Research Article

Tunnel Construction Workers' Cognitive Biases and Unsafe Behaviors: The Mediating Effects of Risk Perceptions

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The poor safety performance of the construction industry is a global concern. Workers' unsafe behaviors (WUBs) are viewed as critical causes of construction accidents. Thus, it has been a leading research topic to identify antecedents of WUBs and establish reliable models to explain WUBs. Cognitive biases (CBs) are salient antecedents of WUBs. However, the relationships between CBs and WUBs are not further explored in construction safety management. As such, this study selected three prevalent CBs, i.e., availability bias (AB), confirmation bias (FB), and overconfidence, and investigated the relationships between the three CBs and WUBs and the functions of RPs in these relationships among tunnel construction workers. We established six multiple regression models. Research results show that CBs can directly influence RPs and WUBs, RPs are antecedents of WUBs, and the mediating effect of RPs on the relationships between CBs and WUBs is salient. In detail, AB and FB explain more ERP and overconfidence explains more BRP. AB and FB indirectly influence more WUBs through ERP, while overconfidence indirectly affects more WUBs through BRP. The study provides a novel theoretical paradigm for conceptualizing CBs and their relationships with RPs and WUBs. The research results can also guide managers to take debiasing measures to decrease workers' unsafe behaviors on the construction site.

1. Introduction

The construction works have always been criticized for high injury and fatality rates across the world, and construction accidents caused huge losses to the government, industry, enterprises, and the workers themselves [1–3]. According to the statistic of China's Ministry of Housing and Urban Rural Development (MHURD), 773 accidents resulted in 904 deaths in the construction and municipal engineering sector in 2019 [4]. Similar statistics were also settled in other countries or regions such as the U.S. where 39.7 thousand cases occurred in building construction in 2018 [5]. In Hong Kong, the construction industry had 2,974 accidents and 16 deaths in 2019 [6]. In Singapore, the Workplace Safety and Health (WSH) reported 13 fatal injuries and 121 major injuries in the construction industry in 2019 [7]. Among the different types of construction works, tunnel construction works are with higher safety risks [8, 9]. The reasons are that these works are often carried out in complicated geological and hydrological conditions and safety risks in these works are characterized with imperceptibility, complexity, and instability [10]. As such, safety problems in tunnel construction should drive more researchers' concerns.

Previous literature identified numerous factors that potentially cause construction accidents [11–13]. Of these factors, workers' unsafe behaviors (WUBs) are the most salient [11, 14]. Therefore, identifying the potential contributing factors to WUBs and then designing potent programs to cultivate workers' safety behavior are leading research topics in construction safety management [15–17]. Unsafe behaviors are not only the results of response process influenced by wide ranges of social, organizational, and management factors

[18–21], but also the results of individuals' decision-making processes affected by self's psychological status or features [15, 22–25]. Cognitive biases (CBs) are such a type of psychological factors that critically influence individuals' decision-making process of unsafe behaviors [25–27]. The concept refers to "systematic information-processing shortcuts that result in judgment errors" [28]. Prior studies pointed out that CBs could bring about managers' risk-taking behaviors. The reason is that different types of CBs can cause lower-level risk perceptions (RPs) and then lead to their risky decision-making [29–31]. As for the construction workers, Low et al. [26] simply highlighted that CBs as a whole can induce WUBs; however, more questions about the functions of CBs on WUBs are also triggered. For instance, do different types of CBs exert different effects on WUBs? And can RPs work as mediators in the relationships between CBs and WUBs as they do on managers' behaviors? Both questions need further examination.

As such, this study focuses on the aforementioned questions and further reveals the mechanism by which CBs influence WUBs. We selected three significant cognitive biases, namely, availability bias (AB), confirmation bias (FB), and overconfidence. The aims of this research are (1) to examine the relationships between the three CBs and WUBs and (2) to evaluate the mediating effects of RPs on the relationships between CBs and WUBs. The study can enrich the knowledge of CB and workers' safety behavior research. In addition, it also can help project managers and psychologists to design safety programs to improve worksite safety management.

2. Literature Review and Conceptual Model

2.1. CBs and Their Relationships with WUBs. CBs refer to a wide range of recurring reasoning tendencies that can cause deviations from the realistic facts [32, 33]. These psychological tendencies indicate human's systematic analysis shortcuts in information-processing [28]. The term was initially introduced by Tversky and Kahneman [34] and they identified three CBs, including representativeness, availability, and adjustment and anchoring. Further, Kahneman [35] examined the origin of CBs. He differentiated human's thinking into two systematic processes: systematic process one depends on heuristics that were characterized with unconsciousness, effortlessness, intuitiveness, and inclination to biases; on the contrary, systematic process two relies on conscious, effort-cost, more rational, and statistical reasoning [34]. And he highlighted CBs often generate in the systematic process one [35], although follow-up researchers found that other factors, such as emotion and social influence, can also lead to CBs [33].

More researchers introduced CBs to their disciplines and conducted salient investigations including health-caring [36], management [29], forensic [37], software engineering [33], and strategic decision-making [32]. Thus, over 200 CBs have been identified in previous studies [33]. Fleischmann [38] proposed a taxonomy of CBs and divided them into eight categories, including interest biases, stability biases, action-oriented biases, pattern recognition biases,

perception biases, memory biases, decision biases, and social biases. The authors investigated the construction workers' CBs and identified three critical CBs in their safety judgment. They are AB, FB, and overconfidence. AB refers to a propensity that individuals overestimate the probabilities associated with events causing them to give excessive weightage on the information available leading them to err. FB is viewed as an inclination that personnel tend to misinterpret new information to support their prior beliefs. Overconfidence can be defined as an unwarranted faith in one's reasoning, judgments, and abilities in decision-making [28, 39].

According to the definition of CBs, prior studies demonstrated that CBs can cause the incorrect understanding of the situation and the self and then lead to improper behaviors [25, 29]. In detail, AB manifests that individuals interpret the context relying on the information that they are easy to recall. And the easy-to-recall information is always limited and induces erroneous and superficial behavior decision-making [33]. FB manifests that an individual confirms a new situation using the experienced ones; thus, the same behaviors, however, lead to unsatisfied safety results instead. Overconfidence manifests irrational confidence to handle confronted risks, which always leads to risk-taking behaviors [40]. As for the construction workers, no research has been found focusing on the relationships between the three CBs and unsafe behaviors. However, based on the above analysis, we can posit that there exist negative relationships between the three CBs and WUBs.

(i) Hypothesis (Ha1). AB is positively associated with construction WUBs

(ii) Hypothesis (Ha2). FB is positively associated with construction WUBs

(iii) Hypothesis (Ha3). Overconfidence is positively associated with construction WUBs

2.2. Risk Perceptions and Their Mediating Roles. Risk perception gradually draws scholars' attention in construction safety research [15]. The concept was initially proposed in social sciences research in the 1980s, most of which focused on judgment and decision-making [41]. Although no consistent and explicit definitions were documented in the existing literature, a widely accepted definition of RP is individuals' subjective judgment of risk [42–44]. Slovic et al. [43] further highlighted that the subjective judgment processes are complicated and influenced by diverse factors, including individual's beliefs, attitudes, feelings, social and cultural values, and dispositions when assessing risks or hazards. The dimensions of RP are the bases to evaluate this concept. Sjöberg [45] pointed out that individuals' intuitive risk judgment comprises two components, i.e. the cognitive component and the affective component. Earlier research demonstrated more concerns on the cognitive aspects, including probability (likelihood) of the risky events and the consequences (severity) the risky events caused

[46, 47]. Recently, researchers argued that the affective aspects should also be considered. For instance, Man et al. [48] developed a novel measurement for construction workers' RPs and validated three dimensions of the RPs, namely, probability, severity, and worry and unsafe.

RPs can be influenced by a wide range of psychological, social, institutional, and cultural variables, such as safety climate, social pressure, occupational features, and demographic characteristics [43, 49, 50]. Of these variables, CBs are salient antecedents of RPs [30, 51, 52]. In water security research, Kosovac and Davidson [52] validated that CBs are associated with lower risk scores. Zaiane and Moussa [53] argued that overconfidence and illusion of control reduced RPs when managers start a venture. According to the perceptive objects, we divided RP into two types, namely, environmental risk perception (ERP) and behavioral risk perception (BRP). ERP is a type of RP pertaining to natural and management environment, and BRP focuses on individuals' behaviors. Thus, we posited that the three CBs (i.e., AB, FB, and overconfidence) exert negative effects on RPs.

    (i) Hypothesis (Hb1). AB is negatively associated with ERP

    (ii) Hypothesis (Hb2). FB is negatively associated with ERP

    (iii) Hypothesis (Hb3). Overconfidence is negatively associated with ERP

    (iv) Hypothesis (Hb4). AB is negatively associated with BRP

    (v) Hypothesis (Hb5). FB is negatively associated with BRP

    (vi) Hypothesis (Hb6). Overconfidence is negatively associated with BRP

Individuals' RPs guide the risk decision-making processes, and thus, erroneous and deviated RPs often lead to improper behaviors [49]. Existing studies in construction safety management demonstrated that RPs were predictors of WUBs [15, 26, 54]. For instance, Bohm and Harris [46] found that RPs were linked to driver's risk-taking behaviors. Xia et al. [15] further argued that RPs could act as job hindrance or job challenge and solely validated that RPs can be job hindrance that are negatively related to safety behaviors. Therefore, we posit that this paradigm also can be applied to workers during tunnel construction and there exist negative relationships between RPs and WUBs.

    (i) Hypothesis (Hc1). ERP is negatively associated with WUBs

    (ii) Hypothesis (Hc2). BRP is positively associated with WUBs

Based on the abovementioned hypotheses, we posit that RPs can be mediators in the relationships between CBs and WUBs. In detail, the hypotheses below can be drawn.

    (i) Hypothesis (Hd1). ERP mediates the relationship between AB and WUBs

    (ii) Hypothesis (Hd2). ERP mediates the relationship between FB and WUBs

    (iii) Hypothesis (Hd3). ERP mediates the relationship between overconfidence and WUBs

    (iv) Hypothesis (Hd4). BRP mediates the relationship between AB and WUBs

    (v) Hypothesis (Hd5). BRP mediates the relationship between FB and WUBs

    (vi) Hypothesis (Hd6). BRP mediates the relationship between overconfidence and WUBs

Therefore, we hypothesized a conceptual framework for this study (see Figure 1).

3. Research Method

3.1. Questionnaire Design and Participations. The questionnaire was developed based on five-point Likert scales. The whole questionnaire consisted of four sections. Section *A* was utilized to collect the demographic information of the surveyed workers, including age, enterprise type, education level, and tenure. Section *B* was used to measure AB, FB, and overconfidence. The selected items were modified based on the prior studies [55, 56]. Section *C* was designed to measure RPs and scale items were adapted from the existing research [15, 48]. In section *D*, seven items were used to capture WUBs. These items are the discussion results from eight experienced experts in tunnel construction management. Items in Sections *B*, *C*, and *D* are presented in Table 1.

This questionnaire was administered to tunnel construction workers in four projects, including tunnel engineering in Zhengzhou-Wanzhou railway, Metro Line 9 of Chongqing, and Metro Line 6 of Changsha. The survey was conducted by authors from July 2019 to September 2019. In order to include more construction workers, the survey was conducted with confidentiality and anonymity, such that these workers can express their true feelings. During this period, 320 questionnaires were released, and finally, 237 valid respondents were collected (odd = 74.1%). The demographic information of these respondents is statistically presented in Table 2.

3.2. Data Analysis Procedures. We designed multi-step analytical processes on the collected data using Statistical Package for Social Science (SPSS) 23.0 software [57]. Firstly, Cronbach's alpha was selected to test the reliability of the data [58, 59]. Then, six multiple regression models were established to stepwise-examine the impacts of CBs and RPs on WUBs. The models and corresponding explanations are presented in Table 3.

4. Data Analysis

4.1. Date Preprocessing. The descriptive statistics, reliability, and inter-correlations of all the variables are presented in Table 4. All the Cronbach's alpha values are greater than
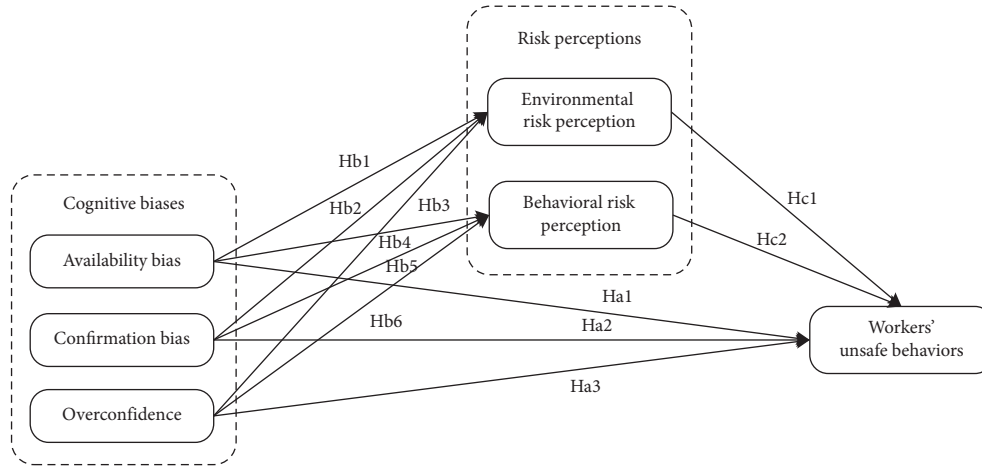
Figure 1: The hypothesized conceptual framework.

Table 1: Measurement items for CBs, RPs, and WUBs.

Variables	Measurement items
Availability bias	I think coworkers' unsafe behaviors can be used for reference if the behaviors did not cause accident, because they are more convenient.
	I can continue to adopt unsafe behaviors as long as no accidents were caused, because these behaviors are more convenient.
	I always think there will be no accidents because no accidents occurred in the past few months.
	I think they will handle the events because previous emergencies have been properly resolved.
Confirmation bias	My experiences tell me it is okay even though not wearing the PPE in some contexts. So, I cannot wear the PPEs because the PPEs make me inconvenient.
	My experiences tell me it is okay, even though slightly overloading the machine. So, I can overload the machine when we need to rush to work.
	Violating some regulations can hardly cause accidents. So, I am willing to take slight risks because these behaviors can be energy-saving.
	Some unrecommended behaviors hardly cause accidents. So, I am willing to take slight risks when we need to rush to work.
Overconfidence	I can handle the works better and faster than my coworkers.
	I am very skillful and can handle all unexpected situations even though I violate the regulations.
	I am very familiar with the environment and can run away from risky situations even though I violate the regulations.
	I can handle all difficulties encountered during tunnel construction.
Environmental risk perception	My work is prone to safety accidents.
	My job can be life-threatening.
	There are uncontrollable risks in my work.
Behavioral risk perception	My unsafe behaviors have high probabilities of causing a safety incident.
	My unsafe behaviors are likely to cause huge losses.
	My unsafe behaviors are easily discovered and I will be punished for them.
	My unsafe behaviors can result in bad consequences that will affect my follow-up works.
Workers' unsafe behaviors	I may ignore the warning signs and perform safety violations.
	I may wear a safety helmet in a non-standard way.
	I may use tools and equipment with slight safety hazards.
	For the convenience of work, I may use cargo transportations.
	In order to catch up with the construction period, I may overload the mechanical equipment for a long time.
	I may climb and sit at unsafe positions.

0.7, indicating that all the variables have higher internal consistency [57]. Unsafe behaviors are still prevalent among tunnel construction workers (mean of WUBs = 2.43). All CBs are at higher levels (all values > 2.44) and of the three workers' CBs, overconfidence has the highest score and FB has the lowest score. The workers' RPs need further improvement, and workers perceive more behavioral risks than environmental risks (mean of BRP > mean of ERP). In general, the relationships between CBs, RPs, and WUBs are statistically significant. According

TABLE 2: Descriptive statistic of the respondents' demographic information.

Variables	Values	Numbers	Percentages
Age	18–25	82	34.60
	26–30	64	27.00
	31–40	56	23.63
	41–50	21	8.86
	>50	14	5.91
Enterprise types	General contractors	119	50.21
	Subcontractors	49	20.68
	Labor providers	42	17.72
	Others	27	11.39
Education level	Junior high school and lower	17	7.17
	Senior high school	102	43.04
	Specialty college	94	39.66
	Bachelor or higher	24	10.13
Tenure	<5 years	75	31.65
	5–15 years	87	36.71
	15–25 years	43	18.14
	>25 years	32	13.50

TABLE 3: The six models and their explanation.

Models	Model explanations	Objects	Hypotheses
Model 1	AB, FB, and overconfidence were selected as the independent variables. WUBs were the dependent variable.	Test the relationships between CBs with WUBs and evaluate the significance of the three CBs in explaining WUBs.	Ha1; Ha2; Ha3
Model 2–1	AB, FB, and overconfidence were selected as the independent variables. ERP was the dependent variable.	Test the relationships between CBs with ERP and evaluate the significance of the three CBs in explaining ERP.	Hb1; Hb2; Hb3
Model 2–2	AB, FB, and overconfidence were selected as the independent variables. BRP was the dependent variable.	Test the relationships between CBs with BRP and evaluate the significance of the three CBs in explaining BRP.	Hb4; Hb5; Hb6
Model 3	ERP and BRP were selected as the independent variables. WUBs were the dependent variable.	Test the relationships between RPs with WUBs and evaluate the significance of the two RPs in explaining WUBs.	Hc1; Hc2
Model 4–1	AB, FB, overconfidence, and ERP were selected as the independent variables. WUBs were the dependent variable.	Test the mediating effect of ERP in the relationships between CBs and WUBs	Hd1; Hd2; Hd3
Model 4–2	AB, FB, overconfidence, and BRP were selected as the independent variables. WUBs were the dependent variable.	Test the mediating effect of BRP in the relationships between CBs and WUBs.	Hd4; Hd5; Hd6

TABLE 4: Means, SD, reliability, and intercorrelations of all the variables.

Variables	Means	S.D.	Cronbach's alpha	1	2	3	4	5	6
Availability bias	2.65	0.80	0.820	1	—	—	—	—	—
Confirmation bias	2.44	0.80	0.871	0.415*	1	—	—	—	—
Overconfidence	3.21	0.70	0.894	0.326	0.367	1	—	—	—
Environmental risk perception	3.38	0.79	0.856	−0.468**	−0.424**	−0.228**	1	—	—
Behavioral risk perception	3.77	0.65	0.862	−0.228**	−0.323**	−0.442**	0.387*	1	—
Workers' unsafe behaviors	2.43	0.82	0.911	0.416**	0.342**	0.437**	−0.477**	−0.521**	1

Notes: $^{*}p < 0.05$; $^{**}p < 0.01$.

to the inter-correlations, it seems that ERP is more associated with AB and FB, BRP is more linked to overconfidence, and WUBs are more influenced by RPs when compared to CBs. Besides, although not so significant, there exist statistical linkages between AB and FB, and between ERP and BRP.

4.2. Evaluating the Direct Influential Impacts. This study established four models to validate the direct relationships between CBs, RPs, and WUBs and the descriptions of the four models are presented in Table 3. After conducting multiple regression analyses in SPSS, the statistical results are shown in Table 5.

Model 1 was employed to examine the direct relationships between the three CBs (AB, FB, and overconfidence) and WUBs. Based on the analytical results (see Table 5), the direct relationships between CBs and WUBs are significant ($\chi 2 = 46.74$, $p < 0.001$). AB, FB, and overconfidence totally interpret 42.2 percent of WUBs. Besides, each of the CBs is positively correlated to WUBs, and thus, hypotheses Ha1–Ha3 are validated. Of the three CBs, FB is more related to WUBs ($\beta = 0.438$).

Model 2–1 and Model 2–2 were used to examine the direct relationships between CBs and RPs. As shown in Table 5, the direct relationship between AB, FB, overconfidence, and ERP was significant ($\chi 2 = 27.19$, $p < 0.001$). AB, FB, and overconfidence totally interpret 25.0 percent of ERP. Each of the CBs is negatively associated with ERP, and thus, hypotheses Hb1–Hb3 are validated. However, when compared to AB and FB, the relationship between overconfidence and ERP is less significant and also overconfidence explains less ERP ($p > 0.05$; $\beta = 0.264$). Besides, the direct relationship between AB, FB, overconfidence, and BRP was significant ($\chi 2 = 31.06$, $p < 0.001$). AB, FB, and overconfidence totally interpret 27.3 percent of BRP. Each of the CBs is negatively associated with BRP, and thus, hypotheses Hb4–Hb6 are validated. However, when compared to overconfidence, the relationship between AB, FB, and ERP is less significant, respectively, and they also explain less BRP ($p = 0.09$, $\beta = 0.277$; $p = 0.06$, $\beta = 0.293$).

Model 3 was constructed to examine the direct relationships between RPs and WUBs. According to Table 5, the direct relationships between RPs and WUBs are significant ($\chi 2 = 69.09$, $p < 0.001$). ERP and BRP totally interpret 34.7 percent of WUBs. Both RBs are negatively correlated with WUBs, and thus, hypotheses Hc1–Hc2 are validated. Besides, when compared to ERP, BRP interprets more WUBs ($\beta = 0.434$).

4.3. Evaluating the Mediating Effects. Two regression models were further established to evaluate the mediating roles of RPs in the relationships between CBs and WUBs (more explanation of models can be seen in Table 3). The analytical results are presented in Table 6.

Model 4–1 was employed to examine the mediating roles of ERP in the relationship between CBs and WUBs. As can be seen in Table 6, the mediating effects of ERP are salient ($\chi 2 = 26.97$, $p < 0.001$). CBs together with ERP totally interpret 53.2 percent of WUBs. According to values of $\Delta\beta$, the mediating effects of ERP on the relationships between AB, FB, and WUB are much stronger, which is consistent with the analyses about Model 2–1.

Model 4–2 was constructed to test the mediating effects of BER on the relationships between CBs and WUBs. As shown in Table 6, the mediating effects of BRP are salient ($\chi 2 = 29.38$, $p < 0.001$). CBs together with ERP totally interpret 49.3 percent of WUBs. Besides, when compared to AB and FB, the mediating effects of ERP on the relationship between overconfidence and WUB are much stronger, which is consistent with the analyses about Model 2–2.

5. Discussion

5.1. The Construction Workers' BCs, RPs, and WUBs. This study surveyed 237 tunnel construction workers on their BCs, RPs, and WUBs in China. The statistical results demonstrate that CBs and WUBs are common phenomena among these workers and their RPs also need further improvement. These results are consistent with the prior studies. Unsafe behaviors or risk-taking behaviors are still critical factors of construction accidents in China [14, 60]. Han et al. [61] pointed out that construction workers often adopted habitual unsafe behaviors on China's construction worksite and this type of behaviors is characterized by lower risks, higher occurrence, and stability. In general, construction workers show lower risk perception [54, 62, 63]. Xia et al. [54] argued that RPs are salient factors contributing to construction accidents. Scholars interested in this topic still focus on the measurement of RPs and their effects on safety behaviors. Existing studies cannot provide a resilient model to explain the lower construction workers' RPs. Few studies have been found on the construction workers' CBs and this area needs more researchers' exploration.

5.2. Relationships between BCs, RPs, and WUBs. This study validated that there exist direct relationships between BCs, RPs, and WUBs. Construction workers' BCs can directly influence WUBs. This finding is consistent with prior studies in other fields [32, 33]. Low et al. [26] included cognitive bias as an antecedent in their construction workers' risk-taking behavior model. Igual and Santamaría [64] highlighted that overconfidence can lead to irrational investor behaviors. In this paper, we further selected three CBs, i.e., AB, FB, and overconfidence, and found that they all directly influence WUBs. Workers' CBs also can be antecedents of workers' RPs. This finding is consistent with prior studies on team decision-making [28] and venture-starting [53, 65]. In detail, we validated that AB and FB more likely influence ERP, and overconfidence more likely influences BRP. Two views might provide insight into this finding. Firstly, according to the definitions of AB and FB, these two CBs often occur when individuals make judgments on external events. And construction workers might often use this type of process to evaluate environmental risks. Secondly, as highlighted earlier, tunnel engineering is often situated in complicated environmental contexts. As such, workers are more likely overconfident in their internal ability or skills other than risk identification on the external environment.

Workers' RPs were tested to be salient factors of WUBs. The linkages have been documented in some previous studies [15, 49]. In this paper, RPs were divided into ERP and BRP and each of RPs is negatively associated with WUBs.

TABLE 5: Statistical results of four models for direct effects.

Variables	R^2	ΔR^2	F	β	t	Sig.
Model 1 (WUB as dependent variable)						
AB	0.422	0.411	46.739**	0.364	5.879**	0.000
FB	—	—	—	0.438	7.303**	0.000
Overconfidence	—	—	—	0.315	5.156**	0.000
Model 2–1 (ERP as dependent variable)						
AB	0.250	0.242	27.193**	−0.285	−5.345**	0.000
FB	—	—	—	−0.336	−3.849**	0.000
Overconfidence	—	—	—	−0.264	−4.351*	0.073
Model 2–2 (BRP as dependent variable)						
AB	0.273	0.268	31.062**	−0.277	−6.262*	0.094
FB	—	—	—	−0.293	−4.740*	0.065
Overconfidence	—	—	—	−0.323	−4.471**	0.000
Model 3 (WUB as dependent variable)						
ERP	0.347	0.344	69.092**	−0.302	−4.570**	0.000
BRP	—	—	—	−0.434	−6.971**	0.000

Notes: $^{*}p < 0.05$; $^{**}p < 0.01$.

TABLE 6: Statistical results of two models for mediating effects.

Variables	R^2	ΔR^2	F	β $(\Delta\beta)$	t	Sig.
Model 4–1 (WUB as dependent variable)						
AB	0.532	0.522	26.973**	0.273 (0.09)	5.596**	0.000
FB	—	—	—	0.357 (0.075)	6.943**	0.000
Overconfidence	—	—	—	0.295 (0.02)	4.973**	0.000
ERP	—	—	—	−0.243	−4.320	0.000
Model 4–2 (WUB as dependent variable)						
AB	0.493	0.490	29.379**	0.347 (0.017)	5.463**	0.000
FB	—	—	—	0.419 (0.019)	6.803**	0.000
Overconfidence	—	—	—	0.227 (0.088)	4.816**	0.000
BRP	—	—	—	−0.407	−6.367**	0.000

Notes: $^{**}p < 0.01$.

We also validated that RPs act as mediators in the relationships between CBs and WUBs. The mediating effects of RPs on the relationship between CBs and individuals' unsatisfied behaviors can also be found in other fields. The mediating effects can function at the individual level or the group level. For instance, CBs influence managers' risky behaviors by decreasing managers' risk perception [32]. In team decision-making, Houghton et al. [28] highlighted that group cognitive biases can cause deviated RP and then lead to improper risky behaviors. Different CBs indirectly influence WUBs through different patterns. The mediating effects of ERP on the relationships between AB, FB, and WUBs are stronger than those on the relationship between overconfidence and WUBs. However, the mediating role BRP plays in the relationship between overconfidence and WUBs is more salient than it does in the linkages between AB, FB, and WUB. The possible reasons are akin to these we highlighted earlier in explaining the relationships between CBs and RPs.

5.3. Implications for Theory and Practice.
This study provides a novel theoretical perspective on the relationships between CBs and WUBs, and the functions of RPs in these relationships. Unsafe behaviors are the salient factors contributing to construction accidents [14, 66]. As such, a plethora of studies have been focused on the antecedents of unsafe/safety behavior. Existing research has confirmed a wide range of factors influencing WUBs, including social capital [18], safety climate [67], leader-member exchange [68], risk perception [54], etc. Although Low et al. [26] highlighted that CBs were important factors of workers' risk-taking behavior, the relationships between CBs and WUBs were not further discussed. Construction workers are prone to influences from diverse CBs when they process safety information, and the relationships between different CBs and WUBs might be more complicated. In this study, we validated that the relationships between CBs and WUBs can be either direct or indirect. In detail, AB, FB, and overconfidence all can directly influence WUBs and indirectly influence WUBs through RPs. Besides, AB and FB indirectly affect WUBs more relying on ERP, and overconfidence indirectly affects WUBs more relying on BRP. This paper offers a novel theoretical reference for conceptualizing CBs and their relationships between RPs and WUBs.

This paper also can trigger the project managers' concern on CBs when making safety-related decisions. CBs are prevalent in workers' safety information-processing;

therefore, some debiasing measures should be taken, such as providing more detailed safety information and including more experts to help workers' safety information decision-making. RPs act as mediators in the relationships between CBs and WUBs, which indicates that managers can motivate workers' safety behavior by improving their safety risk perception. As such, conducting more safety training and cultivating positive safety climate both can be effective management strategies.

5.4. Research Limitations and Future Directions. This study has three limitations. The first concern is that the survey utilizes a self-administered technique to measure CBs, RPs, and WUBs, which can lead the retrospective data to be slightly sensitive and dubiously accurate. The second worry is that we just considered three CBs in this study. Many other CBs also influence workers' safety information-processing, such as anchoring and adjustment, framing effects, etc. This paper provides a preliminary investigation on CBs; follow-up researchers can deepen this research by including more CBs. The third limitation is that this study tried to give some possible assumptions on why different CBs influence WUBs through different RPs. The assumptions need further validations. We also suggest that more researchers can work on the contributing factors to the CBs, which can provide bases for debiasing.

6. Conclusion

This article provides a theoretical insight into the impacts of cognitive biases (CBs) on the workers' unsafe behaviors (WUBs) during tunnel construction. We selected three prevalent CBs, namely, availability bias (AB), confirmation bias (FB), and overconfidence, and examined the relationships between the three CBs and WUBs and the functions of RPs in these linkages. Several conclusions can be drawn from the aforementioned analyses.

Four multiple regression models were established to examine the direct relationships between CBs, RPs, and WUBs. CBs were validated as salient antecedents of WUBs and each of the three CBs is positively associated with WUBs. CBs can also be contributing factors of RPs. The relationships between AB, FB, and environmental risk perception (ERP) are more significant and overconfidence explains more BRP. Besides, the linkages between ERP, BRP, and WUBs were tested as significant.

Two other multiple regression models were further established to test the mediating effects of RPs. RPs were validated as mediators in the relationships between CBs and WUBs. However, the mediating roles of the two RPs are different. In detail, AB and FB can indirectly influence more WUBs though ERP, and overconfidence relies more on BRP.

The study was the first to examine the relationships between different CBs and WUBs in construction safety management. We also revealed the mediating effects of different RPs on the relationships between CBs and WUBs. The study can enrich the knowledge of CB and workers' safety behavior research. In addition, it also helps project managers and psychologists to design safety strategies to improve worksite safety management.

Data Availability

All data generated or used during the study are included within the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

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