Safety Climate in Construction Site Environments

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Abstract: This paper discusses empirical research aimed at examining the relationship between the safety climate and safe work behavior in construction site environments. A literature review has identified a number of independent constructs with the potential to affect the safety climate. A research model was developed based on the hypothesis that safe work behaviors are consequences of the existing safety climate, which, in turn, is determined by the identified independent constructs. A questionnaire survey was used in order to facilitate the collection of information from construction sites. The model was tested using structural equation modeling. The paper presents the results of testing the research model. The results corroborate the importance of the role of management commitment, communication, workers' involvement, attitudes, competence, as well as supportive and supervisory environments, in achieving a positive safety climate.

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Introduction

The construction industry is notorious for its poor safety record when compared with other industries. The major causes of accidents have been identified, and can be directly attributed to unsafe design and site practices. Accidents arise from different causes that can generally be classified as physical incidents posing hazardous situations, and behavioral incidents caused by unsafe acts (Kartam 1997). The construction process itself is also seen as being poorly planned in terms of both design and construction, with major inadequacies relating to the erection, maintenance, and demolition of buildings and structures (Cooke and Williams 1998). An underlying belief is that the majority of accidents are not caused by careless workers but by failure in control, which ultimately is the responsibility of management (Baxendale and Jones 2000).

In recent years, there has been a movement away from safety measures purely based on retrospective data or "lagging indicators," such as accident rates, toward so-called "leading indicators," such as measurements of safety climate (Flin et al. 2000). The shift of focus has been driven by the awareness that organizational, managerial, and human factors rather than purely technical failures are prime causes of accidents (Weick et al. 1999; Langford et al. 2000). Zohar (1980) uses the term "safety climate" to describe a construct that captures employees' perceptions of the role that safety plays within the organization. It is regarded as a descriptive measure reflecting the workforce's perception of, and attitudes toward, safety within the organizational atmosphere at a given point in time (Gonzalez-Roma et al. 1999). Budworth (1997) refers to measuring the safety climate as taking the "safety temperature" of an organization. Flin et al. (2000) reviewed existing safety climate measures in an attempt to establish a common set of organizational, managerial, and human factors that are being regularly included in measures of the safety climate. Based on this particular review, the most frequently measured factors are related to management, risk, and safety arrangements (systems). Work pressure and competence are the other two emerging, although less frequently used, factors in the literature.

Unfortunately, the construction industry continues to rely heavily on traditional measures such as accident and workers' compensation statistics. This implies that the issue of measuring the safety climate in construction is in its infancy and needs to be addressed. As Grubb and Swanson (1999) note, there is virtually no research examining work organizational factors such as the safety climate in construction. To address this need, the present paper develops a research model linking safety climate determinants in the context of construction safety practice. The model is used to examine and assess relationships between these determinants and the safety climate in construction site environments, and seeks a correlation between the safety climate and workers' safe behavior.

Model Constructs and Hypotheses

The research model, shown in Fig. 1, follows the broad hypothesis that safe work behaviors (and, thus, their reciprocal, unsafe behaviors) are consequences of the existing safety climate, which is determined by the five independent sets of factors identified in the literature—i.e., management, safety, risk, work pressure, and competence. Therefore, the model has three distinct components—(1) antecedents to safety climate; (2) safety climate (workers' perception of safety in the work environment); and (3) outcome of safety climate (safe work behavior). Although a number of recent studies have investigated the impact of one or more elements of the above factors on construction safety levels (Rowlinson 1997; Lingard and Rowlinson 1998; Sawacha et al. 1999; Mohamed 2000), their relationships with the safety climate had specifically not been measured before. It is worth mentioning that

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J. Constr. Eng. Manage., 2002, 128(5): 375-384

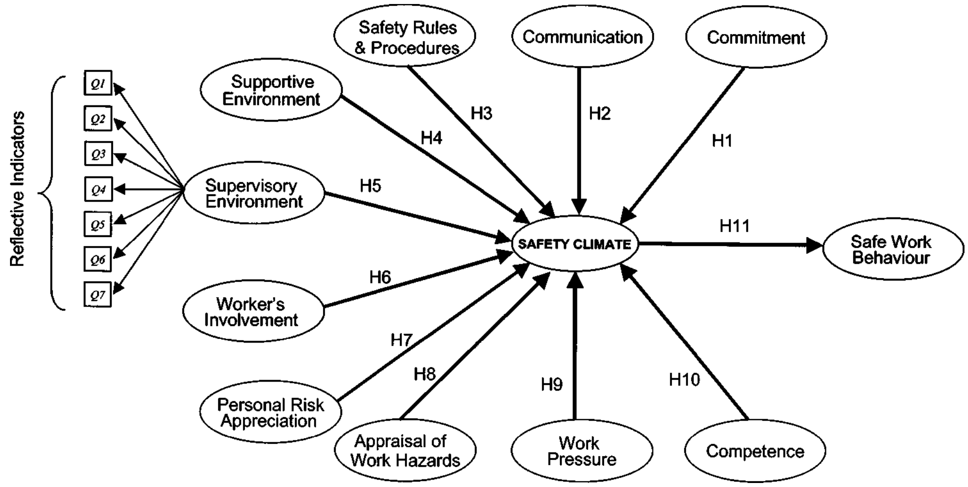

Fig. 1. Research model and hypotheses. Reflective indicators are shown only for one construct for simplicity of presentation.

the interrelationships among these factors, in an integrative or sequential fashion, are beyond the focus of this paper. Underlying constructs (management commitment, communication, rules and procedures, supportive and supervisory environments, workers' involvement, personal appreciation of risk, appraisal of work environment, work pressure, and competence) and hypotheses associated with each path of the model are discussed below.

Commitment Construct

The role management plays in promoting safety cannot be overemphasized. Management's commitment is a central element of the safety climate (Zohar 1980). Management's role has to go beyond organizing and providing safety policies and working instructions. Several studies show that the management's commitment and involvement in safety is the factor of most importance for a satisfactory safety level (Jaselskis et al. 1996). Langford et al. (2000) found that when employees believe that the management cares about their personal safety, they are more willing to cooperate to improve safety performance. Thus, *hypothesis 1*—The greater the level of management commitment toward safety, the more positive the safety climate.

Communication Construct

Management is expected to use a variety of formal and informal means of communication to promote and communicate its commitment to safety (Baxendale and Jones 2000). Simon (1991) suggests that both management communication and employee feedback are critical for suggesting safety improvements and reporting near misses as well as unsafe conditions and practices. Thus, *hypothesis 2*—The more effective the organizational communication dealing with safety issues, the more positive the safety climate.

Safety Rules and Procedures Construct

Rules and procedures are the core component of safety management systems. A major factor influencing the safety level is the extent to which workers perceive safety rules and procedures as promoted and implemented by the organization (Cox and Cheyne 2000). Hood (1994) states that problems related to safety can frequently be traced to inconsistently applied or nonexistent operating procedures. Thus, *hypothesis 3*—The better the perception of safety rules and procedures, the more positive the safety climate.

Supportive Environment Construct

Supportive environment refers to the degree of trust and support within a group of workers, confidence that people have in working relationships with coworkers, and general morale. Having a supportive work environment demonstrates workers' concern for safety and fosters closer ties between them. Coworkers' attitude toward safety has been widely included in safety climate studies (Goldberg et al. 1991). Thus, *hypothesis 4*—The higher the level of support given by coworkers, the more positive the safety climate.

Supervisory Environment Construct

A successful safety management system program is based upon the premise that safety is both a management responsibility and a line function. While managers help develop and implement the program, its actual success depends upon the ability of supervisory personnel to ensure that the program is carried out during daily operations (Agrilla 1999). Langford et al. (2000) indicate that the more relationship-oriented supervisors are, the more likely it is that operatives will perform safely. Thus, *hypothesis 5*—The more safety aware and relationship oriented the supervisors, the more positive the safety climate.

Workers' Involvement Construct

Anecdotal evidence suggests that it is not just management participation and involvement in safety activities that is important, but the extent to which management encourages the involvement of the workforce (Niskanen 1994). Moreover, management must be willing to devolve some decision-making power to the workforce by allowing them to become actively involved in developing safety interventions and safety policies, rather than simply playing the more passive role of the recipient (Williamson et al. 1997). Workers' involvement includes such issues as procedures for reporting injuries and potentially hazardous situations. Thus, *hypothesis 6*—The higher the level of workers' involvement in safety matters, the more positive the safety climate.

J. Constr. Eng. Manage., 2002, 128(5): 375-384

Personal Appreciation of Risk Construct

Cox and Cox (1991) argue that employees' attitudes toward safety are one of the most important indices of the safety climate. Attitudes toward safety have been found to be associated with personal risk perception (Rundmo 1997). Individuals, however, differ in their perception of risk and willingness to take risks, as demonstrated by March and Shapira (1992). Thus, *hypothesis 7*—The higher the level of workers' willingness to take risk, the less positive the safety climate.

Appraisal of Physical Work Environment and Work Hazards Construct

The aim in site layout planning and facilities is to produce a working environment that will maximize efficiency and minimize risks (Gibb and Knobbs 1995). Aspects of site layout planning that need to be addressed include access and traffic routes, material and storage handling, site offices and amenities, the construction plant, fabrication workshops, services and facilities, and the site enclosure (Anumba and Bishop 1997). Previous research shows that tidy and well planned (layout) sites are more likely to provide a high level of safety performance (Sawacha et al. 1999). For the purpose of this study, workplace hazards were defined as tangible factors that may pose risks for possible injuries or ailments. Within this definition, hazards do not always result in accidents, but they lurk in work environments, waiting for the right combination of circumstances to come together. Thus, *hypothesis 8*—The greater safety's integration in site layout planning to identify safety hazards, the more positive the safety climate.

Work Pressure Construct

This construct deals with the degree to which employees feel under pressure to complete work, and the amount of time to plan and carry out work (Glendon et al. 1994). Ahmed et al. (1999) identify the tight construction schedule as the most serious factor that adversely affects the implementation of construction site safety in Hong Kong. This is supported by another study (Sawacha et al. 1999), which found that productivity bonus pay could lead workers to achieve higher production through performing unsafely. Langford et al. (2000) state that supervisors are likely to turn a blind eye to unsafe practices on a site due to the pressure to achieve targets set by agreed-upon programs. They also argue that such ingrained practices of the industry (i.e., valuing expediency over safety) have to be overcome in order for safety management to be effective. Thus, *hypothesis 9*—The higher the perception of valuing expediency over safety, the less positive the safety climate.

Competence Construct

The essence of this construct is the workforce's perception of the general level of workers' qualifications, knowledge, and skills, with associated aspects related to selection and training. Many researchers agree that training, especially in hazard detection, is a major factor influencing safety levels (Simon and Piquard 1991; Jaselskis et al. 1996). In summary, it is the workers' confidence that they have the skill to perform a particular job safely. Thus, *hypothesis 10*—The greater one's experience and knowledge of safety issues, the more positive the safety climate.

Safe Work Behavior

Traditional measures of safety performance rely primarily on some form of accident or injury data. Glendon and Mckenna (1995) identify a number of reasons why accident data, or similar outcome data, are poor safety indicators. The main problems are that such data are insufficiently sensitive, of dubious accuracy, retrospective, and they ignore risk exposure. Although accident statistics are widely used throughout the construction industry, Laitinen et al. (1999) state that it is almost impossible to use accidents as a safety indicator for a single construction site. This is because of random variation, where many sites will have no accidents, and it is not possible to determine whether these sites with zero accidents are safer than sites with four or five accidents. In view of the above reasons, this study adopts safe work behaviors (observable actions) as the safety indicator. This is based on the assumption that unsafe behavior is intrinsically linked to workplace accidents (Thompson et al. 1998). It is also supported by findings from studies and models developed based on the unsafe behavior concept (Smith and Arnold 1991; Staley and Foster 1996; Krause 1997). Thus, *hypothesis 11*—High levels of the safety climate are positively associated with higher levels of self-reported safe work behavior.

Questionnaire and Sample

A quantitative research method was chosen to examine the proposed hypotheses, since it was exploratory in nature. Ojanen et al. (1988) argue that the only way to measure the safety climate is by surveys. A questionnaire survey was used in order to facilitate the collection of information from construction sites. With the exception of the safety climate and safe behavior constructs (both are explained later), all model constructs were measured through seven-item scales and a five-point Likert-type response format. Items, relating to each of the constructs, were used in the form of statements to measure individual constructs under investigation. To the extent possible, the different statements used in developing the questionnaire were drawn upon scales that had been previously used by researchers (Cox and Cox 1991; Tomas and Oliver 1995; Glazner et al. 1999; Cox and Cheyne 2000; Lee and Harrison 2000). A limited number of statements, however, were slightly modified to reflect the nature of the construction industry. Participants were asked to endorse the statements using a five-point Likert-type scale (from 1 = "strongly disagree" to 5 = "strongly agree"). Sample items for each construct are presented in Appendix I.

As mentioned earlier, safety climate refers to the people's perception of the value of safety in the work environment. According to Cooper and Philips (1994), the safety climate is concerned with the shared perceptions and beliefs that workers hold regarding safety in the workplace. To accurately reflect this definition, a new multiple-item scale was developed to measure the safety climate construct. The 10 items listed in Appendix II were identified through an exploratory interview with a construction safety manager, from among 15 items initially considered, as being reflective of workers' perception of the role safety plays in the workplace. Respondents were first asked if they endorse the item (statement). If they answered yes, they were further instructed to rate, on a 1–9 scale, the extent of their belief in the item. If they answered no, the answer was coded as zero. An overall safety climate score, representing an aggregate belief, was then computed by summing the 10 scores. This method was adapted from the well-known

J. Constr. Eng. Manage., 2002, 128(5): 375-384

method of measuring self-efficacy, tested and validated by Lee and Bobko (1994).

The last construct relates to safe work behavior. The hypothesized model indicates that the safety climate affects work behavior. Grubb and Swanson (1999) report that construction workers acknowledge the difference between unsafe behaviors that might result in injury to the individual (who is engaged in the action) and those that might lead to others being injured. They conclude that workers are more willing to confront someone whose behavior is posing a threat to coworkers' safety. As a result, two items (Brown et al. 2000) were selected to assess the dependent construct of safe work behavior. Respondents were asked to indicate, on average, the percentage of time they (self) and their coworkers (others) follow all of the safety procedures for the jobs that they perform (Appendix II).

To achieve acceptable levels of measurement reliability and validity, a draft questionnaire was constructed and pretested on two graduate students and a construction safety manager. Their input was used to refine the original questionnaire. The questionnaire contained, in its final form, a total of 82 statements (70 statements listed in Appendix I, plus 12 statements listed in Appendix II) about safety issues at the organizational, group, and individual levels. A number of negatively worded statements were presented in the scale, as recommended in the measurement literature (Pedhazur and Schmelkin 1991). While the majority of reported construction safety surveys target top management, senior project managers, and safety managers/officers, this research study has identified construction workers (contractors as well as subcontractors) as the survey sample. This is in line with the main purpose of the research—seeking a correlation between the safety climate and work behavior in construction site environments. A total number of 19 construction sites in the south of the state of Queensland, Australia were selected as the potential sample target. Main contractors, operating on these sites, were approached through an introductory letter explaining the purpose of the study, and seeking permission to conduct site visits.

A total of nine contractors responded to the introductory letter. However, only six positive replies were received. Those who declined our invitation to collaborate felt that they could not afford the contact time required to complete the questionnaire. The questionnaires were administered over the course of 4–6.5 h site visits. The researcher administered the survey to construction workers. The sample included carpenters, steel fixers, equipment operators, and electricians representing 10 different companies (six that responded positively to the invitation plus four subcontractors that were personally approached during site visits). In summary, a total of 68 questionnaires representing 10 organizations (on six different construction sites) were completed. To avoid the problem of bias, it was decided to interview no less than four employees working for the same organization. A total of 79% of the sample had not suffered any accident in the previous five years; the remaining 21% had no more than one accident. Falling from heights and being struck by moving objects caused most of the accidents. About 12% of the sample were apprentices with less than 12 months of site experience.

It is worth mentioning that although climate perceptions are inherently individual, the safety climate questionnaire was developed to operate at both the individual and the group level. Salancik and Pfeffer (1978) argue that over time and through social information processing influences, individual perceptions can become shared and, as a result, can be aggregated and used to describe a group as a whole. In other words, this study expects that perceptions of the safety climate and its determinants would be relatively homogeneous within the groups, constituting shared perceptions, and therefore could be aggregated to the group level of analysis. Therefore, the research model was tested using the total sample (combining all responses solicited from all sites).

Data Analysis

The research hypotheses were tested using structural equation modeling (SEM). The SEM is a statistical analysis tool used largely by sociologists and psychologists. It is, however, underutilized in construction engineering and management research despite its distinct advantages (Molenaar et al. 2000). SEM is a multivariate methodology that allows the simultaneous examination of the relationships among independent and dependent constructs within a theoretical model (Kilne 1998). An SEM technique called partial least squares (PLS) was chosen for analyzing our hypothesized model. PLS is a technique that uses a combination of principal components analysis, path analysis, and regression to simultaneously evaluate theory and data (Pedhazur 1982). PLS estimates parameters for both the links between measures with their respective constructs (i.e., loadings) and the links between different constructs (i.e., path coefficients). The loadings can be interpreted as factor loadings, while the path coefficients are standardized regression coefficients. The explanatory power of the model can be tested by examining the sign, size, and statistical significance of the path coefficients between constructs in the model. PLS has been used by a growing number of researchers from a variety of disciplines (Green et al. 1995; Smith and Barclay 1997; Hulland 1999; Mohamed 1999).

The nature of the links between constructs and measures (indicators) is referred to as an epistemic relationship. Two basic types of epistemic relationships are relevant to SEM—reflective indicators and formative indicators (Hulland 1999). The indicators (questionnaire items) in our model were treated as reflective, as they were expected to covary. They were assumed to reflect the unobserved, underlying construct, with the construct giving rise to (or "causing") the observed measures. For example, constructs such as management commitment and communication are typically viewed as underlying factors that give rise to something that is observed. Accordingly, their indicators tend to be realized as reflective (Fig. 1).

The program used for the path analysis is PLS (version 1.8). PLS follows the methods initially described by Wold (1983), and developed by Lohmoller (1989). The PLS model is a combination of a factor model (measurement model) and a path model (structural equation model). The former represents the relation between indicators and constructs, and enables us to evaluate whether the constructs are measured with satisfactory accuracy, whereas the latter represents the relation between constructs, and is used to test and analyze the hypothesized relationships. Anderson and Gerbing (1988) suggest that both the measurement model and the structural model should be assessed sequentially, as this two-stage approach reduces the likelihood of interpretational confounds because the validity of the constructs is established prior to investigating the hypothesized relationships. The assessment of both models is described below.

Assessment of Measurement Model

Prior to data analysis, three measurement properties need to be examined to ensure that the model has a satisfactory level of reliability and validity (Fornell and Larcker 1981). The first of

J. Constr. Eng. Manage., 2002, 128(5): 375-384

Table 1. Convergent Validity of Independent Constructs

Construct	Cronbach's alpha	Average variance extracted (A_v)
1. Commitment	0.90	0.73
2. Communication	0.82	0.78
3. Safety rules and procedures	0.72	0.70
4. Supportive environment	0.70	0.68
5. Supervisory environment	0.86	0.71
6. Workers' involvement	0.88	0.62
7. Personal appreciation of risk	0.78	0.69
8. Appraisal of work hazards	0.76	0.68
9. Work pressure	0.80	0.64
10. Competence	0.79	0.66

these is the individual item reliability, where loadings (or simple correlations) of the items on their respective constructs are assessed, using 0.70 as a cutoff point (Fornell and Larcker 1981). Exceeding this value simply implies that less than half of the item's variance is due to error. Obtained values for items exceeded this threshold, with many loadings in the range of 0.75–0.90, demonstrating the satisfactory level of individual item reliability. Convergent validity (also referred to as the homogeneity of the construct or composite reliability) is the second measurement property to be examined, and is evaluated by Cronbach's alpha. The Cronbach's alpha obtained for each construct is listed in Table 1. All constructs have acceptable convergent validity, as a value of 0.70 is usually accepted as the minimum desired value of the Cronbach's alpha (Litwin 1995). The Cronbach's alpha for the 10 items used to measure the single score for the newly developed *safety climate* scale was 0.67. Although this value is slightly less than 0.70, Churchill (1979) argues that a value of 0.60 can be considered acceptable for newly developed scales.

The third measurement property is the discriminant validity—that is, the extent to which each construct differs from other constructs in the model. It is assessed by using the average variance extracted (A_v), suggested by Fornell and Larcker (1981) (Table 1). This measure should be greater than the variance shared between the construct and other constructs in the model (i.e., the

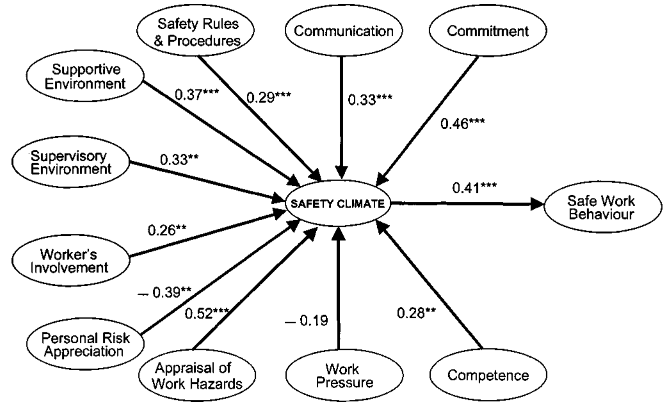

Fig. 2. Path coefficients and levels of significance; $^{**}p<0.01$ and $^{***}p<0.001$ (two-tailed set)

squared correlation between two constructs). This can be demonstrated in the correlation matrix, shown in Table 2, which includes the correlations between different constructs in the lower left off-diagonal elements of the matrix, and the square root of the average variance extracted (A_v) calculated for each of the constructs along the diagonal. Having all of the diagonal elements greater than any other corresponding row or column implies adequate discriminant validity.

It is worth mentioning, however, that the work pressure and personal appreciation of risk constructs are closely interrelated, as the correlation among these two constructs is relatively high and is comparable to the average variance extracted. Having satisfied the three measurement properties, it can be concluded that the constructs are measured with adequate precision.

Assessment of Structural Model

This section presents the results of testing the research hypotheses. With the exception of hypothesis 11, the model's hypotheses addressed factors that could influence a worker's belief and perception of the role that safety plays on sites. The degree to which any particular PLS model accomplishes its objectives can be de-

Table 2. Discriminant Validity Analysis

Construct	1	2	3	4	5	6	7	8	9	10
1. Commitment	**0.85**	—	—	—	—	—	—	—	—	—
2. Communication	0.32	**0.88**	—	—	—	—	—	—	—	—
3. Safety rules and procedures	0.15	0.21	**0.84**	—	—	—	—	—	—	—
4. Supportive environment	0.25	0.14	0.19	**0.82**	—	—	—	—	—	—
5. Supervisory environment	0.32	0.08	0.12	0.40	**0.84**	—	—	—	—	—
6. Workers' involvement	0.27	0.23	0.09	0.36	0.24	**0.79**	—	—	—	—
7. Personal appreciation of risk	0.08	−0.02	0.08	0.12	−0.08	0.06	**0.83**	—	—	—
8. Appraisal of hazards	0.10	0.14	0.21	0.28	0.18	0.04	0.22	**0.82**	—	—
9. Work pressure	0.26	0.13	0.17	−0.10	0.22	0.10	0.73	−0.08	**0.80**	—
10. Competence	0.08	0.11	0.18	0.09	0.20	0.16	0.07	0.19	0.24	**0.81**

J. Constr. Eng. Manage., 2002, 128(5): 375-384

Table 3. Summary of Path Coefficients and Significance Levels

Hypothesis and corresponding path	Expected sign	Path coefficient	t-value (degrees of freedom=68)
H1—Greater management commitment=+ve safety climate.	+	0.46	3.95***[b]
H2—Effective organizational communication=+ve safety climate.	+	0.33	3.60***[b]
H3—Better perception of safety rules and procedures=+ve safety climate.	+	0.29	4.24***[b]
H4—Higher level of coworkers' support=+ve safety climate.	+	0.37	2.76***[b]
H5—Higher level of quality supervision=+ve safety climate.	+	0.33	2.48**[a]
H6—Higher level of constructive involvement=+ve safety climate.	+	0.26	3.12**[a]
H7—Higher level of willingness to take risk=−ve safety climate.	−	−0.39	−1.96**[a]
H8—Greater level of safety's integration=+ve safety climate.	+	0.52	4.16***[b]
H9—Higher perception of work pressure=−ve safety climate.	−	−0.19	−1.04
H10—More of one's experience and knowledge=+ve safety climate.	+	0.28	2.12**[a]
H11—Higher level of safety climate positively impacts safe behavior.	+	0.41	5.52***[b]

[a]** $p<0.01$.

[b]*** $p<0.001$ (two-tailed set).

termined by examining the R-square values for the dependent construct(s). To achieve this objective, path analysis was used for assessing the model. The higher the path coefficient, the stronger is the effect that one variable has on another variable. Fig. 2 indicates the estimated path coefficients, while Table 3 contains a summary of the hypotheses, the path coefficients obtained from the PLS analysis, the t-values, and associated levels of significance for each path.

As can be seen, all of the paths were in the direction hypothesized. The regression of the independent constructs on the safety climate construct is an R-square of 0.74, or 74%. R-square can be interpreted in the same manner as that obtained for the multiple regression analysis. Thus, the model explains about 74% of the variance in safety climate for the sampled data. As for hypothesis 11 and testing how well the safety climate predicted safe behavior, a relatively high R-square value of 0.80 was obtained. Therefore, for the outcome (dependent) construct safe work behavior, the safety climate would seem to be the major factor affecting the workers' safe behavior. With the exception of one path, all of the path coefficients were statistically significant in the predicted direction, providing strong overall support for the hypothesized model. The majority of the independent constructs affect the creation of a positive safety climate, which, in turn, leads to safe work behavior. Management commitment and appraisal of work hazards have a strong influence on the safety climate. Hypothesis 9 (the higher the perception of pressure to value expediency over safety), however, was not supported.

Discussion of Results

The broad hypothesis is that safe work behaviors are consequences of the existing safety climate, which, in turn, is determined by the five independent constructs—management, safety, risk, work pressure, and competence. Strictly speaking, support was found for the influence of management, safety, and risk systems on the safety climate.

Both hypotheses 1 and 2 dealt with management commitment and communication, as suggested by the literature. The path from the commitment construct to the safety climate is significant. This finding verifies previous research (Zohar 1980) and further emphasizes the importance of managers being committed to and personally involved in safety activities to emphasize safety issues within the organization. Also, the path from the communication construct to the safety climate is positive, supporting the finding by Edmondson (1996), who found that handling errors in a negative way engendered a negative climate that in turn influenced the willingness of both management and employees to communicate freely and discuss mistakes and problems. Therefore, one can conclude that both commitment and communication are prerequisites to creating and sustaining a positive safety climate in construction site environments.

The results for hypotheses 3, 4, and 5 (safety rules and procedures, supportive environment, and supervisory environment) suggest that these three components of the safety system have an influence on the safety climate. The supportive environment seems to be perceived as having relatively more importance than the supervisory environment. This is not very surprising, as a construction worker who continually interacts with coworkers also relies on them to a greater extent to provide a safer work environment. These findings suggest that workers in more positive safety climates are more likely to have above-average working relationships with managers, supervisors, and coworkers.

The structural model provides support for hypotheses 6, 7, and 8 (workers' constructive involvement, personal appreciation of risk, and appraisal of work hazards). As expected, the ability to identify hazards has a strong positive relationship with the safety climate. This finding was expected and corresponded to the findings of Mohamed and Bostock (1999), who found that the ability to detect potential hazards has an important role in affecting the overall safety performance for an organization and is dependent upon the intensity of management activities toward safety. In the same line, Salminen (1995) also strongly emphasized the role of

J. Constr. Eng. Manage., 2002, 128(5): 375-384

detecting hazards and suggested increased training in detecting these hazards.

The model also predicted that the relationship between the competence and safety climate constructs is a significant one. It is, therefore, likely that a high level of competence will create a positive safety climate. Laukkanen (1999) reports that skilled and experienced construction workers have fewer stress symptoms and are less prone to hazards than the inexperienced ones. The expected influence of work pressure on the safety climate (hypothesis 9) was not supported, as the work pressure construct was not significantly related to the safety climate. Although nonsignificant, the relationship between the two constructs was as hypothesized (higher perception of work pressure is associated with a less positive safety climate).

The absence of a significant direct relationship may be partially explained by the way in which work pressure was defined (i.e., a condition created by an imbalance between high demand and low control at the work environment) in the current study. Indicators used to measure this construct dealt solely with the psychological aspects of working under pressure (perceiving the conflicting safety and production requirements). However, ‘‘working under pressure is the *norm* in the construction industry.’’ This is a concern that was frequently expressed by informants during the course of data collection. As a result, and in view of the statistical interrelation found between the work pressure and personal appreciation of risk constructs, an attempt was made to investigate whether an indirect relationship between work pressure and safety climate exists. The direct link between these two constructs was dropped from the model, and a new link between work pressure and personal appreciation of risk was introduced. In doing so, the new link implies that the higher the perception of pressure to value expediency over safety, the higher the level of workers' willingness to take risk; consequently, the less positive the safety climate becomes. The refined model was then analyzed using the same data. Not surprisingly, support was found for the indirect influence that work pressure has on the safety climate. The amount of variance explained in the safety climate was slightly reduced from 74 to 71%. However, all paths remained largely unchanged, suggesting that the newly introduced link does not significantly affect the model.

Limitations

Two potential limitations of the current research study, which are suggestive of future research paths, deserve attention. First and foremost, this study was concerned with the influence of each of the independent constructs on the safety climate; hence, it did not deal with the interaction among the independent constructs. Although these constructs enjoyed a relatively high degree of discriminant validity, one cannot ignore the interaction effect. Further research should introduce interaction among the independent constructs and examine its significance. Second, as with most research surveys, the data collected were self-reported; hence, some of the relationships may be exaggerated due to common-method bias. Available information from top management and supervisors would be useful, in particular, in matters concerning management commitment, communication, and the supervisory environment. This will be addressed in a future study. Despite these limitations, and given its exploratory nature, the present study offers support for the proposed conceptual model and an empirical basis for comparison in future research.

Conclusions

This paper attempted to examine the relationship between determinants of the safety climate and the safety climate, and that between the safety climate and safe work behavior on construction sites. A research model was developed and tested using a survey, which contained multiple measurement items relating to each of the constructs in the model. Whenever possible, appropriate scales that had demonstrated good psychometric properties in previous studies were employed. Support was found for the influence of management, safety, and risk systems on the safety climate. The empirical results indicate a significant relationship (positive association) between the safety climate and safe work behavior. Positive safety climates seem to result from management's showing a committed and nonpunitive approach to safety, and promoting a more open, free-flowing exchange about safety-related issues. Contrary to the expectation, this study indicated that work pressure has no significant direct relationship with the safety climate. Instead, it has an indirect negative effect on the safety climate through its impact on workers' willingness, under pressure, to take time-saving shortcuts.

Appendix I. Questionnaire Items in Measurement Scales

All scale items are measured on five-point Likert-type scales. Please indicate your level of agreement or disagreement with the following statements about construction site safety (1=strongly disagree; 3=neither disagree nor agree; 5=strongly agree).

Commitment

Management

- Clearly considers safety to be equally as important as production,
- Expresses concern if safety procedures are not adhered to,
- Acts decisively when a safety concern is raised,
- Acts quickly to correct safety problems,
- Acts only after accidents have occurred,
- Praises site employees for working safely, and
- Disciplines site employees for working unsafely.

Communication

Management

- Clearly communicates safety issues to all levels within the organization,
- Continues to bring safety information to site employees' attention,
- Operates an open-door policy on safety issues,
- Encourages feedback from site employees on safety issues,
- Listens to and acts upon feedback from site employees,
- Communicates lessons from accidents to improve safety performance, and
- Undertakes campaigns to promote safe working practices.

Safety Rules and Procedures

Current safety rules and procedures

- Are made available to protect us from accidents,
- Are adequate sources of information on safety,
- Are so complicated that some workers do not pay much attention to them,

J. Constr. Eng. Manage., 2002, 128(5): 375-384

- Should be consulted only by new recruits,
- Require us to report any malpractice by a fellow worker,
- Enforce the use of personal protective equipment whenever necessary, and
- Require detailed work plans from subcontractors or self-employed individuals.

Supportive Environment

As a group, we
- Adopt a no-blame approach to highlight unsafe work behavior,
- Often remind each other on how to work safely,
- Believe it is our business to maintain a safe workplace environment,
- Always offer help when needed to perform the job safely,
- Endeavor to ensure that individuals are not working by themselves under risky or hazardous conditions,
- Maintain good working relationships, and
- Ensure that the workload is reasonably balanced among ourselves.

Supervisory Environment

My supervisor/safety manager
- Has positive safety behavior,
- Believes safety is very important,
- Usually engages in regular safety talks,
- Welcomes reporting safety hazards/incidents,
- Is a good resource for solving safety problems,
- Advocates working around safety procedures to meet important deadlines, and
- Values my ideas about improving safety when significant changes to working practices are suggested.

Workers' Involvement

Everyone
- Aims to achieve high levels of safety performance,
- Plays an active role in identifying site hazards,
- Reports accidents, incidents, and potentially hazardous situations,
- Participates in safety planning, according to our safety policy if being asked,
- Has the responsibility to reflect on safety practice,
- Avoids being involved in accident investigations, and
- Contributes to job safety analysis if being asked.

Personal Appreciation of Risk

I
- Am sure that it is only a matter of time before I am involved in an accident,
- Am sure I can influence the level of safety performance,
- Am clear about what my responsibilities are for safety,
- Am aware that safety is the number one priority in my mind while working,
- Believe some rules are really necessary to get the job done safely,
- Believe some rules and policies are not really practical, and
- Cannot do the job safely without following every safety procedure.

Appraisal of Physical Work Environment and Work Hazards

In our work environment
- Safety is a primary consideration when determining site layout,
- Poor site layout planning is an accepted feature of the industry,
- The chances of being involved in a site accident are quite large,
- Operating site conditions may hinder one's ability to work safely,
- Detecting potential hazards is not a major aim of the site planning exercise,
- Working with defective equipment is not allowed under any circumstances, and
- Potential risks and consequences are identified prior to execution.

Work Pressure

Under pressure
- I work under a great deal of tension,
- I am not given enough time to get the job done safely,
- It is necessary for me to depart from safety requirements for production's sake,
- I perceive operational targets in conflict with some safety measures,
- It is normal for me to take shortcuts at the expense of safety,
- I tolerate minor unsafe behaviors performed by coworkers, and
- It is not acceptable to delay periodic inspection of plant and equipment.

Competence

I
- Received adequate training to perform my job safely,
- Am aware, through training, of relevant safety procedures,
- Do fully understand current, relevant legislation,
- Am skilled at avoiding the dangers of workplace hazards,
- Am capable of identifying potentially hazardous situations,
- Am proactive in removing workplace safety hazards, and
- Am capable of using relevant protective equipment.

Appendix II. Safety Climate and Safe Behavior Scales

Do you endorse any of the following statements? If yes, please rate each statement on a 1–9 scale (where 9=very strong endorsement). Think about the current role that safety (concept, measures, and practices) plays within your work environment.

Safety in My Current Workplace

- Plays an effective role in preventing accidents,
- Reduces occupational risk,
- Makes it possible to get the job done,
- Is of high quality compared to other sites,
- Is not restrictive and superficial,
- Helps increase my productivity,
- Contributes to my work satisfaction,
- Inspires me to work more safely,
- Has a positive influence on morale, and
- Makes me proud to tell others I am part of it.

J. Constr. Eng. Manage., 2002, 128(5): 375-384

Safe Work Behavior

On a scale of 0–100%, please indicate, on average, the percentage of time

- I (self) follow all of the safety procedures for the jobs that I perform, and
- My coworkers follow all of the safety procedures for the jobs that they perform.

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