Is Safety Climate Different by Project Size and Activity with Different Risk Levels?

Hyunho Jung[a] and Youngcheol Kang[b]

[a]Graduate Research Assistant, Department of Architecture and Architectural Engineering, Yonsei University, South Korea
[b]Associate Professor, Department of Architecture and Architectural Engineering, Yonsei University, South Korea
E-mail: jhh1234@yonsei.ac.kr, yckang@yonsei.ac.kr

Abstract

The purpose of this study is to compare the safety climate by project size and construction activity with different risk levels. Accidents tend to occur more frequently at smaller sites. As safety climate has been regarded as one important leading indicator preventing accidents, this study hypothesized that larger project tend to have higher level of safety climate. In addition, this study also hypothesized that labours working for the activities with high level of risk tend to have higher level of safety climate than those for the activities with low level of risk. The hypothesis is related to the theory of homeostasis that humans tend to behave riskier in a situation with low risk and behave less risky in a situation with high risk. This paper presents a research model testing these hypotheses. Literature review about the constructs included in the model and data collection plan are also presented. The test of these hypotheses will contribute to helping practitioners when they establish the plans to increasing the level of safety climate for various projects and activities, which will eventually contribute to better safety performance.

Keywords –

Safety climate, Construction safety; Project size; activities with different levels of risk

1 Introduction

The construction industry is one of the most hazardous industries. In the United States, 1,061 fatalities occurred in the industry in 2019 and the number of deaths has continued to rise since 2010 [1, 3]. For the comparison of accidents by industry sector, 19.9% of fatalities occurred in the construction industry in 2019, which is the highest percentage among all industries [1].

In order to reduce accidents in the construction industry, many researchers have conducted various studies about construction safety. Among these studies, researchers recently have focused on the factors related to humans. Examples include studies investigating safety climate and safety behavior. Martínez-Córcoles et al. [34] investigated the effect of leadership on safety behavior. Wu et al. [50] found the main factors that appeared most frequently and had large impacts on safety climate through literature review. These factors include safety priority, safety supervisor, training and communication, safety involvement, and safety rule and procedure. The statistical analysis by using data collected by a questionnaire has been the typical research methodology for these topics.

This study investigates the safety climate differences by project size and activity with different risk levels. For the studies investigating safety climate, while there have been a number of studies investigating the indicators measuring safety climate and factors affecting safety climate, the current body of knowledge lacks whether safety climate differs by project size and by activity with different risk levels. Some argued that small projects in terms of total project cost tend to have more accidents than large projects [35]. This study conjectured that safety climate is the main factor contributing to this tendency. In addition, when comparing the human's behavior and circumstances, some studies argued that human behavior is the main direct cause of accidents [22]. If safety climate is the main factor contributing to the prevention of accidents, labors working for the activities with high level of risk should behave more carefully, which will lead to different level of safety climate. Thus, there should exists different level of safety climate by activities with different levels of risk.

This study presents a research model with two hypotheses: 1) Larger projects tend to have higher level of safety climate and 2) Activities with high level of risk tend to have higher level of safety climate. The research model and constructs in the model are presented in this paper. In addition, this paper presents the survey development and data collection plan. The result of this study is expected to help practitioners in establishing more sophisticated plans to enhance safety climate for their construction projects, which will eventually

contribute to preventing accidents.

2 Literature review

This section presents the definition of safety climate and provides some studies investigating safety climate. Two hypotheses of this study are presented as well in this section.

2.1 Safety climate

Zohar [58] firstly proposed a safety climate as a workers' shared perception regarding the safety aspects of their working environments. Based on Zohar's studies, Neal and Griffin [39] described safety climate as "individual perceptions of policies, procedures and practices related to workplace safety". González-Romá [19] summarized that safety climate is a measure that reflects the employees' perceptions and attitudes toward safety within the organizational climate at a specific point in time. Guldenmund [21] defined safety climate as a summary concept representing the beliefs of employees about all safety issues. Glendon and Stanton [18] stated that safe climate includes the current position of the firm. Fang et al. [14] noted that safety climate is a 'snapshot' of safety culture. For some studies, safety culture and safety climate are not distinguished and are used interchangeably [6]. Since then, it has been described that safety climate reflects the state of safety at a specific point of time in an organization [5, 14, 19]. After all, safety climate is a common perception regarding safety shared by employees within an organization at a specific point in time.

It also has been used as an indicator for organizational safety through various studies. Many researchers have found that safety climate contributes to reducing accidents. McCabe et al. [36] found that safe climate accounted for 20% of the variation in the injury rate. Many previous studies have confirmed the positive role of safety climate in improving the safety performance at construction sites [5, 30, 33, 42, 46].

As humans' unsafe behavior is one main cause of accidents, there have been many studies investigating the human factors for safety [26]. Studies about safety climate and safety culture are examples studying the human factors. Griffin and Neal [20] found that the safety climate influences employees' safety motivation, thereby influencing the safety behavior. Many researchers have identified that key dimensions related to safety climate influence safety behavior [15, 31, 34, 38]. Jin et al. [26] found that the most research studies on safety climate and safety culture have been performed in the recent 10 years.

The construction industry is large, complex, and involved in non-routine works compared to other industries [53]. In addition, stakeholders in the field are more diverse than other industries. Based on the literature review, Al-Bayati et al. [1] presented 12 indicators examining safety culture and safety climate and those indicators were classified into four stakeholders: upper management, safety personnel, frontline supervisors, and workers). The paper summarized the organizational responsibilities of each of the four stakeholders for safety performance and accident reduction. Chen and Jin [4] investigated the multi-level safety culture and safety climate to evaluate newly introduced safety programs. For the investigation, the hierarchy of the construction organization was classified into three (Top management, Middle management, and worker) and the framework for understanding the relationship among safety program, safety culture, and safety climate in each hierarchy was organized based on the literature review. Li et al. [29] studied safety climate dimensions and safety climate indicators by three perspectives (safety management and supervision, construction team workers, the safety environment).

Table 1 summarizes the dimensions which presumably affect the safety climate. As shown in the table, there are various stakeholders being involved in the development of safety climate. Another thing to note is that researchers investigated those factors from the perspective of construction workers because they are the main victims of construction accidents [23].

Table 1 Factors affecting safety climate

Factor	Reference
Management commitment	[6, 8, 10, 14, 31,38, 51, 56]
Supervisors' role	[6, 8, 10, 14, 27, 38, 55, 56]
Workers' involvement in safety	[12, 14, 31, 38, 51, 56]
Workers' perception of safety	[6, 29, 31, 38, 51]
Co-workers' interaction	[6, 8, 15, 29, 38]
safety environment	[14, 15, 29, 31, 38]

2.2 Research Hypothesis

This study proposes two research hypotheses. The theoretical background for the hypotheses is summarized below.

2.2.1 Project scale and safety climate

The project size is usually determined by project cost. In general, the amount of resources used for safety is influenced by project size. For example, in South Korea, the Occupational Safety and Health Act designated the number of safety managers by the size of construction project [41].

In addition, cost for health, safety, and environment (HSE) is determined by multiplying the direct

construction cost and a standard rate determined by the Occupational Safety and Health Act of Korea. Japan also uses a standard rate offered by the government to determine the HSE cost from the direct cost [9, 41]. Thus, for a project with higher the direct construction cost is, more resources can be used for the safety and health management [9, 41].

Differences in the amount of safety resources can affect the safety performance. Indeed, smaller organizations tend to perform worse in safety than larger organizations. Targoutzidis [47] argued that small organizations account for 67% of employment in all sectors but occupational accidents account for 82% of accidents in Europe.

Based on the fact that the accidents at small organizations, which have relatively lower level of resources available for safety management than large organizations, account for 82% of all accidents, and the number of management personnel and management costs invested in safety management vary slightly depending on the size of the construction, it can be hypothesized that larger projects tend to have higher level of safety climate as the existing literature confirmed that safety climate and safety performance are positively associated [4, 30, 33, 42, 46].

Hypothesis 1. Larger projects tend to have higher level of safety climate.

2.2.2 Risk level of work activity and safety climate

As the degree of risk is different by type of work [28], frequency of potential loss-of-control events varies by work activity [44]. Lee et al. [28] showed that there is a quantitative difference in the risk according to the type of work. They argued that activities involved in roof, elevator, curtain wall, reinforced concrete, and steel are relatively high-risk activities, and finishing, wood, metal, tile, and brick are relatively low-risk activities.

Ronzenfeld et al. [44] conducted the construction job safety analysis (CJSA) and found that frequency of potential loss-of-control events differs by work activity. Particularly, workers executing foundation and structural activities have more loss-of-control events than finishing work activities. Depending on the type of work activity, frequency that workers face the risk of accidents varies. Thus, safety managers should manage such activities more carefully by conducting special safety training, and preparing rules to prevent accidents. Such actions should raise the level of awareness of workers' safety.

Among the theories related to risk perception, Gerald Wilde published the theory of risk homeostasis in 1982 [49]. According to his theory, humans tend to behave riskier in a situation with low risk and behave less risky in a situation with high risk. Thus, this study assumed that the level of risk by type of work would affect the safety climate of workers.

Based on the studies showing that the level of risk is different by type of work activities and the level of management efforts safety managers spend increased for the work activities with high level of risk, and the theory about the relationship between the level of risk and the behavior of workers, the following hypothesis can be established.

Hypothesis 2. Activities with high level of risk tend to have higher level of safety climate.

3 Research model

To test the hypotheses of this study, it is necessary to quantify the safety climate by project size and activity type. To quantify the safety climate, the authors conducted a thorough literature review and identified seven factors presumably affecting the safety climate of workers. **Error! Reference source not found.** shows the research model. As shown in the figure, the model has seven factors. There are some features to discuss in the model. First, some factors such as management commitment, supervisor's role, and two factors related to workers measure various issues such as safety procedure, communication, and attitude by different hierarchical perspective from top management (management commitment) to workers. As mentioned previously, a construction project is involved in diverse stakeholders. Thus, similar to other studies investigating safety climate [1, 4], this study considers the workers' perceptions on hieratically different types of stakeholders influencing safety climate. Second, while the aforementioned factors are about certain perceptions within a stakeholder, two factors related to co-workers are about interaction among the frontline workers. The last factor, safety environment, is about the circumstances of a site in terms of safety.

3.1 Management Commitment

Management commitment is related to how top managers manage the organization with the safety issue as a priority. Zohar (1980) referred to management's commitment as a central element of the safety climate. Mohamed [38] found that management commitment is a prerequisite for a positive safety climate. Alruqi et al. [60] argued that top manager's assurance that safety is a priority in their organizations is critical for safety climate. In other words, management commitment is a dimension that explains how the top manager prioritizes safety-related issues. Loosemore et al. [31] investigated six dimensions influencing safety climate. They include management commitment, communication, rules and procedure, supportive environment, personal accountability, and training. They found that management commitment shows the highest impact.

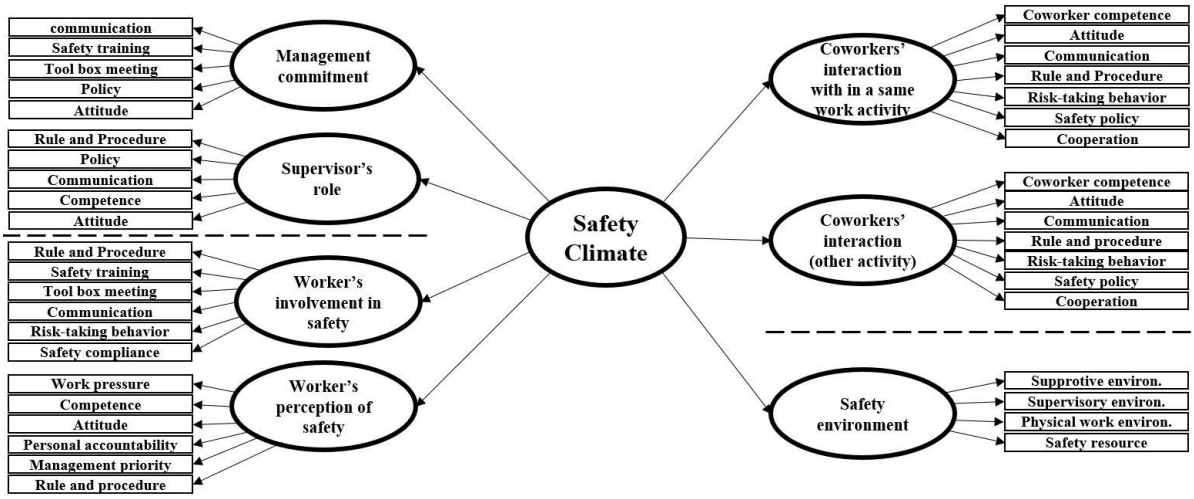

Figure 1. Research model

Items used from previous studies for this factor include safety priority, communication, safety training, tool box meeting, policy, and attitude [31, 38, 60].

3.2 Supervisor's role

Zhang et al. [55] investigated the effect of supervisor's behavior on safety climate and safety behavior of workers. They confirmed that supervisor's behavior improved the safety climate and workers' safety-related behavioral performance. Fang et al. [14] complied the structure of 10 safety climate dimensions including the supervisor's role. The climate survey tool (CST) developed by the UK Health and Safety Executive has 71 measurement items to measure 10 safety climate factors and supervisor's role is included in the factors. Zohar [59] explained that supervisors play a major role in implementing organizational safety policies and procedures. Alruqi et al. [60] described the supervisory safety response is about how accountable the front-line leaders are for carrying out an organization's safety procedures. In other words, safety supervision can be explained as an index explaining the performance of safety-related tasks in the organization by the supervisor, who plays the most important role in safety practice. The questionnaire items measuring the supervisor's role on safety include rule and procedure, policy, communication, ability, and attitude [14, 55, 60].

3.3 Coworkers' interaction within a same work activity

Li et al. [29] explained that in order to improve the safety climate of workers, it is necessary to create a reliable safe work environment. Such an environment can be created if team members pay attention to each other about unsafe behaviour and safety violations. Many studies highlighted the importance of co-workers' interaction for safety climate [14, 29]. Mohamed [38] mentioned co-workers as a component of a supportive environment. Fang et al. [14] explained that co-workers can interact with each other through their risk perceptions and mutual attitudes in an environment where they work together in the construction industry. To measure the interaction with co-workers, indicators include co-workers' competence, safety attitude, communication, rules and procedures, risk-taking behaviour, safety policy, and cooperation [14, 29, 38].

3.4 Workers' perception of safety

Workers' perception of safety relates to workers' psychological state, safety attitudes on potentially hazardous situations, as it relates to workers' identification of safety concerns. Li et al. (2017) explained workers' self-perception of safety based on self-perception theory (SPT), observing their own or co-workers' behavior and determining their own psychological state or attitude toward safety. Flin et al. (2000) explained that safety climate can be viewed as a superficial feature of safety culture identified by workers' perceptions and attitudes. Cox and Cheyne [11] explained that workers' awareness of organizational safety rules and procedures is a major factor influencing the level of safety. Items on workers' safety perception included work pressures, competence, attitudes, personal accountability, rules and procedures, management commitment [11, 29].

3.5 Workers' involvement in safety

Workers' involvement is concerned with the efforts of workers to actively participate in safety to ensure their own safety. Workers' involvement has also been described by several researchers as an important component of creating positive safety climate [38, 14, 29,

38, 60]. Reporting injuries and hazardous situations are examples of workers' participations in safety [38]. Li et al. [29] described workers' involvement as workers' efforts to regulate their own safety, including self-protection, participation in safety meetings and training, and adherence to safety procedures. Alruqi et al. [60] described workers' involvement as the extent to which workers are encouraged by senior management to participate in the safety procedures and are asked to participate in the policy. Wu et al. [50] reported that workers' safety involvement is one of the core dimensions appearing in safety climate studies. Workers' involvement responds to the level of participation of workers in their own safety, and the item included rule and procedure, training, tool box meeting, communication, risk-taking behavior, and safety compliance [14, 29, 38, 60].

3.6 Safety environment

The safety environment can be described as a factor related to the physical environment of a construction site, safety resources, and surrounding efforts to support the safety of workers, rather than a factor as one of the organizational hierarchies. Li et al. [29] defined the safety environment as environments involved in all construction activities and working conditions, including four indicators of personal protective equipment, workplace safety status, accidents record, and machine safety status, so that workers can complete their works safely. Niskanen [40] explained that the absence of adequate protective equipment and tools is one main cause an accident. Mohamed [38] explains that the supervisor's ability and safety performance are related to the supervisory environment. The items asking about the safety environment affecting worker safety included supportive environment, supervisory environment, physical working environment, and safety resources [38, 29].

3.7 Coworkers' interaction with different work activities

Through literature review, it was found that co-workers influence the safety of workers [14, 29]. There are various work activities at construction sites. Unlike other industries, construction sites have multiple activities working together on one project, so not only the same work activity group, but also other work activities (groups) can affect workers' safety. Depending on the type of job, type of safety equipment used are different, and the frequencies of loss-of-control events are different. So, the factor investigating the influence of safety climate on workers of other types of work are added. For the items to measure this, same elements to co-workers' interaction within a same work activity are used but the subjects of questionnaire items are changed to "workers doing other activities".

4 Survey development and data collection

To test two hypotheses, this study developed a survey. The survey consists of two sections. The first section collects information about the size of the project and the type of work activity. The second section consists of a total of 38 items related to seven constructs shown in Figure 1. For the items linked to each construct, how construction workers perceive the items will be asked because workers are most directly exposed to accidents.

The questionnaire plans to be distributed to construction workers and responses will be collected directly at construction sites. Factor analysis will be used to sort out some items and finalize the research model. As this study investigates the safety climate difference by project size and activity with different risk levels, data will be classified into two groups in terms of project size and activity type. In terms of the project size, US$12 million will be used to divide large and small projects as the size of safety resource is legally different based on the value in South Korea [9, 41]. In terms of the activity type, structural, foundation, roof, temporary, excavation, and wall are classified as high-risk activities and finishing works such as tile, wallpaper, wood, metal, stone, windows and doors are classified as low-risk activities [28]. Structural equation modeling will be used to compare how safety climate differs by project size and activity with different levels of risk.

5 Discussion and Conclusion

There have been many studies in the construction industry investigating safety climate and influential factors for safety climate. Although many studies asserted that there exists a positive association between safety climate and safety performance, the current body of knowledge doesn't have enough evidence on the different safety climate by project size and activity with different risk levels. Two hypotheses about these relationships in this study have some important implications. First, small projects tend to be more involved in accidents. This study tackles that one possible reason for this tendency is that larger projects can spend more resources for safety management thus have high level of safety climate which is known to have direct impacts on safety performance. Thus, if there can be more safety resources available for small projects, the frequency of accidents occurred in small projects can decrease. One issue here is that a higher percentage of cost or resources must be invested in safety, which can be quite challenging for small projects. By verifying the first research hypothesis, this study can contribute to

justifying a decision to spend more resources to cultivate safety culture for small projects. Indeed, some researchers argued that if comparing the cost expended to respond accidents and that used for prevention, responding cost is much greater than prevention cost [2, 48]. Thus, it is possible that the amount of cost necessary to enhance safety climate can be smaller than the cost spent to respond after accidents occurred. Future studies are recommended on this comparison.

Some might argue that safety climate is formed in the level of company or project [13, 14, 35, 43]. But, this study hypothesized that there can exist the safety climate difference by activity with different risk levels. For a construction project, there are various kinds of subcontractors being involved. The levels of risk on the activities they performed vary as well, which means that the level of safety climate for them can be different even though they work in same physical space. This safety climate difference by activity can have negative impacts on co-workers' interaction to reduce accidents. After all, it is possible that activity can be more appropriate level for managing safety climate for a construction project, inferring that more sophisticated plan to develop safety climate is necessary. Overall, the results of this study can contribute to establishing a more strategic and effective plans when establishing new policies, education, and rules related to safety in the future, which will eventually contribute to reducing the accident rate in the construction industry.

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