

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

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4 **Abstract**

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

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

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

33 **Introduction**

34 Construction is one of the most risky industries due to its comparatively lower safety
35 performance measured by injury rates (Lingard and Rowlinson 2015). An earlier study by
36 Zou et al. (2007) found that safety was one of the main risks in China's construction industry,
37 including insurance not purchased for employees, no insurance for major equipment,
38 inadequate safety measures or unsafe operations, and poor competency of construction
39 workers, etc. In China, construction workers are largely from rural and less economically-
40 developed regions. It is common that they learn basic construction skills from their family
41 members who are on the same team, and they are likely to mimic unsafe behaviors from
42 peers (Zhang 2017). More than half of construction workers in China have not completed or
43 barely finished middle school education (Zhang and Li 2016). In more recent years, high
44 occurrences of construction accidents have caused public concerns. Safety requirements are
45 being enforced and monitored, such as mandatory usage of personal protection equipment
46 (PPE). Although it is expected of the 100% adoption rate of mandatory PPEs in all projects,

47 the safety attitude, perception, and awareness of construction workers could vary crossing
48 projects. Construction workers might behave in a more risky way to gain more income or to
49 save time especially under a tight project schedule. There is a lack of empirical evidence of
50 how certain investment categories (e.g., insurance) affect the behavioral safety performance.

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

72 to the body of knowledge in construction safety management by establishing the theoretical
73 framework incorporating safety investments, behavioral safety performance, and other
74 human-based safety factors (e.g., safety cognition).

75 Prior studies (e.g., Yong et al. 2000; Zou et al. 2007; Wang et al. 2014; Man et al. 2017)
76 either investigated the importance of safety investments at the organizational level, or
77 analyzed the formation of unsafe behaviors in a qualitative approach. Workers are direct
78 participants in all construction activities and are most vulnerable to be victims of accidents. A
79 further study from the employees' perspectives in the context of safety culture (Guldenmund
80 2007) would be needed to investigate the correlations among safety investments for site
81 employees, their safety cognition, and behavioral performance. Aiming to address these
82 aforementioned limitations, this study investigates the effects of safety investments on
83 behavioral performance with safety cognition as the vehicle. The objectives of this study
84 include: (1) initiating a theoretical model incorporating safety investments, safety cognition,
85 and behavioral safety performance. Safety investment is measured in four main categories
86 related to safety education, PPE, safety incentive, and safety insurance defined by Cao (2018).
87 Behavioral performance is divided into behavioral compliance and behavioral participation
88 suggested by Neal (1995); (2) investigating the effects of safety investment categories on
89 behavioral performance; and (3) discussing the mediating effect of safety cognition as the
90 vehicle to bridge safety investments and employees' behavioral performance. This study
91 contributes to the body of knowledge in construction safety management both practically and
92 academically. Practically, the current study offers insights of how various safety investment
93 factors could impact behavioral safety performance. Academically, it leads to further research
94 in optimizing safety investment categories towards enhanced safety culture and improved
95 safety performance.

96 **Literature Review**

97 ***Investments in construction safety***

98 Investments in safety must be formulated as preventive measures against fatal accidents
99 (Shohet et al. 2018). According to Shohet et al. (2018), safety investments cover costs of
100 equipment, training, insurance, and other personal costs related to construction activities. The
101 investments in safety would lead to enhancement in safety performance (Lu et al. 2016).
102 Safety education, safety incentives, safety insurance, and PPE, as listed by Cao (2018), are
103 critical factors or categories in construction safety investments. Safety investment, according
104 to Feng (2013), could be divided into different categories such as basic investment and
105 voluntary investment. Basic safety investments are defined as accident prevention activities
106 that are required by industry or governmental regulations, including staffing cost, safety
107 equipment and facility cost, and mandatory training cost (Feng et al. 2014). Voluntary
108 investments are generally determined by individual organizations or projects (Feng et al.
109 2014). They include costs related to in-house safety training, safety inspection and meeting,
110 safety incentives and promotion, and safety innovation (Laufer 1987; Tang et al. 1997; Hinze
111 2000; Feng et al. 2014). Different types of safety investments could have various effects on
112 safety performance (Feng 2013), and are affected by other internal and external factors such
113 as safety culture and site hazard levels (Feng 2015). Safety performance is improved with a
114 higher level of safety investments, but could be mediated by safety culture (Feng et al. 2014).
115 Studying the effects of different safety investment categories on safety performance is hence
116 considered important (Cao 2018).

117 ***Safety cognition in the context of safety culture***

118 Personal cognition reflects how an individual selects, organizes, and explains information
119 from external sources (Chen et al. 2011). Social cognition is not separated from safety
120 climate, which forms safety culture as indicated by Marquardt et al. (2012). Multiple studies
121 (e.g., Guldenmund 2000; Rowatt et al. 2006; Parker et al. 2006) indicate that safety cognition

122 would significantly affect employees' safety behavior, which further influences safety
123 performance. Individual safety cognition is crucial to construction safety performance (Chen
124 et al. 2011). Safety cognition could be linked to employees' implicit assumptions of safety,
125 their prior safety scenarios, and their own safety knowledge (Liu 2018). Marquardt et al.
126 (2012) further divided safety cognition according to the implicit and explicit levels. In the
127 construction industry, employees' implicit safety cognition is formed from their prior work
128 scenarios which establish their own safety knowledge (Han et al. 2019c). The prior work
129 scenarios and safety knowledge affect individuals' safety perceptions (Marquardt et al. 2012).
130 Safety perception is a core part of explicit safety cognition (Han et al. 2019c), which is
131 largely equal to safety climate in terms of the measurement criteria (Guldenmund 2000;
132 Rowatt et al. 2005). These measurement criteria include perceptions towards jobsite hazards
133 (Han et al. 2019c), individuals' perceptions of self-capability to identify, evaluate, and
134 control site hazards (Han et al. 2019b), as well as their awareness and knowledge of safety
135 behaviors of themselves and their peers (Chen and Jin 2012).

136 *Behavioral safety performance*

137 It was found that employees' behavior in the forms of acts or omissions contributed to up
138 to 80% of work-related injuries (Health and Safety Executive 1999). IOSH (2015)
139 emphasized that one way to improve safety performance was to introduce a behavioral safety
140 process and to reduce unsafe behaviors. These unsafe behaviors (e.g., improperly wearing
141 PPEs) could result in accidents, including falls, electrocution, struck-by, and caught-in-
142 between which are defined as Focus 4 Hazards (OSHA 2011). Construction safety
143 management should highly target workers' unsafe behaviors (Chen and Jin 2012). Studies
144 from Lingard and Rowlinson (1998) and Cooper (2003) indicated that the behavior-based
145 safety (BBS) program could enhance safety performance. Nevertheless, critical factors within
146 safety climate are key to successful implementation of BBS, including employee engagement,

147 safety training, and management capabilities (DePasquale and Geller 1999). Griffin and Hu
148 (2013) defined two key safety behavioral measurements, namely safety participation and
149 safety compliance. It was recommended by Griffin and Hu (2013) that future research could
150 explore individual and organizational mediators influencing safety behaviors. The social
151 psychology theory of Baron and Kenny (1986) and the construction safety cognition
152 framework defined by Han et al. (2019c) inferred that safety cognition could serve as the
153 mediator influencing individuals' safety behaviors.

154 **Methodology**

155 *Research design*

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

159 <Insert Fig.1 here>

160 The details of these hypotheses are explained in details below:

- 161 • H1a: investments in PPE significantly affect employees' behavioral participation;
- 162 • H1b: investments in PPE significantly affect employees' behavioral conformance;
- 163 • H1c: investments in PPE significantly affect employees' safety cognition;
- 164 • H2a: investments in safety education significantly affect employees' behavioral
165 participation;
- 166 • H2b: investments in safety education significantly affect employees' behavioral
167 conformance;
- 168 • H2c: investments in safety education significantly affect employees' safety cognition;
- 169 • H3a: investments in safety incentives significantly affect employees' behavioral
170 participation;

- 171 • H3b: investments in safety incentives significantly affect employees' behavioral
172 conformance;
- 173 • H3c: investments in safety incentives significantly affect employees' safety cognition;
- 174 • H4a: investments in safety insurance significantly affect employees' behavioral
175 participation;
- 176 • H4b: investments in safety insurance significantly affect employees' behavioral
177 conformance;
- 178 • H4c: investments in safety insurance significantly affect employees' safety cognition;
- 179 • H5a: employee's safety cognition significantly influences their behavioral
180 participation;
- 181 • H5b: employee's safety cognition significantly influences their behavioral
182 conformance.

183 It is further noticed that the four investment categories can be combined as one overall
184 safety investment, which could have significant effects on behavioral safety performance as
185 indicated by Lu et al. (2016). It is seen in Fig.1 that this research aims to explore the role of
186 safety cognition as the mediating factor between safety investments and behavioral safety
187 performance. Han et al. (2019c) defined the framework of safety cognition, which could be
188 divided into implicit and explicit cognitions. The implicit social cognition refers to
189 employees' assumptions which influence individual behaviors (Schein 1992). The implicit
190 cognition affects the explicit cognition, which could be equated to safety climate in
191 measuring individual attitudes, awareness, and perceptions towards safety (Guldenmund
192 2000; Rowatt et al. 2005). Safety cognition reflects a construction employees' awareness and
193 perception of potential site hazards, as well as the capability of decision making to behave
194 properly. Behavioral safety performance is defined as safety participation and safety
195 compliance in this study following Neal (1995) and Neal et al. (2000). According to Neal et

196 al. (2000), safety participation refers to employees' involvement in safety-related activities in
197 the workplace; safety compliance mainly refers to employees' conformance to safety
198 regulations.

199 Safety investment generally refers to funds spent on preventing accidents, and on
200 protecting the health/physical integrity of construction workers (Tang et al. 1997; Zou et al.
201 2010). The overall safety investment could be divided into various categories which could
202 have varied influences on safety performance (Feng 2013). These investment categories listed
203 by Feng (2014) can be labelled as tangible or intangible factors from the perspective of site
204 employees. Tangible investments refer to those categories that are easily seen or physically
205 sensed by employees. They are generally visible hardware devices or products, such as PPE
206 which can be seen and physically used by employees. The intangible investments are
207 generally progressive actions or processes which are not in a physical form of products or
208 hardware. For example, employers invest on safety insurance and training for their employees,
209 but employees may ignore these intangible investments because they do not directly see the
210 cost of insurance or education as they would physically sense their PPE. The safety incentive
211 is defined as a tangible investment because employees can directly see the extra income
212 awarded for their good safety performance.

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

219 <Insert Fig.2 here>

220 The social psychology theory proposed by Baron and Kenny (1986) stated that there was

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

227 *Questionnaire survey*

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

242 <Insert Table 1 here>

243 These 28 indicators were statements asked to employees during the site questionnaire
244 survey. Each statement was generated from references listed in Table 1. From October 2017
245 to January 2018, questionnaire surveys were conducted from a total of 39 construction sites

246 in the south-eastern region of China. Site employees were guided to rank each indicator with
247 a Likert-scale score, from “1” meaning “strong disagree with the statement” to “5” indicating
248 “strongly agree”.

249 *Sampling*

250 Since 2010, along with the national promotion of digitalization in construction (Jin et al.
251 2015), China has been promoting the digital strategies in construction site management, for
252 example, virtual reality (VR) and other video technologies used in construction safety
253 education. In this study, the consistent random and unbiased sampling procedure described by
254 Li et al. (2017) was conducted in the south-eastern coastal region of China, which represented
255 the country’s economically active region where the video-based safety education had been
256 more commonly adopted in building construction projects. Site employees recruited in the
257 questionnaire survey were from the high-rise residential building sector. It was expected that
258 site employees had either undergone or at least been aware of video-based safety education.
259 The consistent top-down method described by Chen et al. (2018) for site survey was adopted.
260 Basically, the research team initially contacted the top management personnel (e.g.,
261 executives) of ongoing construction projects. If the top management personnel agreed on site
262 visits and showed interests on the research, they would then schedule the questionnaire
263 survey to their site employees. Afterwards, administering of questionnaire surveys was
264 coordinated between three research team members and project management staff for each site
265 visit. At the beginning of each site survey, all employees were explained with the purpose of
266 the study and ensured that no personal or company information would be included. Each
267 question was explained to survey participants to ensure no vagueness or confusion. For
268 example, the high intensity of incentives described in the indicator of X7 in Table 1 meant
269 the frequency and amount of cash award for employees’ excellent safety performance. A
270 larger amount of cash award or a more frequent award would mean a higher intensity. During

271 the site survey, participants were further encouraged to ask for clarification if anything in the
272 questionnaire was unclear to them. They were also made aware that they could withdraw the
273 survey at any time.

274 Among the totally 380 questionnaires received through site surveys, 326 of them were
275 found valid after excluding incomplete questionnaires or those with the same Likert-scale
276 scores for all indicators within the same category (e.g., safety education investment). About
277 55% of the survey population was construction workers and the remaining 45% came from
278 crew foremen or other site management personnel (e.g., safety manager, superintendent, etc.).
279 Nearly 60% of them had over 10 years' site experience. The detailed demographic
280 information of the survey participant sample is provided in Table2.

281 <Insert Table 2 here>

282 ***Structural Equation Modeling Approach***

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

296 (Suhr 2006). EFA has been traditionally adopted to explore the possible underlying factor
297 structure of a set of measured variables without preconceived structure on the outcome (Child
298 1990). EFA KMO (i.e., Kaiser-Mayer-Olkin) and Bartlett sphere test were introduced in EFA
299 for the validity analysis. KMO measures the amount of a variance shared among the
300 indicators which are designed to measure a latent variable (Shan et al. 2018). The KMO value
301 higher than 0.5 would be considered acceptable (Kaiser 1974). The SEM was later conducted
302 to analyze the loading factors and path coefficients between different factors. The model-fit
303 test following the guide provided by Wu (2009) was performed to evaluate the SEM
304 outcomes. These measurements for Goodness-of-fit of SEM are defined in Table 3, where the
305 ideal numerical range of each measurement is provided. More detailed explanations of these
306 indices in Table 3 can be found in Hox and Arnhem (1998), Kaplan (2001), and Shadfar and
307 Malekmohammadi (2013).

308 <Insert Table 3 here>

309 **Results**

310 *Initial validation of data collected from site questionnaire surveys*

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

312 <Insert Table 4 here>

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

319 <Insert Fig.3 here>

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

322 Fig.2 was conducted and presented in Table 5.

323 <Insert Table 5 here>

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

326 ***Model modification***

327 The modification of the initialized model in Fig.3 should not only meet the statistical
328 requirements shown in Table 3, but should also make the theoretical sense in construction
329 safety management. These two criteria (i.e., statistical and theoretical aspects) were both
330 considered in the modification process. When the Goodness-of-fit test did not yield
331 satisfactory outcomes, either model building or model trimming should be applied to modify
332 the model. As guided by David Garson and Statistical Associates Publishing (2015), the
333 model building approach by adding paths based on the theoretical sense and the MI (i.e.,
334 Modification Indices) was implemented to improve the Goodness-of-fit. According to Wu
335 (2009), a path could be added for a pair of indicators whose MI value is over 4.0. Following
336 this initial test, several pairs of indicators shown in Fig.3 were found with relatively large MI
337 values, such as e12 and e13 with the MI value at 21.584, as well as e22 and e23 (MI value at
338 16.408). From the theoretical sense according to the researchers' prior construction safety
339 research (e.g., Cao et al. 2018), using PPE could increase construction workers' safety
340 awareness towards unsafe behaviors of co-workers. Similarly, workers' active demonstration
341 of safe operation was correlated to their participation in safety meetings. Therefore, similar
342 pairs of indicators with higher MI values validated from the theoretical sense were added
343 with paths in the modified model as seen in Fig.4.

344 <Insert Fig.4 here>

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

347 <Insert Table 6 here>

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

357 <Insert Table 7 here>

358 All path coefficients higher than 0 and p values below 0.05 indicated that all the four
359 safety investment factors were significantly correlated to the overall safety investment, which
360 further significantly contributed to safety cognition, and finally behavioral safety
361 performance. The path coefficients displayed in Fig.4 quantified the significance level of
362 each investment category to the overall safety investment. Safety incentives are found with
363 the strongest correlation to the overall safety investment with the path coefficient at 0.98,
364 followed by PPE investment (0.92), and safety education investment (0.89). Safety insurance
365 was identified as the least significant investment category, with the path coefficient at 0.75.
366 The modified model displayed in Fig.4 and Table 7 inferred that although safety investments
367 had directly significant effects on behavioral safety performance, these direct effects were
368 less significant (p values at 0.047 and 0.001 respectively) compared to the significance levels
369 of other paths in Table 7. In comparison, safety investments turned out with stronger
370 correlation with safety cognition with the path coefficient at 0.90. Safety cognition was
371 further significantly connected to behavioral performance. Specifically, safety cognition had
372 a stronger correlation to behavioral participation with the path coefficient at 0.67 compared to

373 its correlation with behavioral conformance (0.52). It was inferred that safety cognition
374 worked as a vehicle that bridged safety investments and behavioral performance. All the four
375 investment categories were found with significant correlations to safety cognition, which was
376 found significantly affecting the two main behavioral performance factors.

377 **Discussion**

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

391 The social psychology theory described by Baron and Kenny (1986) indicated that the
392 stressor was input variables that could affect individuals' behavioral outcomes. Applying the
393 social psychology theory into construction safety management, the stressor could be site
394 conditions (e.g., tight project schedule) that affect employees' decision of whether or not to
395 behave riskily in order to achieve certain desires. Man et al. (2017) and Feng (2019) stated
396 that these desires included saving time and effort, or gaining more income. Gaining more
397 income in less working time was identified as one of the major causes of construction

398 workers' unsafe behaviors (Feng, 2019). Therefore, safety incentive was defined as one
399 investment category in this study to address employees' desire to gain more income. It was
400 verified that incentive had the highest correlation to the overall safety investment compared
401 to three other categories of investments (i.e., insurance, education, and PPE).

402 The social behavioral theories proposed by Deci and Ryan (1985) and Ryan and Deci,
403 (2000) revealed that human behaviors were driven by a variety of motivations and the
404 motivation-initiated behaviors aimed to satisfy the innate psychological desire. This desire
405 was a necessary but not a sufficient condition for employees to conduct risky behaviors.
406 Construction employees might have different motivations to behave unsafely, such as being
407 social and demonstrating self-capability (Choudhry and Fang 2008; Man et al. 2017). Lack of
408 safety knowledge or biased attitudes towards safety could drive these motivations towards
409 unsafe behaviors among newer employees. But for more experienced employees, over-
410 confidence of their own capability could also cause risky behaviors (Han et al. 2019a). It is
411 hence suggested that periodic safety training and education be carried out to construction
412 employees at different experience levels (Han et al. 2019b). Intervening construction workers'
413 motivation (e.g., gaining more income) towards unsafe behavior through education is part of
414 safety investment. Investments in safety education is needed besides incentives to correct
415 employees' biased safety perceptions or attitudes, and to enhance their safety knowledge (e.g.,
416 proper use of PPEs). Examples of safety education investments include organizing periodic
417 safety workshops, implementing safety programs, and hiring safety professionals for site
418 monitoring, etc. Therefore, investments in safety education or training is another critical
419 factor affecting the behavioral performance of site employees.

420 Besides safety incentives and education/training, safety insurance and PPE costs are two
421 other investment categories affecting employees' behavioral performance. The Risk
422 Homeostasis Theory (Wilde 1982) stated that individuals tend to take more risks if they had a

423 stronger sense of safety. Klen (1997) further showed that workers behaved more riskily with
424 PPEs. However, researchers in this study do not aim to deny the importance of PPE, but
425 emphasize that the stressor (e.g., PPE) does not necessarily lead to improved behavioral
426 performance. Instead, the mediating effect through safety cognition could bridge the
427 investment in PPE and employees' behavioral outcomes. Individuals' safety cognition could
428 be enhanced through proper safety education.

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

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

444 It should be noticed that the tangible and intangible features of these four investment
445 categories are defined from the perspective of site employees, depending on whether the
446 investment items could be directly sensed by employees. This study implies the gap between
447 employees' safety climate and the organizational safety culture. From the employer or the

448 organization's perspective, all of the four investment categories are actually tangible, as the
449 organization can directly see the financial expenditure for purchasing PPE, insurance for
450 employees, incentives, and training. Nevertheless, employees would have different
451 perceptions towards the four investment categories. They would generally view incentives as
452 a more tangible category because they could gain extra income. In contrast, insurance that
453 their employer purchase for them might not be well noticed or even ignored. This gap
454 between individual employees and the organization leads to further research on bridging
455 individual needs and organizational strategies through mediators such as safety cognition.

456 **Conclusion**

457 This study adopted four main safety investment factors (i.e., categories), namely safety
458 education, personal protection equipment (PPE), safety incentive, and safety insurance.
459 Through site questionnaire surveys and Structural Equation Modeling approach, these four
460 categories were investigated of their correlation to site employees' safety cognition and
461 behavioral performance. All the four investment categories were found positively
462 contributing to the overall safety investment, which was found significantly affecting site
463 employees' safety cognition and behavioral performance. Safety cognition was also found
464 positively contributing to the behavioral performance, especially behavioral participation.
465 Among the four investment categories, the more tangible safety investment (i.e., incentives)
466 was found with the highest correlation to the overall safety investment. In contrast, the
467 intangible investment categories (e.g., insurance) were perceived by employees with lower
468 significance. The current findings indicate that there is a mediator (i.e., safety cognition) to
469 bridge investments on employees' safety and the behavioral performance. This study
470 contributes to the body of knowledge both practically and academically. Practically, it
471 provides insights for construction enterprises on the effects of safety investments on
472 enhancing employees' behavioral safety performance, as well as the significance of different

473 investment categories towards employees' behavioral performance. Specifically, employers
474 need to realize that these investment categories (e.g., education) which are all tangible at the
475 organizational level, may be perceived differently by individual employees. Employers are
476 suggested to have balanced safety investments between tangible (e.g., incentives) and
477 intangible (e.g., insurance) categories. Academically, the current findings lead to further
478 research on how different categories of safety investments would affect employees'
479 behavioral safety performance with safety cognition as the vehicle. A positive safety
480 cognition embedded in the site safety climate and organizational safety culture is a key
481 mediator to bridge safety investments and behavioral performance.

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

492 **Data Availability Statement**

493 Data generated or analyzed during the study are available from the corresponding author
494 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.	

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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

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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
<i>p</i>	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

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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

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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

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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

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

Path	Estimate	Standard Error	Critical Ratio	<i>p</i>	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

1005 Note: 1.* denotes that $p < 0.05$; **denotes $p < 0.01$; ***means $p < 0.001$; 2. Following the guide of Wu
 1006 (2009), the estimate for safety education investment correlating to safety investment is standardized as 1 to
 1007 run the significance tests for other paths in Table 7.
 1008