



A Literature Analysis of Construction Workers' Safety Training based on narrative review and Citespace

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Abstract. The construction industry has a high incidence of safety accidents. To reduce the incidence of safety accidents and avoid the high casualty rate caused by safety accidents, safety training methods have been proposed. Research has proven that safety training plays an important role in reducing worker injuries and fatalities. In recent years, researchers have conducted studies and published a number of findings. With the development of information technology and building industrialization, the current hot topics in the field of construction workers' safety training should be summarized and future research directions should be identified. Thus, this paper comprehensively reviewed the literature on safety training in the construction industry and then used CiteSpace software to visually analyze the literature. The results of the CiteSpace analysis indicated that the hot research issues in the field of construction workers' safety training include prevention, hazard recognition, and safety training based on computer information technology. Based on the literature analysis, this study proposed four future research directions: the research in addition to hazard recognition is suggested to be strengthened in the future; individualized training for different individual workers should be given enough attention; more in-depth research should be conducted on fall from height accidents, and how to assess the practical effectiveness of safety training is still needed research. This study is expected to serve as a resource for industry practitioners and research groups to address safety issues encountered in the construction industry.

Keywords: Construction, Worker, Safety training, CiteSpace, Literature review

1 Introduction

Construction industry safety has always been a challenge around the world, and the construction industry causes a large number of injuries and fatalities each year. According to Safesite [1], nearly 20% (1066) of fatal injuries that occurred in the workplace in 2019 in the US were from the construction industry. The technology applied to the construction industry is evolving, but the threats to workers are not diminishing. Heinrich [2] found that 88% of construction injuries and fatalities were caused by the unsafe practices of building construction workers. The occurrence of safety accidents can often

be controlled through prevention, for instance, workers' safety training. Prior safety training for construction workers has been shown to be an important method for reducing the number of injuries and fatalities [3,4].

The study of workers' safety training originated in the mining industry, it has been widely used and played an important role in other industries, such as manufacturing. The existing construction safety training is appraised since safety training was introduced to the construction industry [5]. The factors that affect safety training were identified for improving the efficiency of safety training [6]. Various electronic information technology tools have been continuously applied to safety training in the construction industry, such as VR technology [7]. The existing reviews of safety training in the construction industry are all centered on a specific link or a means to carry it out, without a clear grasp of the focus of current research. For example, Prasad [8] provided an overview of the factors that influence the transfer of training in the safety training process.

CiteSpace is a freely available Java application for visualizing and analyzing trends and patterns in scientific literature. It is designed as a tool for progressive knowledge domain visualization [9]. It focuses on finding critical points in the development of a field or a domain, especially intellectual turning points and pivotal points. As an excellent literature analysis software, it has been widely used in various fields of research, such as scient metric analysis to analyze the impact of climate change on tourism[10]

In order to position the focus of existing research, the current research hotspots and priorities should be analyzed. Therefore, the objectives of this paper include 1) visualizing and analyzing trends and patterns of safety training in the construction industry; 2) identifying emerging and non-traditional training methods that break through the current limitations based on the key factors analyzed.

This paper is organized as follows: Section II introduces the methodology of literature review and cluster analysis applied in this study, followed by Section III which presents the results of literature review and cluster analysis; Section IV discusses the results and Section V concludes this study.

2 Method

This study applied for narrative literature review and cluster analysis based on bibliography information to review previous studies on workers' safety training in construction. The methodology is presented in detail in this section.

2.1 Search Strategy

In the literature search phase, sets of index words were initially identified through discussion in the group. Then, based on the literature retrieved by these sets of index words, the keywords within the literature were summarized. Finally, a set of index words were extracted to determine the entire literature that could be examined, including "construction", "safety", "health*", "train*" and "educat*". The searching formula

in this study is as follows: (("construction") AND ("safety OR health*") AND ("train* OR educat*")).

Web of Science Core Collection, Scopus, and EI are the major sources of the literature retrieval platforms. Given the extensive history of study in this field, there is no restriction on the publication date. The language was restricted to English. After screening the results of the first round, two authors conducted a backward and forward snowball screening method to expand the search for the selected literature, based on the references and authors of articles that were returned through the search [11].

2.2 Inclusion Criteria

After holding a group discussion to confirm the criteria for inclusion in the literature, the following inclusion criteria were finalized:

1. the content of the literature must be an empirical case study on the topic of housing construction safety training;
2. the article must be published in English.

2.3 Selection of Relevant Articles

Based on the objectives of this study, Search results were screened by two of the authors for excluding duplicates and studies that did not meet the inclusion criteria according to the titles and abstracts. The two authors assessed independently the full text of all studies deemed relevant for inclusion. Any disagreements were resolved through discussion or, if required, by consulting the third author.

The article filter procedure is depicted in Fig. 1 according to the requirements of Systematic Reviews and Meta-Analyses (PRISMA) [12]. Based on the initially identified search terms, 179 papers were retrieved from the Web of Science database, 241 papers from the Scopus database, and 124 papers from the EI database. After de-duplication, 309 papers remained. The two authors initially screened the titles and abstracts of the literature according to the selection criteria, leaving 85 papers; then, by reading the full-text content, 53 papers were finally selected. After that, a snowball method was started to browse through the references and citations of the 53 documents, and 26 documents were retained based on the full text. Finally, a total of 81 papers were included in this review after a two-stage selection process.

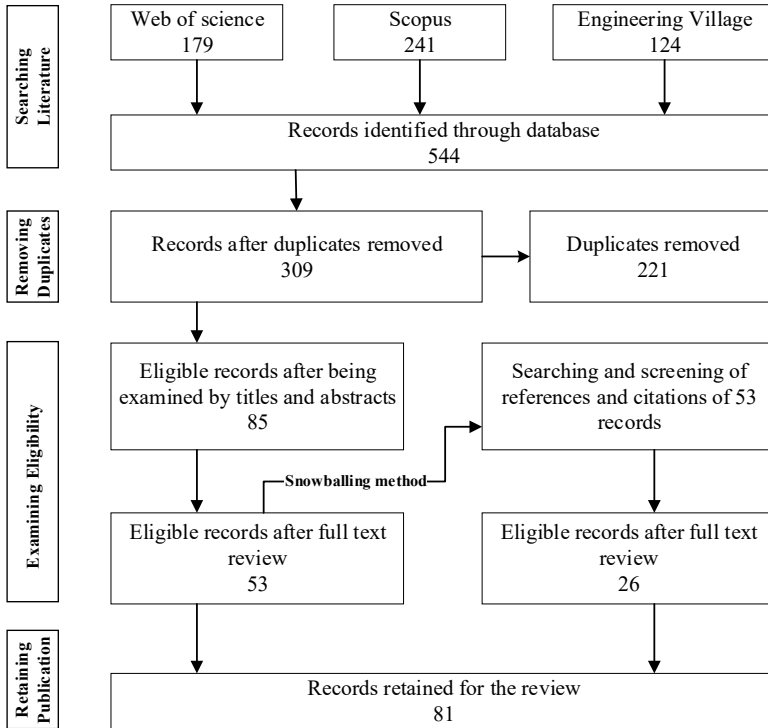


Fig. 1. PRISMA flowchart

2.4 Quality Assessment

A quantitative version of the McMaster rating tool [13] was used to assess the quality of the study methodology. The McMasters Critical Review Form for Quantitative Studies [13] is a methodological quality assessment tool frequently used within systematic reviews synthesizing quantitative studies [14-16]. There are eight overarching criteria on the review form. These eight criteria are supported by 14 domains, each of which can be responded to with a yes or no response. Since the original form was created to conduct research scoring in the medical field, the medical field-specific scoring items were eliminated from this paper. The final domain items include 8 items, including purpose clearly stated, relevant literature reviewed, sample described in detail, sample size justified, reliable outcome measure, valid outcome measure, statistical significance reported, appropriate analysis method, drop-outs reported, and conclusion appropriate. Furthermore, some domains provide response alternatives for 'not applicable' or 'not addressed.' As a result, the 10 domains were used to grade the studies in this study. A rating of 'yes' was assigned a 1 in each research, whereas a rating of 'no' or 'not addressed' was assigned a 0. The studies were graded by two authors independently, and any differences in quality appraisal between graders were re-viewed by another author.

2.5 CiteSpace Analysis

In this work, the CiteSpace literature analysis tool was utilized to assess the relationship more precisely among the literature. The software version used here is CiteSpace.6.1.R2(64-bit) Basic. Due to limitations of the CiteSpace tool, CiteSpace can only process citation data from popular sources such as the Web of Science, Scopus, Dimensions, and the Lens. CiteSpace also supports basic visual analytic functions for datasets without citation-related information, for example, PubMed, CNKI, ProQuest Dissertations, and Theses. The analysis tool can only evaluate the literature from Web of Science and Scopus particular databases. Thus, the final number of papers involved in the CiteSpace analysis was 71. Bibliography data were converted into plain text files for export, including title, author, abstract, and source. To analyze the bibliographic data, four folders were first created on the computer: input, output, data, and project. The plain text information described above was placed into the input folder and converted to a specific form using CiteSpace software, which was named 'download_XXX.txt'. And then pasted into the data folder. It is important to note that the data exported from the Scopus database should be converted to WOS database format before it can be recognized. The analysis was time-sliced to select one year, with keywords as the type of analysis. The plain text files were then imported into CiteSpace.6.1.R2 for cluster analysis. Cluster analysis of co-occurrence keywords revealing the main topics was performed using CiteSpace. And then the data were sorted in a timeline fashion to produce the analysis results.

3 Results

3.1 Literature Characteristics

According to the entire literature screening, the final number of selected documents is shown in Fig. 2. The horizontal coordinates of the graph represent the year and the vertical coordinates represent the number of publications included in this study. As can be seen from the graph, the research on safety training in the construction industry was initially conducted in 2001, after which the number of publications was continuously increasing. There was a significant rise in the number in 2013, with the number of articles published in that year reaching 10. From 2018 onwards, there was a significant increase in the number of articles addressing the study of construction safety training, which has continued until today. The number of publications for 2018, 2019, 2020, 2021, and 2022 is 10, 8, 6, 11, and 11, respectively.

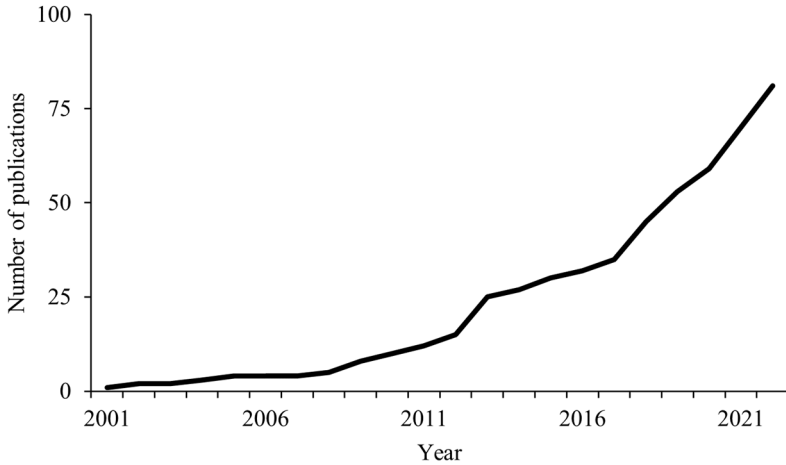


Fig. 2. Publications of empirical studies on construction safety training by year

Based on a thorough review of the literature, the articles' objectives were summarized in Fig. 3. The most frequent objective mentioned in the literature is developing new safety training methods. One reason may be that researchers aim to solve practical safety problems by developing new safety training methods. another reason may be that information technology evolve quickly in recent years, which benefits the development of safety training methods. The second frequent objective is evaluating the effects of safety training. Whether the new safety training methods are effective is of significant importance in this field. The frequency of discussing the current state of building safety training and the importance of safety training is similar to the frequency of increasing workers' safety awareness in construction. Then, researchers focus on exploring factors affecting safety training.

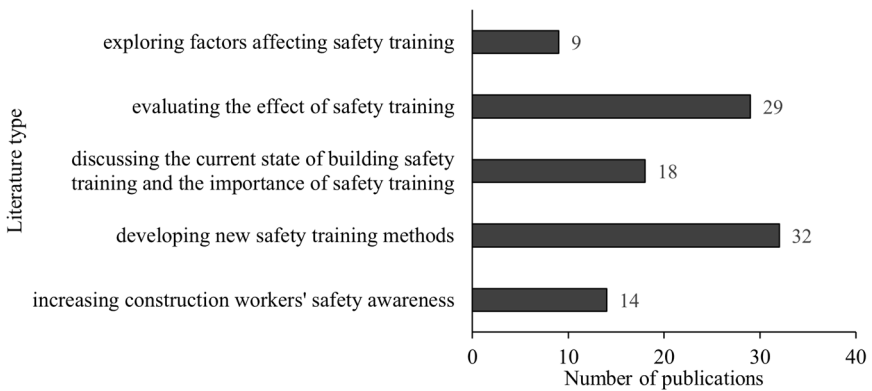


Fig. 3. Research objectives of the included literature in the construction safety training field

Besides, the main experimental methods used in the literature are found to be as follows:

1. surveys to obtain data (including questionnaires, focus group interviews, and structured and semi-structured interviews)
2. experiments to verify the proposed methods
3. electronic information technology and other means to develop new tools for building safety training

The number of literature using different research methods is plotted in Figure 4. There are cases where different research methods were used simultaneously in the same paper.

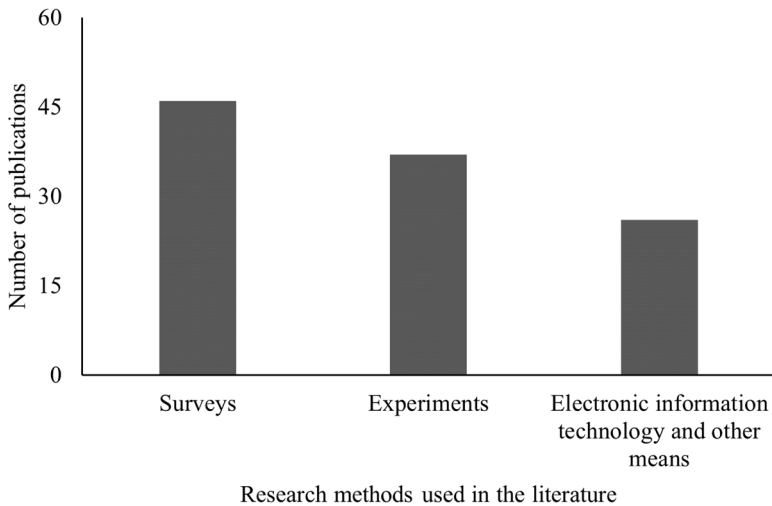


Fig. 4. Statistical table of research methods in the literature

3.2 Quality Assessment

According to the scoring results of the McMaster scoring table, the highest score is 8 points, and the minimum score of 3. The median 9 indicates that the overall quality of the literature is very high under this evaluation criterion. Generally speaking, the studies have a relative quality on Purpose clearly stated and Conclusion appropriate. The Drop-out reported with the lowest average score is 0.395, which indicates that Most of the articles analyze the result data without excluding some of the data.

3.3 CiteSpace Clusterin Analysis Results

The keywords and references of the included literature were analyzed visually by CiteSpace, and the clustering results obtained were sorted as shown in Figure 5. The smaller number marker in the picture represents the higher frequency of that keyword in this analysis. As can be seen from the figure, prevention appears most frequently,

indicating that prior prevention is very critical in safety training in the construction industry. Then, it is followed by hazard recognition since it is difficult for workers to clearly and quickly be aware and recognize potential hazards prior to an accident.

In the first place of all the keywords is prevention. In safety training in the construction industry, prevention of accidents is critical, and most researchers take prior prevention into account in their research framework. In second place is risk identification. Construction workers are not able to fully identify hazards before an accident occurs, and the inability to identify and deal with impending hazards can lead to injuries and deaths. Of course, hazard recognition is a part of prevention, and the two are very closely related. In the third place is mobile computer, in recent years the research is more and more focused on the application of computer-aided equipment for research, more dependent on computer technology means. In fifth place is context-based, which is more often found in the application of traditional means of training. The next is fall protection, which is a very frequent occurrence, and there is a lot of research related to falls from height.



Fig. 5. Results of keyword clustering analysis

4 Discussion

4.1 Hazard recognition is one of the most frequently studied topics

The main goals of safety training are to both prevent accidents from happening and lessen the harm they do to people. Accidents on the construction site cannot be fully predicted, and hence hazard recognition is important for worker safety on construction sites. Workers and professionals are encouraged through safety training to make safety-aware decisions to reduce risks and prevent potential injuries [17,18]. Currently, however, despite being required to receive safety training, construction workers are unable to recognize more than half of construction safety hazards [19]. By training people, it is possible to detect hazards in the environment and avoid the occurrence of safety

accidents, and there have been many studies on the hazard recognition ability of field workers. Thus, hazard recognition becomes the most frequently studied topic, as shown in Fig. 4. Besides, research on hazard recognition is more feasible with the help of advanced technologies. For example, Wu [20] verified virtual reality-based Interactive Education System for construction hazards shows great potential to enhance the safety knowledge, consciousness, and behavior of the construction workers to prevent the occurrence of construction accidents.

Specifically, various research questions about hazard recognition have been studied and a huge number of findings have been published. First, worker heterogeneity can affect how well workers perceive hazards in their environment. When inexperienced workers are exposed to multiple hazards at once, hazard recognition rates are even lower [21-23]. Even the same employee may behave differently in various environmental circumstances. In dynamic and occasionally unpredictable contexts, it can be challenging for even knowledgeable and expert people to make correct forecasts [24]. Site managers with varying levels of experience and education perceive risk differently [25]. Secondly, there are differences in the tolerance for risk among workers. Hollowell [24] found a statistically significant difference between the risk tolerance of construction workers and managers. Additionally, Zhang [26] discovered that safety experts, construction managers, engineers, and architects had different perspectives on risk. It indicates that individual differences affect the training's ultimate results as a crucial aspect of the hazard recognition process.

4.2 The use of advanced information technology in this field is quickly developing.

A number of training techniques are severely constrained to provide hands-on practice. However, the use of advanced information technology gives new solutions to past difficult problems. Take 3D and 4D technologies, for example. Combining serious games with 4D approaches can boost user stickiness and influence workers to recognize health and safety risks [27]. Migrant laborers with language problems are also more interested in safety training with 3D virtual models [28]. The application of 3D-based training scenarios to personnel with low literacy and poor English proficiency could overcome communication barriers during safety training [29]. For steel-workers, real-time position tracking and 3D immersive data visualization technology are combined in the existing construction worker education and training environment. The results indicated that unsafe behaviors in the chemical worker training environment could be detected and visualized [30].

All at the same, as VR technology advances, it is increasingly being used in construction safety training. Compared with traditional safety training techniques, VR-based safety training outperforms lecture-based safety education training in terms of recognizing safety-related elements and danger awareness which keeps participants' attention more concentrated [31-33]. Furthermore, participants said the VR training was more impressive, realistic, and stressful [31]. For example, VR-based training can reduce barriers produced by the invisibility and danger of electricity and improve workers' awareness and capacity to intervene in electrical risks [34]. Experiential

construction safety education frameworks based on VR and AR can be beneficial in enhancing construction safety and health because of their capacity to enhance the training experience [35]. To address workers' inadequate awareness and control of hazardous settings, a personalized VR-based stereo panoramic environment is proposed to be built [36]. A dangerous interactive teaching system based on virtual reality is given to assist in the development and outcome evaluation of construction safety training programs [20]. In addition, using serious games in VR as a supplement to active learning experiences can help to improve construction worker education and training [37].

4.3 Future directions of construction safety training are identified

At present, although there are different safety training methods for different groups and using specific tools, there is still much room for improvement. Based on the results of the narrative literature review and cluster analysis of bibliography information, this study identified three future directions for future research.

First, topics except for hazard recognition should be paid more attention to. As shown in Figure 4 and Subsection 4.1, one of the main focuses in construction safety training is hazard recognition. Although hazard recognition is critical and contributable to protecting workers, other aspects deserve more attention and effort in research, such as construction management.

Second, construction safety training should be targeted at workers with different characteristics, rather than taking a "one-size-fits-all" approach. One reason is that workers of different types and backgrounds may not receive the same knowledge to the same extent. Another reason is that current progress in construction safety training and advanced technologies makes individualized safety training possible. To that end, individualized training models can be tailored to workers' learning characteristics and individual needs. Xu [38] developed a recommendation algorithm that pushes training materials to workers based on their trades, work activities, site risk sources, and learning abilities, based on identifying features of construction workers' learning processes. With the help of this algorithm, the research on personalized training of workers will be further advanced.

Third, fall from height accidents need more attention. Moreover, the main purpose of safety training is to reduce casualties, but according to statistical data, falling from height accidents are the most important accident causing casualties. Also, in Fig. 4, it can be seen that fall from height is the 6th most important word, and compared to others, fall from a height does not get deeper attention. Moreover, safety training research for fall from height accidents is no longer a priority by 2018, but until now, fall from height accidents are still a major threat to the life safety of construction workers. However, in contrast to the existing research, most of the extant fall from height literature does not include learning theories and methods. This limits the potential of the fall from height literature to provide theoretically supported recommendations and strategies for organizations to develop learning capabilities to prevent falling from height incidents. Also, the vast majority of extant fall from height research does not consider a holistic systems approach, i.e., how factors interdepend on each other, which also limits the research on fall from height accidents [39]. Research on construction safety training should be

dedicated to the prevention of worker falls from heights, based on theoretical learning, combined with the characteristics of the types of work of those who participate in work at heights, to explore the occurrence of fall from height accidents from a more comprehensive perspective in order to reduce casualties.

Forth, how to assess the practical effectiveness of safety training is still needed research. While much research focused on developing training techniques and methods in the field of construction safety, it is still unavailable for assessment of the practical effectiveness of construction safety training. Researchers have analyzed and compared the effectiveness of different training methods, such as immersive VR-based safety training versus traditional style safety training [7]. However, whether workers could utilize the knowledge they learned and conduct the correct behavior in practice is still unclear. Efforts on assessing the practical effectiveness of safety training and then improve the practical effectiveness of current safety training methods should be strengthened.

5 Conclusion

This study presents a comprehensive analysis of publications on empirical studies of safety training in the construction industry. Cluster analysis of bibliography information was conducted by using CiteSpace visual analysis software. Based on the results of the analysis, it can be seen that the current hot topic of safety training in the construction industry includes the prevention of accidents, hazard recognition ability of workers, and the training of workers in combination with computer technology. Although research on safety training in the construction industry has been gradually gaining attention, there is still work to be done in this field. Four future directions have been identified. Firstly, the research on hot topics other than risk identification should be continued in depth; there is also an exploration of the research on personalized safety training; in addition, the attention to fall from height accidents in the construction industry should be increased; finally, how to evaluate the actual effect of safety training is explored.

This review identifies current research hotspots and priorities by CiteSpace, while clarifying future research directions for researchers of safety training in the construction industry. Although a detailed review has been done in this paper, there are still some limitations in the article due to insurmountable reasons. First, in screening the literature, although this paper has used the snowballing literature search method, it does not guarantee that all the literature in the field of safety training in the construction industry is covered. Secondly, there are cases where the literature screened by the snowball method is not retrieved by Web of Science and Scopus databases. Although two authors scored the entire literature with McMaster and passed the score, some of the literature was of low quality. Finally, in the CiteSpace analysis of the articles, the literature selected for the review was not fully covered due to software reasons, and the data of 10 papers were not visually analyzed, which may lead to some bias in the final ranking of the keyword analysis results and affect the final analysis conclusion.

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