not reflect how the job is now done
26. Some health and safety procedures/instructions/rules are difficult to follow
27. The permit to work system is over the top given the real risks of some of the jobs it is used for
28. People here think health and safety is not their problem - it's up to management and others
29. I am clear about what my responsibilities are for health and safety
30. Supervisors seldom check that people here are working safely
31. The company encourages suggestions on how to improve health and safety
32. Some of the workforce(s) pay little attention to health and safety
33. There is nothing I can do to further improve health and safety here
34. People here always wear their health and safety protective equipment when they are supposed to
35. Action is seldom taken against people who break health and safety procedures/instructions/rules
36. Some health and safety procedures/instructions/rules are only there to protect management's back
37. People who cause accidents here are not held sufficiently accountable for their actions
38. The training I had covered all the health and safety risks associated with the work for which I am responsible
39. Management would expect me to break health and safety procedures/instructions/rules to get the job done
40. Not all the health and safety procedures/instructions/rules are strictly followed here
41. People can always get the equipment which is needed to work to the health and safety procedures/instructions/rules
42. There are always enough people available to get the job done according to the health and safety procedures/instructions/rules
43. The company really cares about the health and safety of the people who work here
44. Sometimes I am uncertain what to do to ensure the health and safety in the work for which I am responsible
45. Sometimes it is necessary to take risks to get the job done
46. The health and safety committee makes an important contribution to health and safety here
47. Sometimes site conditions may hinder people to work safely
48. I can trust most people who I work with to work safely
49. My immediate boss often talks to me about health and safety
50. There are too many health and safety procedures/instructions/rules given the real risks associated with the jobs for which I am responsible
51. Management place a low priority on health and safety training
52. I am worried about my job security
53. People here are sometimes pressured to work unsafely by their colleagues
54. Sufficient resources are available for health and safety here
55. Health and safety briefings /tool -box talks here are a waste of my time
56. Some people here have a poor understanding of the risks associated with their work
57. My immediate boss would be very helpful if I asked for advice on health and safety matters
58. The company shows interest in my views on health and safety
59. People who work here sometimes take risks at work which I would not take myself
60. People who work here are not recognized for working safely
61. The permit to work system causes unnecessary delays in getting the job done
62. My immediate boss is receptive to ideas on how to improve health and safety
63. I sometimes turn a blind eye to some less important health and safety procedures/instructions/rules
64. I fully understand the health and safety procedures/instructions/rules associated with my job
65. Supervisors devote sufficient effort to health and safety here
66. I do not think my immediate boss does enough to ensure health and safety
67. Supervisors sometimes turns a blind eye to people who are not working to the health and safety procedures/instructions/rules
68. My workmates would react strongly against people who break health and safety procedures/instructions/rules
69. All the people who work in my team are fully committed to health and safety
70. It is important for me to work safely if I am to keep the respect of the others in my team
71. I trust my workmates with my health and safety
72. Safety officer and his assistants make an important contribution to promote the health and safety of workers here
73. Most of the job-specific safety trainings I received are effective
74. Most of the general safety trainings (e.g. green card training) I received are effective
75. Safety inspection here is very helpful to improve the health and safety of workers
76. I think management here does enough to follow up safety inspections/accident investigations
77. I know how to response quickly and correctly on emergence situations such as fire, electric shock and personal injury
78. There is good preparedness for emergency here
79. Safety publications and posters have little influence of the awareness and behavior of people here
80. Safety campaigns effectively improve the awareness and behavior of people here (leave it blank if there is no safety campaign)
81. Plants and equipments used here are safely installed and maintained.
82. Health and safety is not my problem
83. People are just unlucky to suffer an accident
84. "Safety" is just a good commercial selling point of a construction company
85. A company will sacrifice his profit when he/she invests in safety
86. Generally speaking, safety is less important than production
87. Safety rules should be cohered even under production pressures

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Appendix II. Factor Loading Matrix

Factor / Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1											0.56				
2			0.38												
3													0.67		
4															0.38
5			0.33												
6													0.32		
7							0.47								
8			0.57												
9			0.50												
10			0.58												
11												0.54			
12							0.55								
13	0.38														
14								0.66							
15						0.57									
16			0.53												
17			0.38												
18										0.38					
19								0.45							
20	0.43														
21				0.39											
22													0.27		
23						0.45									
24					0.32										
25							0.54								
26							0.65								
27	0.43														
28	0.43														
29						0.56									
30			0.41												
31								0.46							
32				0.64											
33	0.37														
34						0.54									
35										0.34					
36	0.37														
37											0.39				
38										0.58					
39			0.36												
40				0.52											
41					0.63										
42					0.57										
43					0.52										
44										0.51					

Factor / Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
45				0.41											
46		0.39													
47				0.32											
48						0.39									
49								0.38							
50	0.37														
51	0.49														
52															0.65
53				0.45											
54					0.52										
55	0.36														
56				0.65											
57								0.35							
58								0.42							
59														0.59	
60			0.34												
61	0.37														
62								0.24							
63				0.40											
64						0.33									
65					0.31										
66	0.45														
67				0.40											
68									0.67						
69									0.49						
70									0.47						
71									0.39						
72		0.63													
73		0.68													
74		0.68													
75		0.70													
76		0.49													
77		0.37													
78		0.41													
79	0.50														
80		0.36													
81		0.35													
82	0.63														
83	0.61														
84	0.58														
85	0.36														
86	0.61														
87						0.31									

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