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Exploring the interactive effects of safety investments, safety culture and project hazard on safety performance: An empirical analysis

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Abstract

This study aims to explore the interactive effects of safety investments, safety culture and project hazard on construction safety performance. Data were collected using multiple techniques from 47 completed building projects in Singapore. Data were analyzed using correlation analysis, regression analysis, moderation analysis and mediation analysis. The results show that: (1) safety performance improves when there is a higher level of safety investments, a higher level of safety culture or a lower level of project hazard; (2) the effect of any individual factor on safety performance varies with the changes in other factors; (3) the effect of voluntary safety investments on safety performance is mediated by safety culture; and (4) the relationship between accident frequency rate and accident severity rate is moderated by project hazard level. The study suggests that safety performance of building projects is determined by the synergy effect of safety investments, safety culture and project hazard.

Keywords: Construction safety; Project hazard; Safety culture; Safety investment; Safety performance

1. Introduction

The Workplace Safety and Health (WSH) statistics (MOM, 2012) reveals that both accident frequency rate (AFR) and accident severity rate (ASR) of the construction industry were far higher than the average level among all the industries in Singapore. Noticeably, among the total of 56 workplace fatal injuries in 2012, 47% of these injuries occurred on construction sites (MOM, 2012), which suggests that the highest risk in Singapore is the construction sector. Such unsafe situation has promoted the government and construction practitioners to take efforts to prevent workplace accidents on construction sites.

Safety investments are defined as the costs which are incurred as a result of an emphasis being placed on safety control, whether it is in the form of safety training, safety incentives, staffing for safety, personal protective equipment, or other activities. They are viewed as a means to reduce the incidence of injuries, rather than just an operational cost (Hinze, 2000). Safety culture, which reflects the attitudes, beliefs, perceptions, and values that employees share in relation to safety, has gained acceptance due to its critical role for accident prevention (Cox and Cox, 1991). Project hazard is a natural part of the initial construction site conditions owing to the scope and location of the project (Imriyas et al., 2007). Higher project hazard level tends to be associated with higher risk level on site.

This study aims to explore the interactive effects of safety investments, safety culture and project hazard level on safety performance of building projects. Since safety costs vary with regions and industries, this study was conducted in the context of building construction in Singapore. The unit of analysis in this study is a contractor’s project. Safety investments are confined to those incurred by the project (including those relevant overhead costs allocated to the project) from the perspective of contractors (including main contractors and sub-contractors).

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2. Theoretical background

Efforts to prevent accidents are likely to be shaped by root causes of accidents (Lingard and Rowlinson, 2005). Heinrich (1931) developed the domino model of accident causation and concluded that 88% of accidents were caused by unsafe acts, and only 10% were caused by unsafe conditions. Many researchers have updated Heinrich's (1931) domino model with an emphasis on management failure as a primary cause in accidents, e.g., Weaver's (1971) updated dominoes, updated domino sequence (Bird, 1974; Bird and Loftus, 1976), and Adams' (1976) updated sequence. The multiple causation models, which are management based, hold that many contributing factors, causes and sub-causes combine together in a random manner causing accidents (Petersen, 1971). Hopkins (1995) suggested that it is misguided to attribute accidents to either unsafe acts or unsafe conditions only because most accidents are the result of a complex interaction of multiple causes. In the construction industry, Abdelhamid and Everett (2000) and Fang et al. (2004) suggested that the root causes of construction accidents include: management failure; unsafe acts of workers; non-human-related events; and an unsafe working condition that is a natural part of the initial construction site conditions.

The accident causation theories (models) suggest that lack of management control is the root cause of accidents and thus the accidents could be somewhat prevented through management efforts (Feng, 2013). However, due to people's strong desire to completely master their environment and control chance events (Adler, 1930; Hendrick, 1943) and the fact that skill and chance factors are so closely associated in people's experience, Langer (1975) found that there is an expectancy of a personal success probability inappropriately higher than the objective probability would warrant, which is referred to as the illusion of control. Langer's (1975) research suggests that lack of management control cannot account for all the failures in managing WSH risks due to the role of chance factors. Therefore, in addition to the level of management efforts in accident prevention, safety performance of building projects is also associated with the inherent project hazards and non-human related events, such as natural disasters and inclement weather (Abdelhamid and Everett, 2000; Imriyas et al., 2007; Teo and Feng, 2010, 2011). The management efforts could be in the form of physical input such as the investments in safety personnel, safety facilities and equipment, safety training, and other safety related activities, and cultural input such as the cultivation of safety culture in construction sites (Feng, 2013). The inherent project hazard is a natural part of the initial construction site conditions owing to the scope and location of the project (Abdelhamid and Everett, 2000; Imriyas et al., 2007). Non-human related events like natural disasters and inclement weather are beyond control and prediction (Teo and Feng, 2010), and thus they were not within the scope of this study.

The above review of accident causation theories (models) suggests that safety performance of construction projects is associated with three fundamental factors, namely safety investments, safety culture and project hazard. Previous studies have examined the individual impacts of safety investments (e.g., Brody et al., 1990; Hinze, 2000; Tang et al., 1997), safety culture (e.g., Choudhry et al., 2007; Cooper, 2000; Guldenmund, 2000) and project hazard level (e.g., Davis and Tomasin, 1996; Imriyas et al., 2007; Jannadi and Assaf, 1998) on safety performance. However, no studies appear to have been conducted to investigate the combined effects of the three factors namely safety investments, safety culture and project hazard. It is unclear whether safety performance of building projects is the result of the interactions of safety investments, safety culture and initial project hazard. It is also not known whether the effect of any factor on safety performance varies with the changes of the other two factors. This research was conducted to address these gaps by exploring the impact of the interactions between safety investments, safety culture and project hazard on safety performance. The general proposition for this study is that the safety performance of building projects is determined by the level of safety investments, safety culture level and project hazard level as well as the interactions among the three factors.

The next few sections present the measurements or indicators of each factor.

3. Safety investments

Safety investments include expenses for various accident prevention activities undertaken by the contractor's project (including subcontractors). Those safety investments made by the contractor at the company level were allocated to individual projects; and these investments were also considered as part of the project's overall safety investments (Tang et al., 1997). The safety investments made by the other parties of the project (e.g., consultant and client) except for the contractors and subcontractors were not within the scope of this study. Safety investments consist of dollars spent on the accident prevention activities (e.g. salaries of safety personnel and costs of safety equipment) and time invested in the accident prevention activities (e.g. the time invested in safety training and orientation, time invested in emergency response drills, and time invested in safety meetings and inspections) (Teo and Feng, 2011). Thus, safety investments are operationalized as the sum of: staffing cost (C_1), safety equipment and facility cost (C_2), compulsory training cost (C_3), in-house safety training cost (C_4), safety inspection and meeting cost (C_5), safety incentives and promotion cost (C_6), and safety innovation cost (C_7) (e.g., Hinze, 2000; Laufer, 1987; Tang et al., 1997).

Close examination of these reveal that some components are determined by external industry or government regulations and some are determined by internal company or project WSH policy. Thus, safety investments could further be classified into basic safety investments and voluntary safety investments (Feng, 2013). Basic safety investments (BSI) refer to the expenses of those accident prevention activities that are required by industry or government regulations and construction process on minimal safety standards. As a compulsory part of safety investments for any individual building projects in Singapore, basic safety investments consist of C_1, C_2 and C_3. Voluntary safety investments (VSI) refer to the expenses of those accident prevention activities that are generally determined by individual companies or projects. This type of safety