



Is Safety Training Important? Evidence from the Chinese Construction Accident Investigation Report

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ABSTRACT: The construction industry plays a significant role in social production, and ensuring construction safety remains an important and ongoing research topic. This study aims to address how to mitigate the occurrence of construction accidents and identify their causes through an analysis of investigation reports on construction accidents. The data set comprises the total number of construction safety accidents over the past ten years. A combination of constant ratios and random sampling is used to select construction accident reports for analysis. The thematic analysis method examines the indirect causes text of Chinese 226 construction accident investigation reports. The findings indicate that overall, training management needs more standardisation, and the training process often involves formalism, resulting in low effectiveness of safety training. Furthermore, there needs to be more safety awareness among construction workers. Importantly, the study establishes that safety training and education are the primary factors contributing to accidents on construction sites. The ineffectiveness of safety training emerges as the main cause of these accidents. This study offers valuable guidance for improving construction safety management practices.

Keywords: Safety training; Construction safety; Accident investigation reports; Thematic analysis;

1. INTRODUCTION

When considering work-related risk, the construction industry belongs to one of the most accident-prone industries, and addressing this situation represents a critical and long-term challenge. The focus on investigating safety accidents on construction sites is often related to human behaviour (Ismail et al., 2012; Muir & Thomas, 2004). Hence, focusing on human factors, such as people's behaviour at work, should help determine the potential factors leading to construction safety accidents. There is an almost universal agreement within safety management that human error is the primary cause of accidents (Li & Poon, 2013). Shappell and Wiegmann (2001) argue that to reduce the number of accidents, it is necessary to study and attach importance to human error; human factors such as negligence, carelessness, and lack of knowledge greatly increase the possibility of accidents; Training and experience enable construction workers to acquire the ability to identify and assess risks, which is among the key factors determining their behaviour and, consequently, their safety (Sacks et al., 2013). We may have to raise additional questions about site management, training and education deficits, and workers' attitudes (Abdelhamid & Everett, 2000).

A closely related question is: Raising the question: would safety training be important for construction site safety and reducing related accidents? Construction accident reports are a vital source for addressing this question. Researchers use data from government-issued construction accident investigation reports to analyse spatial and temporal factors related to accidents, and various accident ratios (Xu & Xu, 2021). They employ various models to predict the likelihood of different types of accidents (Meng et al., 2022). Cheng and Cao (2022) conducted an analysis of a large sample of Chinese accident investigation reports to establish a risk assessment factor model. Those studies enable the identification of key risk factors and high-risk chains in the evolution of the accident network. Furthermore, researchers have been able to pinpoint specific direct causes of accidents by conducting in-depth analyses of accident

reports. For instance, Huang and Hinze (2003) found that falls from heights and crane accidents were among the most frequent occurrences, while Haupt and Pillay (2016) examined accident costs. Researchers can obtain empirical evidence to achieve their research objectives by studying accident investigation reports.

This study aims to address how to reduce the occurrence of construction accidents and identify their root causes through comprehensive textual analysis of investigation reports on construction accidents. The data set comprises the number of construction safety accidents in each Chinese province over the past ten years. The findings indicate that overall, the training management needs to be more standardisation, and the training process often involves formalism, resulting in low effectiveness of safety training and a prevalent lack of safety awareness among construction workers. Importantly, the study establishes that safety training and education are primary factors contributing to accidents on construction sites. Our innovation lies in using text themes to analyse the indirect causes of construction accident investigation reports, as text theme analysis, to prove that management problems related to safety training are the primary causes of accidents. This study sheds light on the alarming ineffectiveness of safety training, which emerges as the principal cause of construction accidents. By analysing the information provided delving into by the construction safety accident reports, the researchers gain valuable insights into the precise role and significance of safety training in preventing accidents in the construction sector. This research seeks to contribute essential knowledge and evidence to guide policy-makers and stakeholders in implementing targeted measures to enhance safety standards and practices within the construction industry, thereby reducing the occurrence of construction accidents and safeguarding the well-being of workers. The implications of this study extend beyond academia, offering valuable guidance for the practical improvement of construction safety practices and ultimately fostering a safer working environment for all.

2. LITERATURE REVIEW

Based on previous academic research analysing safety accidents at construction sites can be undertaken by focusing on three related topics: accident-causing theory, safety training for construction site management, accident investigation reports, and thematic analysis.

Among the most prominent accident-causing theories, we can identify Heinrich's domino theory and Ferrel's theory of accident causation. Heinrich described the accident causation theory, the man-machine relationship, the frequency-severity relation, the reasons for unsafe acts, the management role in accident prevention, the accidents' costs, and the safety's impact on efficiency (Heinrich et al., 1980). Heinrich's efforts on accident causation theory can be summed up into two points: people (humans), who are the main reasons for accidents, and management, which has the responsibility of preventing the accidents (having the power and authority) (Hosseinian & Torghabeh, 2012). According to multiple causality, the events that lead to accidents have two main characteristics: unsafe behaviour and unsafe conditions. Safe behaviours and unsafe conditions should be prevented by identifying the multiple causes of these accidents (Stranks, 2007). Ferrel's theory of accident causation is based on a chain of human factors. The occurrence of an accident is based on a wide range of causes, including direct, indirect, and basic causes. Accidents are the result of social factors, management factors, and risk factors triggered by accidental events. This theory is also known as the multiple causation theory. It is used for China's accident investigation reports (Hosseinian & Torghabeh, 2012).

Many studies focus on the factors influencing the implementation of a safety management system for construction sites. Ismail et al. (2012) listed that safety training is the first level adopted by Australia, China, Finland, Jordan, Malaysia, Netherlands, Spain, and the USA (Aksorn & Hadikusumo, 2008; Ali et al., 2009; Mohamed, 1999). Fang et al. (2004b) analysis of site safety management in China shows that safety training is important. Some

previous research is based on interviews to evaluate construction safety management systems (Fang et al., 2004a; Lai et al., 2011). Systematically elaborated on applying social science research methods to construction safety research and practice. Therefore, our study of construction safety is positioned as text metrology and theme analysis of construction accident investigation reports.

Accident reports are valuable material for safety research (Chi & Han, 2013). Considering the importance of accident investigation reports, it is worth remembering that an accident investigation report represents an observation of an accident, trying to identify the accident process, identifying and understanding its direct and indirect cause to detect its basic source. The comprehensive accident mode considers various accident phenomena and factors (Kim & Yoon, 2013). It can describe the cause of the accident more accurately and comprehensively, which is beneficial to the accident's analysis, prevention, and treatment (Abdelhamid & Everett, 2000). Some researchers tried to adopt different models to analyse the accident investigation report, and some focused on the direct causes of accidents or special aims. For example, Xu et al. (2021) analysed the accident report of subway construction for specific factors such as operation fatigue and design defects. Haupt and Pillay (2016) analysed the construction report for the true cost of the accident. Pan et al. (2022) recently identified the workers' accident-injury type and body part from the investigation reports.

Table 1 lists some studies using accident investigation reports as text material.

Table 1 Main related studies' topic and sample size

Researchers	Topic	Number
Kim and Yoon (2013)	Study validates accident causation model	80
Morais et al. (2020)	For analysis and estimation of human errors	238
Klinjun et al. (2021)	Traffic accidents to study the causes of accidents in Thailand	25
Chen and Wang (2022)	Analysis of accident investigation reports with mining text analysis	158

Qiu and Zhang (2019)	High fall cause analysis	123
Zhang and Niu (2022)	How to prevent accident risk	167
Zhang and Jiang (2021)	Research on safety accident policy tools	88
Xu et al. (2021)	Text mining approach to extract safety risk factors from construction accident reports	221

emergency management bureaus at all levels of government where the accidents occur. The principle of compiling the accident investigation report in China refers to the accident causality theory (Suraji et al., 2001; Zhang et al., 2020), which identifies the direct and indirect causes very clearly. Through the analysis of the direct causes of the accident investigation report, we can get the technical factors and other factors of the accident (Xu & Xu, 2021), while the analysis of the indirect causes can get the human factors and management factors (Winge et al., 2019). However, there is a strong research emphasis on direct causes but very little on indirect causes, so it is our research aim.

The fourth aspect, thematic analysis, a data analysis strategy, is mainly used in psychoanalytic research to evaluate qualitative textual data (Castleberry & Nolen, 2018). Thematic analysis has good applicability or flexibility as it is suitable for a wide range and can be combined with many research methods (Alhojailan, 2012; Vaismoradi et al., 2016) for the data collected from survey textual data, diaries, story-based methods such as vignettes and story completion tasks, online discussion tasks, and other media sources (Willig & Rogers, 2017). Castleberry and Nolen (2018) used a thematic analysis method to study the published reports of construction safety climate surveys, with more than a thousand citations in. Tetzlaff et al. (2021) used thematic analysis to analyse mining safety accident reports to study safety culture. At present, it is not found that the indirect cause of construction accident reports is analysed with thematic analysis, which is a gap in the innovation of this paper. For sample size, Willig and Rogers (2017) and Clarke and Braun (2013) suggested thematic analysis used for

qualitative surveys as the whole project has a sample size of more than 200.

3. RESEARCH METHOD

This paper applies a quantitative text analysis using KH Coder, which can analyse data in Japanese, Chinese (simplified), and English for free. It can also do word frequency statistics, word cloud, and cluster analysis. Qualitative research includes a wide range of philosophies, research objectives, target audiences, methods, and reporting styles (Luborsky & Rubinstein, 1995). Quantitative text analysis is the application of some methods and drawing statistical inferences from related text populations; it can answer questions about what themes occur and what semantic relations exist among the occurring themes (Roberts & Quantity, 2000). This broad, legitimate purpose is both a source of power and consternation. However, qualitative research reports must always tell the project's story, convey the perspectives of others in depth and detail implications.

In this regard, this paper focuses on indirect causes from the available investigation reports of building engineering accidents. The aim of this research is to clarify the impact of construction safety training on construction accidents. To obtain the safety education and training-related parts of various safety accident causes, the analysis calculates the degree of influence of safety training in the proportion of indirect causes of construction accidents.

Figure 1 shows the number of construction safety accidents in China that were officially released from 2009 to 2019; the dotted line is the two-period moving average trend line, which can show the trend of the accident numbers change with the year (Triola, 2009).

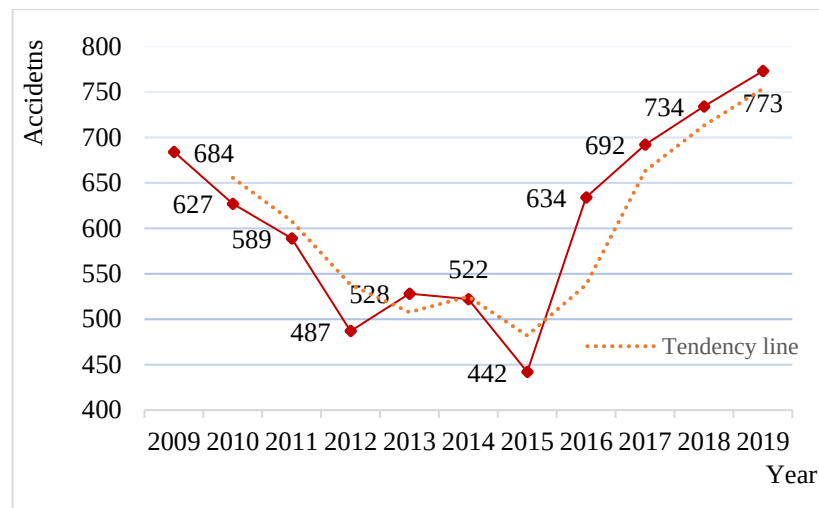


Figure 1 Number of construction accidents in China 2009-2019

We can see that the number of Chinese building accidents was minimal in 2015 and suddenly increased in 2016. That is because, in 2015, the People's Republic of China's Ministry of Housing and Urban-Rural Development issued a notice about submitting the work information on safety accidents in buildings and municipal engineering, standardising the accident report method and content, and strictly investigating and enforcing the law. So, to identify the tendency, one has to pay more attention to the number later than in 2016, as shown in Figure 2. We can see that the number of municipal engineering accidents from 2016 to 2020 is close to a straight rise. We have made a straight trend prediction line in Figure 2, and the dashed line in the figure represents the prediction line with the linear model. All data of Figures 1 and 2 are from the open website of China government (Development, 2011; MHURD, 2013, 2015, 2016, 2018, 2020).

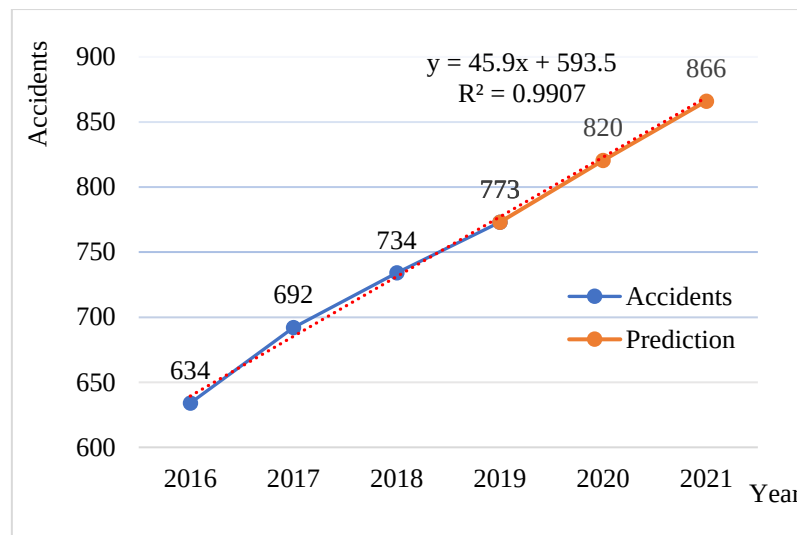


Figure 2 Number of construction accidents in China 2016-2021

We combined fixed ratio sampling and random sampling methods. To determine the number of construction safety accident reports, refer to two aspects: text thematic analysis method, material analysis method and similar research of others. The total number of construction accidents from 2016 to 2019 was 2,833 (official data for 2020 and 2021 has yet to be released) Counting the extrapolated number of accidents in 2020 and 2021, there were approximately 4,519 total construction safety accidents from 2016 to 2021, the number of each province as shown in Figure 3. Still, some reports have not been released, and it is difficult to collect all the reports from the websites of the emergency management bureau scattered in the provinces or sub-cities. For example, we randomly get the report investigation report on the 2.17 collapse of Chenhui construction engineering Co., LTD from the emergency management bureau of Xiangxiang, Hunan province (Xiangxiang, 2020). Therefore, referring to similar studies Kim and Yoon (2013) and Morais et al. (2020), we adopted fixed-ratio sampling, one or two more than 5% of total each province, to obtain 226 samples. The sample numbers of each province are shown in Figure 4. In this study, we fixed numbers from each province and gathered safety accident reports from each provincial government emergency management department's websites.

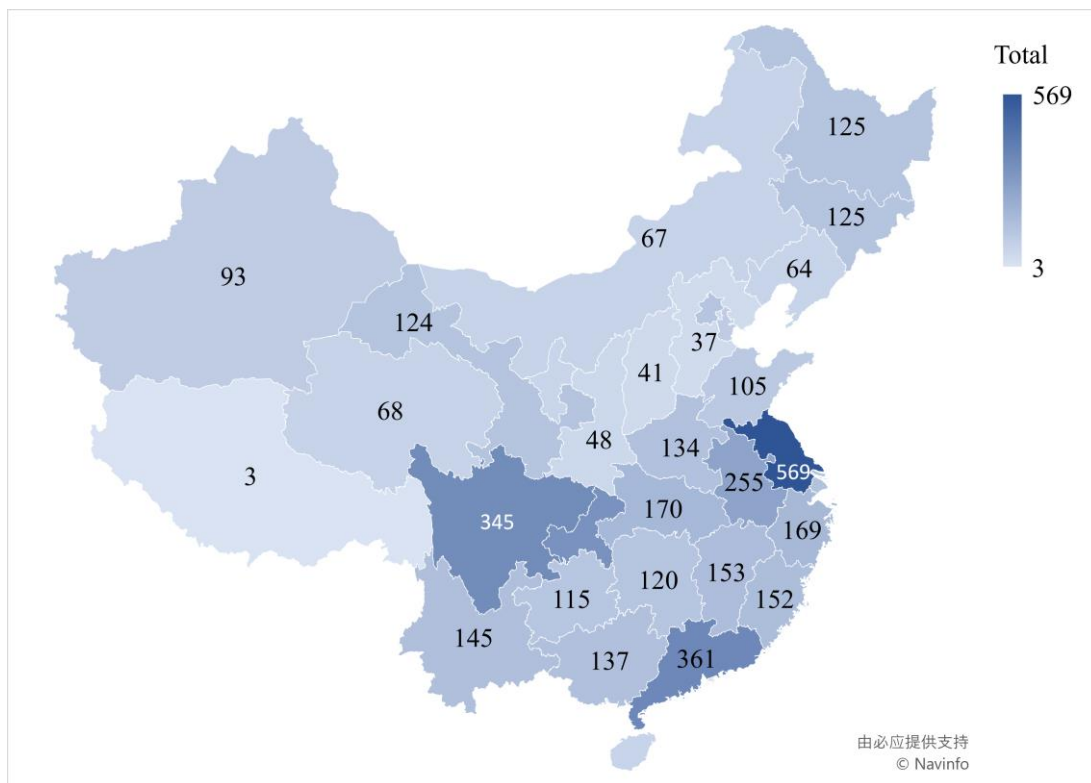


Figure 3 Each province accidents total numbers from 2016 to 2021

Note: The legend is the number of each province, and the dark colour indicates the large number.

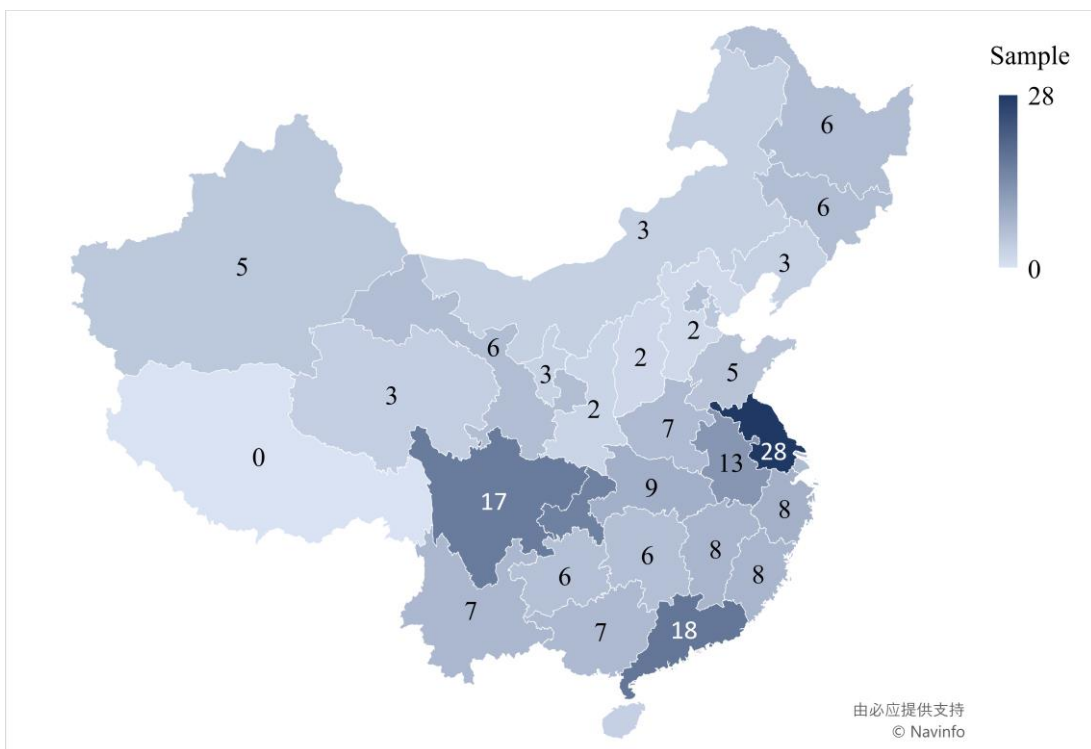


Figure 4 Each province's accidents sample numbers from 2016 to 2021

4. RESULTS AND DISCUSSION

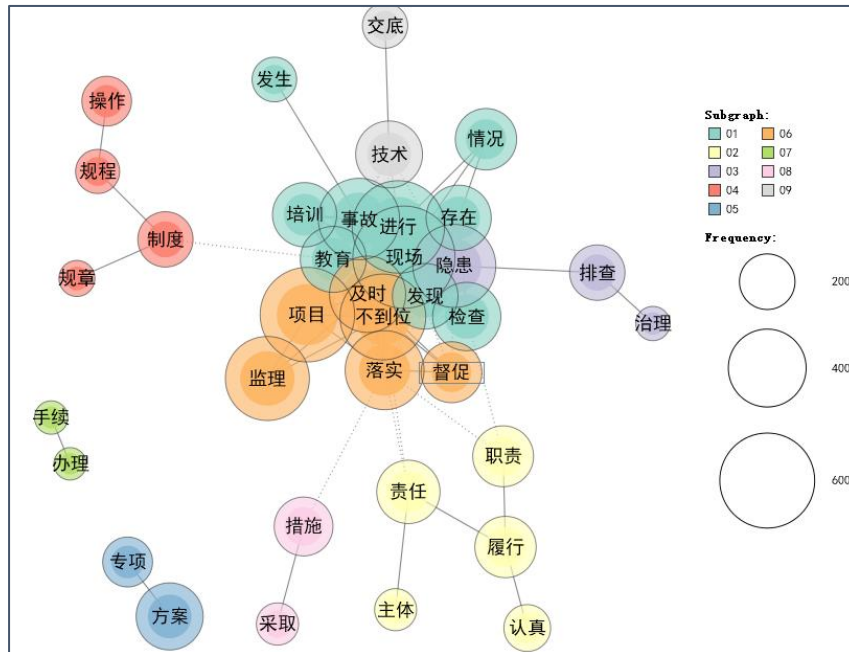


Figure 6 Keywords relationship and clusters of indirect causes

All thematic cluster are listed in Table 3 and we can conclude as follow: basic safety management is unclear; safety responsibility is not assigned to individuals; the technical explanation of special operations is unclear; supervision is lacking; safety training is not institutionalised; it is not carried out following standards, even though it may be lacking. Indeed, the issues of insufficient supervision, failure to look into safety risks, and technical disclosure should be addressed. It should be re-stated that this research does not focus on technical issues, as safety issues are evaluated within the context of safety education and training.

Because the original text was Chinese, we need to extract the theme after the text analysis. However, it is not necessary to translate all the reports into English. So, the word cloud image in Figure 5 is Chinese, and we give the corresponding English and Chinese translations in Table 2.

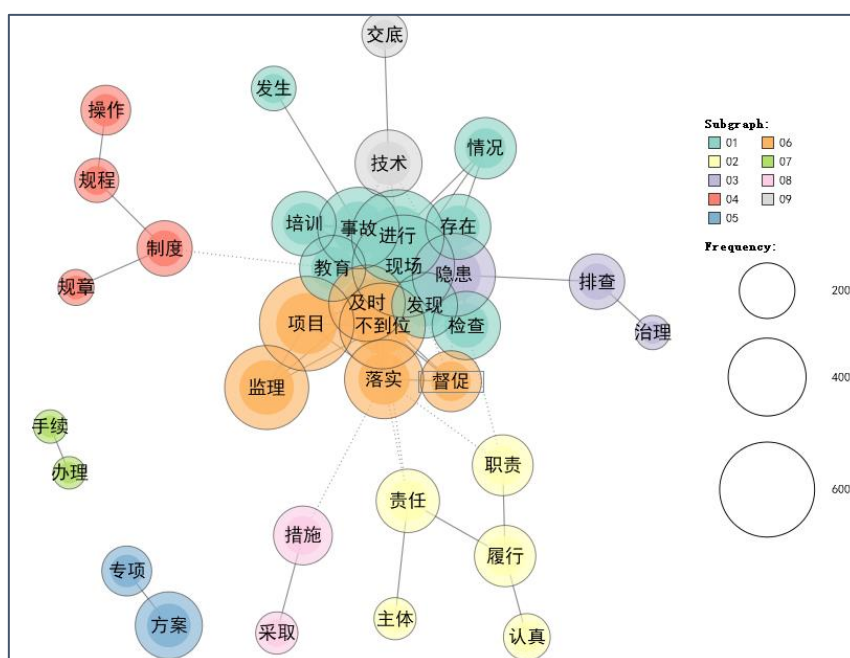


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Table 2 Indirect cause word frequency statistics in the accident investigation report

No.	Keywords	In Chinese	Count s	%	No.	Keywords	In Chinese	Counts	%
1	Management	管理	1200	2.59	26	Situation	情况	246	0.53
2	Personnel	人员	930	2.01	27	Requirements	要求	246	0.53
3	On site	现场	698	1.51	28	To perform	履行	245	0.53
4	In place	到位	674	1.45	29	Responsibilities	职责	241	0.52
5	Project	项目	644	1.39	30	Behavior	行为	234	0.50
6	Proceed	进行	573	1.24	31	Regulatory	监管	232	0.50
7	Supervision	监理	470	1.01	32	Measures	措施	227	0.49

8	Hidden dangerous	隐患	457	0.99	33	Effective	有效	227	0.49
9	Implementation	落实	444	0.96	34	Poor	不力	214	0.46
10	Accident	事故	434	0.94	35	Operation	操作	204	0.44
11	On time	及时	416	0.90	36	Strict	严格	202	0.44
12	Regulations	规定	373	0.80	37	Related	相关	172	0.37
13	Check	检查	346	0.75	38	It is illegal to	违法	169	0.36
14	There is no	没有	324	0.70	39	Design	设计	168	0.36
No.	Keywords	In Chinese	Counts	%	No.	Keywords	In Chinese	Counts	%
15	Found	发现	307	0.66	40	Head	负责人	164	0.35
16	Plan	方案	295	0.64	41	Failed to	未能	161	0.35
17	Education	教育	294	0.63	42	Special	专项	160	0.35
18	Building	建筑	293	0.63	43	Violations,	违规	156	0.34
19	Technology	技术	292	0.63	44	In violation	违反	153	0.33
20	Exist	存在	281	0.61	45	Screening	排查	152	0.33
21	Training	培训	280	0.60	46	Seriously	认真	150	0.32
22	Urge	督促	279	0.60	47	Stop	制止	142	0.31
23	Supervision	监督	260	0.56	48	System	制度	141	0.30
24	Organization	组织	260	0.56	49	The implementation	实施	141	0.30
25	Responsibility	责任	258	0.56	50	The rectification	整改	140	0.30

Figure 5 Keywords frequency of indirect causes

From the word frequency analysis and the related cloud image we can identify management, personal and on-site as the most relevant ones. This is followed by the term supervision, regulations, hidden dangers, implementation, on-time, and checks are top. Training and education ranked 17th and 21st. The first cause of safety accidents is the defects of site management, which mainly includes the dereliction of duty of supervision, the inadequate implementation of programs, and the lack of training and education. Word frequency analysis shows that education and training play a main role in the indirect causes of construction safety accidents.

Figure 6 shows the keyword's relationship and clusters. The different colours are the different clusters, and we adopted the thematic analysis to get each cluster topic, which can get the main content of the text, which we listed in Table 3. First, we identified the number 1 cluster keywords: accident, occurrence, training, on-site, education, proceed, existence, checking, on-site, and situation; Second, we further recognised that the themes management construction site chaos, safety education and training representing certain problems, resulting in safety accidents. Moreover, we also can identify additional cluster theme: Number 2 cluster consist of, responsibility, duty, to perform, subject, responsibility, seriousness. From this analysis, we recognise that some member of the management side team did not take their principal responsibilities seriously.

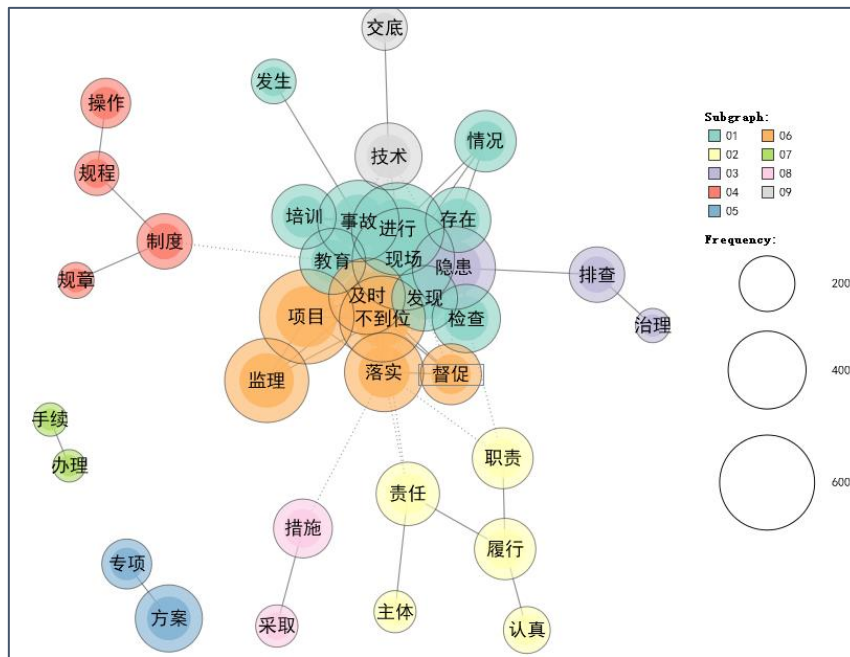


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Table 3 Keywords clusters and thematic statement

Category	Keywords	Thematic statement
01	Accident, occurrence, training, on site, education, proceed, existence,	Construction site management chaos, safety education and training there are certain problems, resulting in safety accidents
02	Responsibility, duty, performance, subject, seriously	Someone did not take their principal responsibilities seriously.

03	Hidden danger, investigation and treatment	Failed to carry out investigation and inspection on potential safety hazards
04	Code regulation, procedure, operation	Failure to comply with the relevant operating rules and regulations
05	Special project, plan	No special construction scheme has been designed
06	Supervision, timely, not in place, implementation, supervision	Supervision is not in place
07	Formalities, deal with	Failed to go through relevant licensing procedures
08	Measures, take	No corresponding special construction measures have been taken
09	Technology, disclosure	Missing, not take place

Our text analysis method verified factor analysis results by Fang et al. (2004b) and Ismail et al. (2012), that safety training is the most vital aspect related to safety management. Specific features include weak safety awareness, ineffective safety education and training systems, insufficient hours allocated for education, perfunctory approaches that undermine workers' safety awareness, and the prevalence of rule violations and risk-taking within the three-level safety education and training system. Consequently, a stronger management commitment for worker safety training and safety knowledge transformation is required. Moreover, the result agrees with Teo et al. (2005) that construction site accidents are more likely to happen when there is poor management commitment and insufficient safety knowledge and training of workers.

Indeed, insufficient safety education and training resulted in workers exhibiting indifferent safety awareness and engaging in risky behaviour at the construction site. Special operations often need more specialised training and education. Additionally, while the pre-job safety training for employees lacks strict enforcement, the on-site safety supervision system

must also be effectively implemented. Additional identified issues are the need for proper daily safety training and workers' limited exposure to safety education.

These contextual insights shed light on the critical role of missing or failing construction site safety education and training as the primary contributing factor to accidents. The analysis underscores the need to address issues such as weak safety awareness, ineffective education and training systems, inadequate allocation of time, formalistic approaches, rule violations, and insufficient safety training for special operations. Moreover, it emphasises the importance of stringent pre-job safety training, effective on-site safety supervision, and regular provision of comprehensive safety education and training to enhance workers' safety awareness and mitigate the occurrence of accidents on construction sites.

5. CONCLUSION

The focus of this study was to investigate the indirect causes of construction accidents through the analysis of accident reports. We have identified several contributing factors by employing word frequency analysis, cluster analysis, and thematic analysis. There needs to be more safety education and training, adequate professional competence, and adequate assessment time were found to lead to workers' indifference towards safety and frequent engagement in risky operations. Moreover, the safety supervision system is often ineffective at construction sites, indicating a management defect. Overall, this study identifies safety training, education, and worker attitudes as common underlying causes of construction accidents. Through qualitative analysis, we have achieved our research objective and clarified the role of construction safety training in reducing accidents. The limitation of this study lies in the use of sampling methods. If it were possible to obtain the complete sample, the population of all accident occurrence reports, the research would have greater persuasiveness.

In conclusion, this study reveals several key findings. Firstly, training management in the construction industry needs more standardisation, and the training process often involves

formalism. As a result, the effectiveness of safety training could be higher. Secondly, there exists a significant need for more safety awareness among construction workers. The research has established that inadequate safety training and education are the primary causes of accidents on construction sites, with the ineffectiveness of safety training emerging as the main reason for these accidents.

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