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Risk Factors for Unsafe Behaviour of Construction Workers and Intervention Countermeasures

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Abstract: In recent years, safety accidents caused by unsafe behaviours have occurred, making it important to control the risk of unsafe behaviours among construction workers. This paper follows the guiding principles and research process of rooted theory research methodology, extensively collects case data and interview data related to construction workers' unsafe behaviours, and constructs a theoretical model of risk factors for construction workers' unsafe behaviours through open coding, spindle coding, selective coding and theoretical saturation tests. The results show that there are four risk factors for construction workers' unsafe behaviour. Three risk points for poor working conditions, inadequate personal protection and work behaviour violations build the risk factors for personal factors, one risk point for improper equipment operation builds the risk factors for human-equipment factors, two risk points for unsuitable weather and unsuitable operating environment build the risk factors for human-environment factors, and four risk points for excessive workload, poor work management, poor training management and poor team communication build the risk factors for human-management factors. The findings deepen the understanding and research on the risk of unsafe behaviours among construction workers and have positive theoretical and practical implications for preventing unsafe behaviours, reducing the spread of unsafe behaviours and reducing the risk of unsafe behaviours.

1. Introduction

The construction industry is one of the most serious industries in China in terms of safety accidents. Many accident causation theories regard workers' unsafe behaviour as a direct cause of safety accidents, so effective control of workers' unsafe behaviour is an effective means of reducing the occurrence of accidents. According to statistics, a total of 20,963 people died in various types of production safety accidents in 2022, and 549 production safety accidents occurred in housing and municipal works nationwide, with 622 fatalities.

In recent years, many scholars have extensively studied the risk of unsafe behaviours, and in 2018, Lang Huang et al [1] used psychological distance to study the formation of individual risk perception biases. In 2019, Ye Gui, et al [2] investigated the influence of three cognitive factors, such as construction workers' risk perception experience, risk-taking level, and action execution level, on their unsafe behaviour in full and incomplete information scenarios. In 2020, Ye Gui et al. identified seven types of individual factors and four types of environmental factors that affect the cognitive process failure of construction workers' unsafe behaviours, created a four-stage model of the causes of cognitive process failure, and used Matlab software to simulate the process of cognitive failure caused by multiple factors [3]. Chi Pengde et al [4] used Guqiao and Chenjiashan coal mines as research objects. They used the improved hierarchical analysis method and entropy weighting method to determine the weights of subjective and objective influencing factors, combined with the theory of unconfirmed measurement, to construct an evaluation system of riskiness indicators for miners' unsafe behaviour, and to analyse the influencing factors and evaluate the risk of miners' unsafe behaviour. An Yu et al [5] constructed a fuzzy Bayesian network (FBN) model of unsafe behaviour in university laboratories and applied model inference analysis to determine the main influencing factors of unsafe behaviour in university laboratories. Zhu Chen et al [6] established a Monte Carlo simulation (MCs) method of risk assessment model for unsafe actions of operators, studied the consequence values of their unsafe actions from a tripartite perspective, and used the sensitivity magnitude to analyse the degree of contribution of unsafe actions actions to the behavioural safety of the subject unit. Wang Ya Xian et al [7] established a risk assessment model based on Monte Carlo method for unsafe actions of accident personnel, and used Crystal Ball 11.1 software to analyse and simulate the risk of unsafe actions in three segments and to analyse the sensitivity and uncertainty of unsafe actions of personnel. Zhang Zichen et al [8] took the risk of unsafe behaviour as the research object, extracted unsafe behaviour from engineering historical accident data and finally constructed a complex network. Zhou Jianliang et al [9], in order to deeply explore the role relationship between personality traits, emotions and unsafe behaviours of construction workers, empirically tested the predictive role of personality traits and emotions on unsafe behaviours as well as the emotion regulation effect. Li Yang et al [10] used the Human Factors Analysis and Classification System (HFACS) and rooting theory to identify risk factors affecting workers' unsafe behaviour based on a combination of interview data and accident reports. The results showed that the risk factors for unsafe behaviour of workers in deep coal mines included environmental factors, organisational influences, unsafe supervision and miners' unsafe status, while the main manifestations of unsafe behaviour were errors and violations. Zhang Xiaoliang et al [11] constructed and optimised a behavioural risk assessment model for city gas accidents by analysing 90 unsafe actions in fatal city gas accidents, and finally used sensitivity analysis to obtain the degree of influence of unsafe actions on behavioural risk for each type of relevant party.

In summary, although the issue of behavioural risk has attracted much attention from scholars at home and abroad, the factors influencing the risk of unsafe behaviour are still not sufficiently studied from prevention results, so it is still important to apply qualitative research methods to identify the risk factors of unsafe behaviour through examples.

2. Study Design

2.1. Research Methodology

Since its introduction by Glaser and Strauss in 1967, the rooting theory has been refined and studied by a series of scholars, resulting in a complete set of research methods. Rooted theory is a bottom-up qualitative research method and this study is based on the perspective of construction workers, conducting research interviews with construction workers working on projects where safety incidents have occurred. Based on empirical materials such as interview data and case data, the comprehensive identification results were obtained through coding refinement, induction and extraction of categories, and series analysis of conceptual categories, with specific steps including:

(1) open coding; (2) spindle coding; (3) selective coding; and (4) saturation testing.

2.2. Data Sources

To ensure the validity and feasibility of this study, 20 construction sites were selected and workers were surveyed through questionnaires as to whether they worked at the sites where the safety incidents occurred, and these workers were selected for on-site visits. Twenty-five construction workers were interviewed for this study, of which four safety incidents were repeatedly described and one incident could not be confirmed, so 20 safety incident materials were recorded and the materials were supplemented with case data described on the official website.

3. Implementation Data Coding

3.1. Open Coding

Table 1: Open coding of construction worker unsafe behaviour risk case information.

Materials	Conceptualisation
April 17, 2007, "04.27" slope collapse in Xining, Qinghai Province	A1-1 Inexperienced, A1-2 Inadequate safety awareness, A1-3 Rash work
May 30, 2007, "05.30" trench collapse in Hefei, Anhui Province	A2-1 Lack of basic construction safety knowledge, A2-2 Lack of emergency rescue knowledge and blind self-help
Collapse of formwork support system in Zhengzhou, Henan Province, 6 September 2007	A3-1 Fluke, A3-2 Failure to listen to instructions, A3-3 Poor safety awareness, A3-4 Inadequate self-protection, A3-5 Inadequate safety education, A3-6 Turning the construction plan into a showpiece
Tower crane collapse, 10 October 2008	A4-1 Disregard of laws and regulations, A4-2 Failure to take safety precautions, A4-3 Unlicensed work, A4-4 Failure to inspect parts before installation
10 September 2011 "9-10" major building construction scaffolding collapse in Xi'an	A5-1 Operating Violations
On 13 December 2014, a fire broke out at a construction site on Zhongmai Road in Nanning's ASEAN Business District, causing a large amount of smoke	A6-1 Smoking, A6-2 Dry weather
July 24, 2016 Shortcut, illegal access caused accident	A7-1 Illegal erection of access road
August 6, 2016, "8-6" electrocution general production safety accident of the second engineering company of a group of China Railway Bureau	A8-1 Irregularities, A8-2 Failure to implement technical measures to prevent electric shock and safety precautions for temporary electrical equipment, A8-3 Dampness in the environment
January 23, 2019, "1-23" large tower crane collapse in Huarong Pearl Phase III Project, Huarong County, Hunan Province	A9-1 Serious Operational Violations
April 25, 2019, "4-25" construction hoist car fall major accident in Hengshui, Hebei	A10-1 Inadequate safety education, A10-2 Failure to carry out self-inspection as required
April 30, 2019 - Tower crane No. 5 collapses at a construction site in Chongqing	A11-1 Playing with mobile phones during working hours, A11-2 Violation of rules and regulations
May 16, 2019, Shanghai Changning District plant "5-16" collapse major accident	A12-1 Failure to take measures to maintain wall stability
3 March 2020, crane driver playing with mobile phone causes 1 person to be killed on the spot	A13-1 Playing with mobile phones during working hours, A13-2 Violation of rules and regulations
On 28 June 2020, a fall from height accident occurred in the second section of Huayao Longwan Phase III on Yongda Road, Limin Development Zone, Songbei District, Harbin City	A14-1 Failure to wear a helmet, A14-2 Poor safety awareness, A14-3 Violation of safety management rules, A14-4 Climbing ladders after rain
August 4, 2020 - Yulin migrant worker dies suddenly from overwork	A15-1 Long working hours
24 January 2021, General fall from height production safety accident	A16-1 Failure to reattach worn seat belt to safety harness, A16-2 Inadequate supervision
July 15, 2021, "7-15" major water seepage accident at Shijingshan Tunnel, Zhuhai Xingye Express (Southern Section) Project, Guangdong	A17-1 Unproven geology
21 July 2021, "7-21" general production safety accident involving a fall from height in Bazhong Economic Development Zone	A18-1 Poor safety awareness, A18-2 Ignorance of safety risks, A18-3 Violation of safety procedures
On 20 February of a certain year, three people fell without wearing seat belts and lost their lives	A19-1 Failure to wear a safety belt when working at height, A19-2 Failure to work in accordance with prescribed methods, A19-3 Lack of safety knowledge of workforce
22 June 2022, "6-22" general fall accident at Yado Hotel, MangoNet Building, Yuehai Street	A20-1 Poor safety awareness, A20-2 Improper operation

After initial analysis of the interview data and case data, this paper presents the original statements in the form of labels, summarising a total of 46 concepts, with the coding process shown in Table 1.

3.2. Scoping

By eliminating the 46 concepts that are repetitive or highly relevant, nine categories can be distilled. This is shown in Table 2.

Table 2: Scoping analysis of the risk of unsafe behaviour of construction workers.

Category	Concept
B1 working state	A6-1, A11-1
B2 workload	A15-1
B3 session violation	A3-6, A4-4, A7-1, A8-2, A10-2, A12-1, A17-1
B4 Personal Protection	A14-1, A16-1, A19-1
B5 working environment	A6-2, A8-3, A14-4
B6 Work Supervision	A16-2
B7 Equipment operation	A20-2
B8 Qualifications and Training	A1-1, A2-2, A4-3, A18-1
B9 Team Communication	A3-2

3.3. Spindle Coding

Based on the field interviews, site visits, literature review and the categories summarised above, the risk factors for construction workers' unsafe behaviours were coded into five main categories: Personnel factors, Person-Working Session factors (factors influencing the risk of construction workers' unsafe behaviours due to working sessions), Person-Equipment factors (factors influencing the risk of construction workers' unsafe behaviours due to mismatched working equipment), Person -environmental factors (factors influencing the risk of unsafe construction worker behaviour due to climatic conditions) and human-management factors (factors influencing the risk of unsafe construction worker behaviour due to organisational management), as shown in Table 3.

Table 3: Categories of factors influencing the risk of unsafe behaviour of construction workers.

Main Category	The scope of the influence relationship
Personnel factors	B1, B4
Human-work link factor	B3
Human-equipment factor	B7
Human-environmental factors	B5
Human-Management Factors	B2, B6, B8, B9

3.4. Selective Coding and Risk Identification

Table 4: Results of identifying risk factors for unsafe behaviour of construction workers.

<table>
<tr><th>Risks</th><th>Causes of risk</th><th>Risk points</th></tr>
<tr><td rowspan="4">Risk points for unsafe construction worker behaviour</td><td>Personal factors</td><td>Poor working conditions, inadequate personal protection, work behaviour violations</td></tr>
<tr><td>Human-equipment factor</td><td>Improper operation of equipment</td></tr>
<tr><td>Human-environmental factors</td><td>Unsuitable weather, unsuitable operating environment</td></tr>
<tr><td>Human-Management Factors</td><td>Excessive workload, poor work management, poor training management, poor team communication</td></tr>
</table>

A selective coding of risk factors is developed based on the main categories in conjunction with the mechanisms of unsafe behaviour occurrence. The personnel factor and the personnel-work link represent the interaction of personal factors in the work of construction workers and can be combined as personal interface factors, i.e. unsafe behaviour due to personal factors influencing the behavioural choices of construction workers. The personal factor is the internal primary cause of unsafe behaviour risk for construction workers, and the three areas of human-equipment factor, human-environment factor and human-management factor are the external primary causes of unsafe behaviour risk. The results of the construction workers' unsafe behaviour risk identification are shown in Table 4.

3.5. Saturation Test

Secondary coding of the raw data and interview data revealed no new conceptual categories, indicating that saturation of risk factors for unsafe construction worker behaviour identified by the rooting theory had been reached and that the interview data were complete and credible.

4. Risk Intervention Countermeasures for Unsafe Behaviour of Construction Workers

4.1. Raising Awareness of Worker Conditions

There is a need to understand the working conditions of frontline workers, organise work according to the workers' areas of expertise and make the best use of their talents, which can improve the efficiency of workers and also provide them with better remuneration for their work. Regularly issue personal protective equipment to construction workers in accordance with the Standard Form for the Issuance of Workers' Labour Protection Supplies, strengthen supervision of workers wearing personal protective equipment, and do a good job of recording, maintaining and servicing occupational protective equipment.

4.2. Strengthening Staff Training

To improve construction workers' awareness of protection and ability to respond to emergencies, training in basic occupational knowledge and safety techniques can be provided; for workers who violate behavioural rules and regulations, experiential safety education training can be provided to improve their hazard perception; for employees who operate equipment improperly, training courses can be conducted before workers use the equipment to ensure they are familiar with its operation.

4.3. Real-time Attention to Weather and Working Environment

In order to keep an eye on the weather and cooperate with the government to obtain accurate weather information, the construction company should set up a professional management department to avoid as much as possible the safety of workers caused by bad weather, and always adhere to the "safety first" guideline.

4.4. Optimisation of Site Equipment

Taking into account work efficiency, workload and work safety, some of the construction material handling should be replaced with highly automated auxiliary equipment, with additional mobile control functions, so that the intelligent control system for construction equipment is fully realised.

4.5. Strengthen Management and Communication

It can promote the construction of civilised construction sites, and thus improve the culture of safe production for all construction personnel, and establish demonstration sites for safe production and typical safe production teams. In the development of engineering construction, construction companies need to pay attention to communication and exchange between teams, using scientific communication methods to improve the development of teamwork and improve the reliability of work.

5. Conclusion

This paper uses rooting theory to systematically identify construction workers' unsafe behaviour risk factors and propose specific intervention countermeasures. The findings show that the risk factors of unsafe behaviour of construction workers mainly involve 10 risk points in four risk causes: personal, equipment, environment and management, including poor working condition, inadequate personal protection, work behaviour violation, improper equipment operation, unsuitable weather, unsuitable operating environment, excessive work load, poor work management, poor training management and poor team communication. Managers of construction companies at all levels should use this as a reference point for focused supervision. In addition, interventions to improve unsafe construction worker behaviour can be considered at five levels: worker status, worker training, work environment, site equipment and management and communication.

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