A Structural Equation Modeling Approach to Studying the Relationships among Safety Investment, Construction Employees' Safety Cognition, and Behavioral Performance

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Abstract

This study aimed to investigate the internal relationships between safety investments and construction employees' behavioral performance with safety cognition as the mediating factor. A comprehensive methodology was adopted, including theoretical modeling of safety investments, questionnaire survey, and Structural Equation Modeling (SEM). In the theoretical model, four factors (i.e., personal protection equipment (PPE), safety education, insurance purchased for site employees, and safety incentives) were adopted as safety investment categories. These four categories were studied of their correlation to the overall safety investment, which was tested of its contribution to employees' behavioral safety performance in both direct and indirect ways. Indirectly, safety cognition was introduced as a mediator to bridge safety investments and behavioral performance. A questionnaire consisting of 28 indicators was adopted to describe safety investment, safety cognition, and behavioral performance. A random sampling approach and the top-down method were implemented to recruit construction site employees from the south-eastern region of China. The follow-up SEM analysis revealed that all the four investment categories positively contributed to the overall safety investment, which was found significantly correlated to employees' safety cognition and behavioral performance. Safety incentive was identified as the most significant factor contributing to the overall investment. The current study extends

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prior studies of safety investments by adopting a quantitative approach from employees' perspective. It provides insights for construction employers regarding how safety investments could affect behavioral performance. Employers are suggested to balance the tangible (e.g., incentive) and intangible (e.g., safety insurance) investment categories. This study also contributes to establishing the internal links among safety investments, safety cognition, and behavioral safety performance. Based on the current findings, future work could investigate how to optimize safety investments to achieve higher behavioral performance. The current study based in China could be applied in a different geographic context by testing the correlations between safety investments and behavioral safety performance.

Keywords: Construction employee; safety behavior; safety cognition; safety investment; Structural Equation Modeling (SEM)

Introduction

Construction is one of the most risky industries due to its comparatively lower safety performance measured by injury rates (Lingard and Rowlinson 2015). An earlier study by Zou et al. (2007) found that safety was one of the main risks in China's construction industry, including insurance not purchased for employees, no insurance for major equipment, inadequate safety measures or unsafe operations, and poor competency of construction workers, etc. In China, construction workers are largely from rural and less economically-developed regions. It is common that they learn basic construction skills from their family members who are on the same team, and they are likely to mimic unsafe behaviors from peers (Zhang 2017). More than half of construction workers in China have not completed or barely finished middle school education (Zhang and Li 2016). In more recent years, high occurrences of construction accidents have caused public concerns. Safety requirements are being enforced and monitored, such as mandatory usage of personal protection equipment (PPE). Although it is expected of the 100% adoption rate of mandatory PPEs in all projects, the safety attitude, perception, and awareness of construction workers could vary crossing projects. Construction workers might behave in a more risky way to gain more income or to save time especially under a tight project schedule. There is a lack of empirical evidence of how certain investment categories (e.g., insurance) affect the behavioral safety performance.

Safety performance could be evaluated by different measurements, including the reactive and proactive measurements. The reactive measurements include accident or injury related occurrences. The proactive measurements highlight the preventive actions to avoid harms, for example, behavior-based safety performance. Safety performance could be affected by multiple factors related to safety investments, employees' safety behavior, safety awareness, and safety monitoring (Flin and Mearns 1994; Choudhry et al. 2007; Chen and Jin 2013). Support at the organizational level to employees' health and safety generally leads to higher safety performance (Mearns et al. 2010). Safety investment, as one of the main ways of organizational support, is affected by multiple factors, such as the organizational capacity to control risks and management skills (Yoon et al. 2000). Safety investment could be divided into different categories such as education and PPE (Qiang et al. 2004). So far, more studies have focused on safety investments at the organizational level, with limited research targeting the individual level. Specifically, there has been limited investigation quantifying the effect of safety investment categories on employees' behavioral safety performance. There has also been limited in-depth research focusing on how the overall safety investments affect safety performance through safety culture (Feng, 2013). Individual awareness and perception towards different safety investment categories (e.g., insurance) could affect the behavioral safety performance in either a direct manner, or an indirect way through the mediation of safety cognition. Investigating the effects of various safety investment categories on behavioral safety performance is critical based on the facts that: it provides the guides for construction employers to properly allocate their budget related to safety; it also contributes to the body of knowledge in construction safety management by establishing the theoretical framework incorporating safety investments, behavioral safety performance, and other human-based safety factors (e.g., safety cognition).

Prior studies (e.g., Yong et al. 2000; Zou et al. 2007; Wang et al. 2014; Man et al. 2017) either investigated the importance of safety investments at the organizational level, or analyzed the formation of unsafe behaviors in a qualitative approach. Workers are direct participants in all construction activities and are most vulnerable to be victims of accidents. A further study from the employees' perspectives in the context of safety culture (Guldenmund 2007) would be needed to investigate the correlations among safety investments for site employees, their safety cognition, and behavioral performance. Aiming to address these aforementioned limitations, this study investigates the effects of safety investments on behavioral performance with safety cognition as the vehicle. The objectives of this study include: (1) initiating a theoretical model incorporating safety investments, safety cognition, and behavioral safety performance. Safety investment is measured in four main categories related to safety education, PPE, safety incentive, and safety insurance defined by Cao (2018). Behavioral performance is divided into behavioral compliance and behavioral participation suggested by Neal (1995); (2) investigating the effects of safety investment categories on behavioral performance; and (3) discussing the mediating effect of safety cognition as the vehicle to bridge safety investments and employees' behavioral performance. This study contributes to the body of knowledge in construction safety management both practically and academically. Practically, the current study offers insights of how various safety investment factors could impact behavioral safety performance. Academically, it leads to further research in optimizing safety investment categories towards enhanced safety culture and improved safety performance.

Literature Review

Investments in construction safety

Investments in safety must be formulated as preventive measures against fatal accidents (Shohet et al. 2018). According to Shohet et al. (2018), safety investments cover costs of equipment, training, insurance, and other personal costs related to construction activities. The investments in safety would lead to enhancement in safety performance (Lu et al. 2016). Safety education, safety incentives, safety insurance, and PPE, as listed by Cao (2018), are critical factors or categories in construction safety investments. Safety investment, according to Feng (2013), could be divided into different categories such as basic investment and voluntary investment. Basic safety investments are defined as accident prevention activities that are required by industry or governmental regulations, including staffing cost, safety equipment and facility cost, and mandatory training cost (Feng et al. 2014). Voluntary investments are generally determined by individual organizations or projects (Feng et al. 2014). They include costs related to in-house safety training, safety inspection and meeting, safety incentives and promotion, and safety innovation (Laufer 1987; Tang et al. 1997; Hinze 2000; Feng et al. 2014). Different types of safety investments could have various effects on safety performance (Feng 2013), and are affected by other internal and external factors such as safety culture and site hazard levels (Feng 2015). Safety performance is improved with a higher level of safety investments, but could be mediated by safety culture (Feng et al. 2014). Studying the effects of different safety investment categories on safety performance is hence considered important (Cao 2018).

Safety cognition in the context of safety culture

Personal cognition reflects how an individual selects, organizes, and explains information from external sources (Chen et al. 2011). Social cognition is not separated from safety climate, which forms safety culture as indicated by Marquardt et al. (2012). Multiple studies (e.g., Guldenmund 2000; Rowatt et al. 2006; Parker et al. 2006) indicate that safety cognition would significantly affect employees' safety behavior, which further influences safety performance. Individual safety cognition is crucial to construction safety performance (Chen et al. 2011). Safety cognition could be linked to employees' implicit assumptions of safety, their prior safety scenarios, and their own safety knowledge (Liu 2018). Marquardt et al. (2012) further divided safety cognition according to the implicit and explicit levels. In the construction industry, employees' implicit safety cognition is formed from their prior work scenarios which establish their own safety knowledge (Han et al. 2019c). The prior work scenarios and safety knowledge affect individuals' safety perceptions (Marquardt et al. 2012). Safety perception is a core part of explicit safety cognition (Han et al. 2019c), which is largely equal to safety climate in terms of the measurement criteria (Guldenmund 2000; Rowatt et al. 2005). These measurement criteria include perceptions towards jobsite hazards (Han et al. 2019c), individuals' perceptions of self-capability to identify, evaluate, and control site hazards (Han et al. 2019b), as well as their awareness and knowledge of safety behaviors of themselves and their peers (Chen and Jin 2012).

Behavioral safety performance

It was found that employees' behavior in the forms of acts or omissions contributed to up to 80% of work-related injuries (Health and Safety Executive 1999). IOSH (2015) emphasized that one way to improve safety performance was to introduce a behavioral safety process and to reduce unsafe behaviors. These unsafe behaviors (e.g., improperly wearing PPEs) could result in accidents, including falls, electrocution, struck-by, and caught-in–between which are defined as Focus 4 Hazards (OSHA 2011). Construction safety management should highly target workers' unsafe behaviors (Chen and Jin 2012). Studies from Lingard and Rowlinson (1998) and Cooper (2003) indicated that the behavior-based safety (BBS) program could enhance safety performance. Nevertheless, critical factors within safety climate are key to successful implementation of BBS, including employee engagement, safety training, and management capabilities (DePasquale and Geller 1999). Griffin and Hu (2013) defined two key safety behavioral measurements, namely safety participation and safety compliance. It was recommended by Griffin and Hu (2013) that future research could explore individual and organizational mediators influencing safety behaviors. The social psychology theory of Baron and Kenny (1986) and the construction safety cognition framework defined by Han et al. (2019c) inferred that safety cognition could serve as the mediator influencing individuals' safety behaviors.

Methodology

Research design

This study was based on the research hypotheses regarding the impacts of safety investments on site employees' behavioral performance. A total of 14 hypotheses were originally proposed as illustrated in Fig.1.

<Insert Fig.1 here>

The details of these hypotheses are explained in details below:

- H1a: investments in PPE significantly affect employees' behavioral participation;
- H1b: investments in PPE significantly affect employees' behavioral conformance;
- H1c: investments in PPE significantly affect employees' safety cognition;
- H2a: investments in safety education significantly affect employees' behavioral participation;
- H2b: investments in safety education significantly affect employees' behavioral conformance;
- H2c: investments in safety education significantly affect employees' safety cognition;
- H3a: investments in safety incentives significantly affect employees' behavioral participation;

- H3b: investments in safety incentives significantly affect employees' behavioral conformance;
- H3c: investments in safety incentives significantly affect employees' safety cognition;
- H4a: investments in safety insurance significantly affect employees' behavioral participation;
- H4b: investments in safety insurance significantly affect employees' behavioral conformance;
- H4c: investments in safety insurance significantly affect employees' safety cognition;
- H5a: employee's safety cognition significantly influences their behavioral participation;
- H5b: employee's safety cognition significantly influences their behavioral conformance.

It is further noticed that the four investment categories can be combined as one overall safety investment, which could have significant effects on behavioral safety performance as indicated by Lu et al. (2016). It is seen in Fig.1 that this research aims to explore the role of safety cognition as the mediating factor between safety investments and behavioral safety performance. Han et al. (2019c) defined the framework of safety cognition, which could be divided into implicit and explicit cognitions. The implicit social cognition refers to employees' assumptions which influence individual behaviors (Schein 1992). The implicit cognition affects the explicit cognition, which could be equated to safety climate in measuring individual attitudes, awareness, and perceptions towards safety (Guldenmund 2000; Rowatt et al. 2005). Safety cognition reflects a construction employees' awareness and perception of potential site hazards, as well as the capability of decision making to behave properly. Behavioral safety performance is defined as safety participation and safety compliance in this study following Neal (1995) and Neal et al. (2000). According to Neal et al. (2000), safety participation refers to employees' involvement in safety-related activities in the workplace; safety compliance mainly refers to employees' conformance to safety regulations.

Safety investment generally refers to funds spent on preventing accidents, and on protecting the health/physical integrity of construction workers (Tang et al. 1997; Zou et al. 2010). The overall safety investment could be divided into various categories which could have varied influences on safety performance (Feng 2013). These investment categories listed by Feng (2014) can be labelled as tangible or intangible factors from the perspective of site employees. Tangible investments refer to those categories that are easily seen or physically sensed by employees. They are generally visible hardware devices or products, such as PPE which can be seen and physically used by employees. The intangible investments are generally progressive actions or processes which are not in a physical form of products or hardware. For example, employers invest on safety insurance and training for their employees, but employees may ignore these intangible investments because they do not directly see the cost of insurance or education as they would physically sense their PPE. The safety incentive is defined as a tangible investment because employees can directly see the extra income awarded for their good safety performance.

It is hypothesized that these safety investments aiming to prevent injuries or other accidents could be mediated by employees' safety cognition which further affects the behavioral performance. Employees with highly positive safety cognition would be more likely to appreciate the safety investments of their employers, to more actively participate in safety education, and to conform to safety regulations. Therefore, the research framework in Fig.1 can be further induced to the adjusted theoretical model shown in Fig.2.

<Insert Fig.2 here>

The social psychology theory proposed by Baron and Kenny (1986) stated that there was a mediator that intervened the effects of a stressor or external scenario on the outcome. In the context of construction safety behavior, these four safety investment categories serve as external scenarios which could affect employees' behavioral outcomes. But the degree of effect, as inferred by Baron and Kenny (1986) and Han et al. (2019c), could be intervened by safety cognition as the mediator. Therefore, Fig.2 is deduced following the theories of social psychology and safety cognition for the follow-up quantitative analysis.

Questionnaire survey

This research started from a review of existing literature (e.g., Hinze 1997; Glendon and Litherland 2001; Newaz et al. 2016; Tholén et al. 2013) in safety investments, employee's safety cognition, and behavioral performance. According to the literature review and the researchers' earlier work (i.e., Cao et al 2018), the indicators of safety investments, safety cognition, and behavioral performance were defined. A questionnaire survey to China's construction site employees was planned incorporating these indicators. The initiated questionnaire was peer reviewed by both academics and construction safety professionals in China. A total of 36 peer reviewers were invited to provide feedback to the initialized questionnaire to ensure that the statements were clear without vagueness, and easily understood by construction employees especially workers. These peer reviewers included graduate students in the construction management program of Jiangsu University, academic staff, and industry professionals in the local construction industry. Their feedback was collected during August and September in 2017, and discussed within the research team. The finalized questionnaire corresponding to the 28 indicators is provided in Table 1.

<Insert Table 1 here>

These 28 indicators were statements asked to employees during the site questionnaire survey. Each statement was generated from references listed in Table 1. From October 2017 to January 2018, questionnaire surveys were conducted from a total of 39 construction sites in the south-eastern region of China. Site employees were guided to rank each indicator with a Likert-scale score, from "1" meaning "strong disagree with the statement" to "5" indicating "strongly agree".

Sampling

Since 2010, along with the national promotion of digitalization in construction (Jin et al. 2015), China has been promoting the digital strategies in construction site management, for example, virtual reality (VR) and other video technologies used in construction safety education. In this study, the consistent random and unbiased sampling procedure described by Li et al. (2017) was conducted in the south-eastern coastal region of China, which represented the country's economically active region where the video-based safety education had been more commonly adopted in building construction projects. Site employees recruited in the questionnaire survey were from the high-rise residential building sector. It was expected that site employees had either undergone or at least been aware of video-based safety education. The consistent top-down method described by Chen et al. (2018) for site survey was adopted. Basically, the research team initially contacted the top management personnel (e.g., executives) of ongoing construction projects. If the top management personnel agreed on site visits and showed interests on the research, they would then schedule the questionnaire survey to their site employees. Afterwards, administering of questionnaire surveys was coordinated between three research team members and project management staff for each site visit. At the beginning of each site survey, all employees were explained with the purpose of the study and ensured that no personal or company information would be included. Each question was explained to survey participants to ensure no vagueness or confusion. For example, the high intensity of incentives described in the indicator of X7 in Table 1 meant the frequency and amount of cash award for employees' excellent safety performance. A larger amount of cash award or a more frequent award would mean a higher intensity. During the site survey, participants were further encouraged to ask for clarification if anything in the questionnaire was unclear to them. They were also made aware that they could withdraw the survey at any time.

Among the totally 380 questionnaires received through site surveys, 326 of them were found valid after excluding incomplete questionnaires or those with the same Likert-scale scores for all indicators within the same category (e.g., safety education investment). About 55% of the survey population was construction workers and the remaining 45% came from crew foremen or other site management personnel (e.g., safety manager, superintendent, etc.). Nearly 60% of them had over 10 years' site experience. The detailed demographic information of the survey participant sample is provided in Table2.

<Insert Table 2 here>

Structural Equation Modeling Approach

Following the site questionnaire surveys, Cronbach's alpha analysis was applied to check the reliability of indicators. According to Bland and Altman (1997) and DeVellis (2003), a Cronbach's alpha value close to or above 0.70 would suggest acceptable internal consistencies among indicators. The Structural Equation Modeling (SEM), which had been widely used in behavioral sciences based on a combination of factor analysis and path analysis (Hox and Bechger 1998), was adopted in this study to test these correlations among safety investment, safety cognition, and behavioral safety performance described in Fig.1 and Fig.2. The sample size for SEM was suggested to be not lower than 10 times the number of variables (Bentler and Chou 1987; Bollen 2014; Nunnally 1967). In this study, the ratio of sample size at 380 to the number of indicators at 28 met the requirement. The exploratory factor analysis (EFA) was adopted to identify the underlying factor structure of a dataset as demonstrated by Shan et al. (2018). EFA is the proper approach for SEM to hypothesize an underlying construct and to estimate factors that influence responses on observed variables

(Suhr 2006). EFA has been traditionally adopted to explore the possible underlying factor structure of a set of measured variables without preconceived structure on the outcome (Child 1990). EFA KMO (i.e., Kaiser-Mayer-Olkin) and Bartlett sphere test were introduced in EFA for the validity analysis. KMO measures the amount of a variance shared among the indicators which are designed to measure a latent variable (Shan et al. 2018). The KMO value higher than 0.5 would be considered acceptable (Kaiser 1974). The SEM was later conducted to analyze the loading factors and path coefficients between different factors. The model-fit test following the guide provided by Wu (2009) was performed to evaluate the SEM outcomes. These measurements for Goodness-of-fit of SEM are defined in Table 3, where the ideal numerical range of each measurement is provided. More detailed explanations of these indices in Table 3 can be found in Hox and Arnhem (1998), Kaplan (2001), and Shadfar and Malekmohammadi (2013).

<Insert Table 3 here>

Results

Initial validation of data collected from site questionnaire surveys

The reliability test based on Cronbach's alpha analysis is presented in Table 4.

<Insert Table 4 here>

All Cronbach's alpha values for each category as well as the overall value close to or over 0.70 indicated that the reliability was generally acceptable. The KMO and Bartlett spherical tests were then conducted for the further validity analysis. The KMO value at 0.837 and the Bartlett spherical test significance at 0.000 indicated satisfactory correlations among indicators. Therefore, the further factor analysis could be conducted. The initial structural model is illustrated in Fig.3.

<Insert Fig.3 here>

Following the SEM procedure using AMOS (Division of Statistics + Scientific Computation 2012) for the initial model shown in Fig.3, the Goodness-of-fit test displayed in

Fig.2 was conducted and presented in Table 5.

<Insert Table 5 here>

The values of AGFI, GFI, and NFI below 0.90 indicated that the initial model should be modified in order to meet the SEM requirements according to Table 3.

Model modification

The modification of the initialized model in Fig.3 should not only meet the statistical requirements shown in Table 3, but should also make the theoretical sense in construction safety management. These two criteria (i.e., statistical and theoretical aspects) were both considered in the modification process. When the Goodness-of-fit test did not yield satisfactory outcomes, either model building or model trimming should be applied to modify the model. As guided by David Garson and Statistical Associates Publishing (2015), the model building approach by adding paths based on the theoretical sense and the MI (i.e., Modification Indices) was implemented to improve the Goodness-of-fit. According to Wu (2009), a path could be added for a pair of indicators whose MI value is over 4.0. Following this initial test, several pairs of indicators shown in Fig.3 were found with relatively large MI values, such as e12 and e13 with the MI value at 21.584, as well as e22 and e23 (MI value at 16.408). From the theoretical sense according to the researchers' prior construction safety research (e.g., Cao et al. 2018), using PPE could increase construction workers' safety awareness towards unsafe behaviors of co-workers. Similarly, workers' active demonstration of safe operation was correlated to their participation in safety meetings. Therefore, similar pairs of indicators with higher MI values validated from the theoretical sense were added with paths in the modified model as seen in Fig.4.

<Insert Fig.4 here>

The further Goodness-of-fit test for the modified model shown in Fig.4 is summarized in Table 6.

<Insert Table 6 here>

All the indices in Table 6, e.g., CMIN/DF value below 3, GFI over 0.90, and RMSEA lower than 0.05, indicated the satisfactory test results for processing the modified model. Other measurements such as AGFI, CFI, NFI, and IFI values not lower than 0.90 showed that the modified model met the statistical requirements shown in Table 2. The modified model was hence considered suitable for further evaluation. Finally, the path coefficient and significance tests were performed to evaluate the modified model. As seen in Table 7, the standard error, critical ratio, as well as *p* value measuring the significance were applied to investigate the correlations among safety investments, safety cognition, and behavioral performance illustrated in Fig.2.

<Insert Table 7 here>

All path coefficients higher than 0 and *p* values below 0.05 indicated that all the four safety investment factors were significantly correlated to the overall safety investment, which further significantly contributed to safety cognition, and finally behavioral safety performance. The path coefficients displayed in Fig.4 quantified the significance level of each investment category to the overall safety investment. Safety incentives are found with the strongest correlation to the overall safety investment with the path coefficient at 0.98, followed by PPE investment (0.92), and safety education investment (0.89). Safety insurance was identified as the least significant investment category, with the path coefficient at 0.75. The modified model displayed in Fig.4 and Table 7 inferred that although safety investments had directly significant effects on behavioral safety performance, these direct effects were less significant (*p* values at 0.047 and 0.001 respectively) compared to the significance levels of other paths in Table 7. In comparison, safety investments turned out with stronger correlation with safety cognition with the path coefficient at 0.90. Safety cognition was further significantly connected to behavioral performance. Specifically, safety cognition had a stronger correlation to behavioral participation with the path coefficient at 0.67 compared to its correlation with behavioral conformance (0.52). It was inferred that safety cognition worked as a vehicle that bridged safety investments and behavioral performance. All the four investment categories were found with significant correlations to safety cognition, which was found significantly affecting the two main behavioral performance factors.

Discussion

Man et al. (2017) suggested that safety incentives and safety education were key drivers to reduce construction workers' unsafe behaviors. Besides safety education and safety incentives, PPE investment and safety insurance, as mentioned by Zou et al. (2007) within the Chinese construction culture, were other key factors for organizations and stakeholders to consider in safety investments. This study investigated the effects of safety investments on employees' behavioral safety performance with safety cognition as the mediator. Adopting a three-step research methodology (i.e., theoretical modeling, questionnaire survey, and Structural Equation Modeling (SEM)), it was found that the overall safety investment was significantly correlated to employees' safety cognition, and further affecting the behavioral performance. Overall, this study provided a quantitative approach to verify the statement of Lu et al. (2016) that safety investments contributed to enhanced behavioral performance. As a step forward, this study divided the safety investment into four major categories and evaluated each category's effect on employees' behavioral performance.

The social psychology theory described by Baron and Kenny (1986) indicated that the stressor was input variables that could affect individuals' behavioral outcomes. Applying the social psychology theory into construction safety management, the stressor could be site conditions (e.g., tight project schedule) that affect employees' decision of whether or not to behave riskily in order to achieve certain desires. Man et al. (2017) and Feng (2019) stated that these desires included saving time and effort, or gaining more income. Gaining more income in less working time was identified as one of the major causes of construction workers' unsafe behaviors (Feng, 2019). Therefore, safety incentive was defined as one investment category in this study to address employees' desire to gain more income. It was verified that incentive had the highest correlation to the overall safety investment compared to three other categories of investments (i.e., insurance, education, and PPE).

The social behavioral theories proposed by Deci and Ryan (1985) and Ryan and Deci, (2000) revealed that human behaviors were driven by a variety of motivations and the motivation-initiated behaviors aimed to satisfy the innate psychological desire. This desire was a necessary but not a sufficient condition for employees to conduct risky behaviors. Construction employees might have different motivations to behave unsafely, such as being social and demonstrating self-capability (Choudhry and Fang 2008; Man et al. 2017). Lack of safety knowledge or biased attitudes towards safety could drive these motivations towards unsafe behaviors among newer employees. But for more experienced employees, over-confidence of their own capability could also cause risky behaviors (Han et al. 2019a). It is hence suggested that periodic safety training and education be carried out to construction employees at different experience levels (Han et al. 2019b). Intervening construction workers' motivation (e.g., gaining more income) towards unsafe behavior through education is part of safety investment. Investments in safety education is needed besides incentives to correct employees' biased safety perceptions or attitudes, and to enhance their safety knowledge (e.g., proper use of PPEs). Examples of safety education investments include organizing periodic safety workshops, implementing safety programs, and hiring safety professionals for site monitoring, etc. Therefore, investments in safety education or training is another critical factor affecting the behavioral performance of site employees.

Besides safety incentives and education/training, safety insurance and PPE costs are two other investment categories affecting employees' behavioral performance. The Risk Homeostasis Theory (Wilde 1982) stated that individuals tend to take more risks if they had a stronger sense of safety. Klen (1997) further showed that workers behaved more riskily with PPEs. However, researchers in this study do not aim to deny the importance of PPE, but emphasize that the stressor (e.g., PPE) does not necessarily lead to improved behavioral performance. Instead, the mediating effect through safety cognition could bridge the investment in PPE and employees' behavioral outcomes. Individuals' safety cognition could be enhanced through proper safety education.

Safety incentive, as one tangible benefit from employees' perspective, is identified as the most significant contributor to the overall safety investment. The direct financial gain through incentives becomes the strongest motivation for employees to behave safely. In contrast, safety insurance that employers invest on site employees, is a less significant contributor to behavioral performance. It is implied from the path coefficient analysis shown in Fig.4 that construction employees tend to perceive tangible safety investments (i.e., incentives and PPE) as stronger motivations to work safely. However, this does not mean employers should invest more in safety incentives or PPE, but a more balanced and comprehensive coverage of safety-related investments between tangible and intangible factors.

Insurance, as one intangible category from the employees' perspective, is found with the lowest effect on the overall safety investment, the importance of insurance should not be downplayed. More studies could be performed to explore the effects of different types of insurance on employees' safety cognition and behavioral performance. The different types of insurance include but are not limited to the legally required minimum coverage of injuries, and a more comprehensive package with a wider coverage of employees' health and safety.

It should be noticed that the tangible and intangible features of these four investment categories are defined from the perspective of site employees, depending on whether the investment items could be directly sensed by employees. This study implies the gap between employees' safety climate and the organizational safety culture. From the employer or the organization's perspective, all of the four investment categories are actually tangible, as the organization can directly see the financial expenditure for purchasing PPE, insurance for employees, incentives, and training. Nevertheless, employees would have different perceptions towards the four investment categories. They would generally view incentives as a more tangible category because they could gain extra income. In contrast, insurance that their employer purchase for them might not be well noticed or even ignored. This gap between individual employees and the organization leads to further research on bridging individual needs and organizational strategies through mediators such as safety cognition.

Conclusion

This study adopted four main safety investment factors (i.e., categories), namely safety education, personal protection equipment (PPE), safety incentive, and safety insurance. Through site questionnaire surveys and Structural Equation Modeling approach, these four categories were investigated of their correlation to site employees' safety cognition and behavioral performance. All the four investment categories were found positively contributing to the overall safety investment, which was found significantly affecting site employees' safety cognition and behavioral performance. Safety cognition was also found positively contributing to the behavioral performance, especially behavioral participation. Among the four investment categories, the more tangible safety investment (i.e., incentives) was found with the highest correlation to the overall safety investment. In contrast, the intangible investment categories (e.g., insurance) were perceived by employees with lower significance. The current findings indicate that there is a mediator (i.e., safety cognition) to bridge investments on employees' safety and the behavioral performance. This study contributes to the body of knowledge both practically and academically. Practically, it provides insights for construction enterprises on the effects of safety investments on enhancing employees' behavioral safety performance, as well as the significance of different investment categories towards employees' behavioral performance. Specifically, employers need to realize that these investment categories (e.g., education) which are all tangible at the organizational level, may be perceived differently by individual employees. Employers are suggested to have balanced safety investments between tangible (e.g., incentives) and intangible (e.g., insurance) categories. Academically, the current findings lead to further research on how different categories of safety investments would affect employees' behavioral safety performance with safety cognition as the vehicle. A positive safety cognition embedded in the site safety climate and organizational safety culture is a key mediator to bridge safety investments and behavioral performance.

Further research could focus on how to optimize the different investment categories in an effective safety program aiming to establish proper site safety climate and to enhance behavioral safety performance. The effects due to different arrangements of incentives can be compared, for example, the effects between more frequent but smaller amounts of cash awards (e.g., $100 cash award monthly per awardee) and less frequent but larger amounts of incentives (e.g., $300 cash award quarterly per awardee). Currently, the initial model established is limited to jobsites in south-eastern region of China. Future studies could apply this model in a different geographic region worldwide, and quantify the mediating effect of safety culture as the vehicle to bridge safety investments and employees' behavioral safety performance.

Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request.

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Table 1. A total of 28 indicators in the questionnaire survey

Category	Indicator in the questionnaire	References
PPE investment	X1:My employer provides me with good personal protection equipment that motivates me to participate actively in safety-related activities.	Feng (2013); Feng et al. (2014); Hao (2015); Lv (2014)
	X2:The specific personal protective equipment that is related to my job duties makes me behave safely in my work.	
	X3:The adequate personal protective equipment improves my understanding of the site hazards (e.g., working at height).	
Investment in safety education	X4: The experiential safety education, for example, watching video, experiencing jobsite operation conditions with Virtual Reality and other safety education approaches, motivates me to more effectively participate in safety activities.	Huang et al.(2018); Qiang et al. (2004); Wang et al.(2015)
	X5: The specific safety education related to my work makes me well comply with safety rules and regulations.	
	X6: The diversified and varied safety education makes me better understand the occupational safety risks.	
Safety incentive	X7: The high intensity of safety incentive motivates me to more effectively participate in setting safety plans and objectives.	Shao et al. (2013); Wang et al. (2014)
	X8: Compared to verbal or certificate-based safety awards, the cash incentive better motivates me to comply with company's safety rules.	
	X9: Compared to multiple small safety incentives, a single but larger amount of safety incentive improves my awareness of site hazard sources.	
Safety insurance	X10: Work-related injury insurance motivates me to proactively correct the unsafe behavior of peers.	Hu et al. (2017); Hu and Tao (2015)
	X11: Medical insurance makes me work in the safest way.	
	X12: The comprehensive safety insurance that my employer purchases for me, has led to a higher level of awareness that I have towards unsafe behavior of my peers.	
Safety cognition	X13: I can fully realize the hazards during work.	Huang (2017); Li and Li (2017); Mitropoulos and Memarian (2012); Zohar and Luria (2004)
	X14: I can fully understand the occupational hazards corresponding to different types of site duties.	
	X15: I know well different unsafe behavior types and the consequences at work.	
	X16: I have developed my knowledge and understanding of the safety rules and regulations.	
	X17: I have developed my strong awareness of hazard sources and occupational risks.	
	X18: I am fully aware of my peers' unsafe behaviors and relevant safety regulations	

Safety behavioral participation	X19: I actively participate in the development of site safety plans.	Choudhry et al. (2007); Wirth and Sigurdsson (2008); Choudhry (2014)
	X20: I will stop the unsafe behavior of my peers during work.	
	X21: I participate actively in the improvement of site safety.	
	X22: I actively demonstrate safe operation and behaviors to other employees.	
	X23: I actively participate in safety meetings.	
Safety behavioral conformance	X24: I always wear the right and appropriate safety protection equipment during work.	Neal (1995); Toole (2002); Zeng et al. (2009)
	X25: I always follow the company's safety rules and regulations during work.	
	X26: I always work in the safest way as I can on-site.	
	X27: I always behave according to the correct safety procedures on-site.	
	X28: I often remind my peers of the importance of safety on-site.	

Table 2. Demographic summary of survey participants (N=326)

Category		**Sample size**	**Percentage (%)**
Gender	Male	282	86.5
	Female	44	13.5
Education level	Primary school or below	53	16.3
	Middle School	140	42.9
	High School	53	16.3
	College or university	80	24.5
Job position	Workers	178	54.6
	Crew foremen	73	22.4
	Management personnel	75	23.0
Years of site experience	0-10	138	42.3
	10-20	165	50.6
	20-30	23	7.1

Table 3. Definitions of Goodness-of-fit indices (source from Wu, 2009)

Measurement	**Definition**	**Numerical range**	**Satisfactory range**	**Ideal range**
CMIN/DF	Ratio of normed chi-square to degree of freedom	＞0	≤5	≤3
RMSEA	Root Mean Square Error of Approximation	0-1	≤0.08	≤0.05
p	Level of significance	0-1	≤0.05	≤0.05
RMR	Root mean Square Residual	/	The lower value indicates a higher degree of goodness	The lower value the better
GFI	Goodness of Fit	0-1	≥0.80	≥0.90
AGFI	Adjusted Goodness of Fit	0-1	≥0.80	≥0.90
NFI	Normed Fit Index	0-1	≥0.90	≥0.90
IFI	Incremental Fit Index	0-1	≥0.90	≥0.90
CFI	Comparative Fit Index	0-1	≥0.90	≥0.90

Table 4. Reliability test results of the factors based on *28* indicators

Factor	Cronbach's Alpha	Number of indicators
PPE investment	0.686	3
Safety education	0.668	3
Safety incentives	0.702	3
Safety insurance	0.751	3
Safety cognition	0.817	6
Safety behavioral participation	0.823	5
Safety behavioral conformance	0.828	5
Overall Cronbach's alpha value	0.947	28

Table 5. Goodness-of-fit test for the initial model

Model type	CMIN/DF	RMSEA	P	RMR	AGFI	GFI	NFI	IFI	CFI
Initial model	1.645	0.045	0	0.024	0.870	0.891	0.870	0.944	0.938
Standard model						1	1	1	1
Independent model	11.492	0.180	0	0.216	0.132	0.192	0	0	0

Table 6. Goodness-of-fit test for the modified model

Model type	CMIN/DF	RMSEA	P	RMR	AGFI	GFI	NFI	IFI	CFI
Initial model	1.311	0.031	0	0.021	0.900	0.916	0.901	0.975	0.970
Standard model						1	1	1	1
Independent model	11.492	0.180	0	0.216	0.132	0.192	0	0	0

Table 7. Path coefficient analysis and significance tests of the initial model

Path	**Estimate**	**Standard Error**	**Critical Ratio**	***p***	**Standardized Estimate**
Safety investment =>Safety cognition	0.844	0.092	9.206	***	0.899
Safety investment =>Safety behavioral participation	0.343	0.173	1.986	0.047*	0.321
Safety investment =>Safety behavioral conformance	0.544	0.165	3.290	0.001**	0.479
PPE investment <=Safety investment	0.964	0.105	9.172	***	0.920
Safety incentives <=Safety investment	0.979	0.101	9.172	***	0.981
Safety insurance investment <=Safety investment	0.925	0.099	9.315	***	0.753
Safety education investment =>Safety investment	1.000				0.892
Safety cognition =>Safety behavioral participation	0.760	0.195	3.901	***	0.668
Safety cognition =>Safety behavioral conformance	0.629	0.178	3.542	***	0.521

Note：1.* denotes that $p < 0.05$; **denotes $p < 0.01$; ***means $p < 0.001$; 2. Following the guide of Wu (2009), the estimate for safety education investment correlating to safety investment is standardized as *1* to run the significance tests for other paths in Table 7.