A Review of Worker Behavior-Based Safety Research: Current Trends and Future Prospects

Xingwei Li1*, Hongyu Long2

1 School of Management, Jiangsu University, Jiangsu, 212013, China
2 School of Civil Engineering and Architecture, Southwest Petroleum University, Sichuan, 610500, China
*Corresponding author’s e-mail: 2111710001@stmail.ujs.edu.cn

Abstract. The daily casualties and environmental damage caused by accidents in different organizations around the world have attracted the attention of industries, academia, and governments. Thus, worker behavior-based safety has become one of the key areas of safety management research, as the unsafe behavior of workers has a significant impact on production performance. This study carries out a systematic literature review to build a model of international worker safety behavior research that examines the relationship between safety behavior and standards, supervisor safety behavior, and other influencing factors. From the perspectives of influential factors, industries, research methods, organizational levels, enterprise size, and demographic characteristics of workers, the pressing issues of worker safety behavior research are generalized and the characteristics of the research results summarized. Finally, based on the analysis, we conclude by identifying scope for future research: (1) innovation in the research theories supporting worker behavior-based safety; (2) innovation in research methods; (3) and innovation in the perspectives of worker behavior-based safety research.

1. Introduction

The daily casualties and environmental damage caused by accidents in different organizations in countries and regions around the world have attracted the attention of industry, academia, and government. Thus, in recent decades, managing safety behavior has gradually gained widespread attention in various industries. Consequently, safety behavior research [1] has become an important part of the research stream in safety management. The focus of behavior-based safety (BBS) specifically is to improve safety behavior by enhancing worker self-awareness and motivation through feedback. Together with experience-based safety (ExBS), theory-based safety (TBS), standards-based safety (SBS), risk-based safety (RBS), accident-based safety (ABS), and countermeasures-based safety (CBS), BBS constitutes a critical research stream of safety management (Fig. 1). In combing the literature, the safety behavior of workers is often discussed in high-risk industries such as construction and coal mining. Various industries like these have instituted many constraints in the field of safe production, particularly in China. In the report of the 19th National Congress of the Communist Party of China in 2017, maintaining the concept of overall national safety was added into the new era of socialism with Chinese characteristics and a basic strategy. In practice, safety management is applied mainly for the prevention of accidents. However, in China, the idea of “nipping it in the bud” has taken hold, underscoring the importance of human safety behavior in accident prevention, in particular, as workers play a direct role in the occurrence of accidents. Against this backdrop, this paper systematically summarizes existing research and focuses on worker safety behaviors by scanning the international literature and identifying...
research trends on worker safety behaviors. Our aim is to support the call for innovation in behavioral safety measures and its research.

![Figure 1. Research areas of safety management.](image)

The breadth and volume of these studies provide further evidence that both academia and policymakers are attaching great importance to safety management issues. In particular, the BBS of workers has received increasing attention among international safety management scholars in recent years. In reviewing the literature, our research questions are as follows: Where does the BBS research originate from? What is the content of the research done on worker BBS? What are the hotspots within worker BBS in recent years? Finally, how will we study the BBS of workers in the future?

In order to answer these questions, we review the extant research on worker BBS through the Web of Science core collection database and clarify the progress of international worker BBS to inspire safety management research in the future.

2. Background: origin and concept definition

Behavioral science has been one of the theoretical foundations of management at home and abroad. It has been recognized and applied in many safety management studies. Heinrich [2] was one of the first to study accident prevention and proposed the theory of the accident causal chain. On this basis, Bird and George [3] proposed the modern accident causal chain theory. They believed that a safety incident was caused by the unsafe behavior of an individual and the unsafe state of an object. Desler[4] posited that human unsafe behavior was one of the basic causes of accidents. First coined by Earnest and Palmer in 1979, two safety professionals in the United Kingdom [5], BBS was officially presented as a concept broadly based on behavioral science; it covers unsafe behaviors and narrowly defined safety behaviors. By observing actions at the production site and dealing with worker behaviors, workers' ability to respond proactively can be promoted to correct unsafe human behavior, and training on safe behaviors can be provided to ensure a safe climate and improve safety performance [6-7]. Unsafe behavior is a manifestation of generalized safety behavior and worker unsafe behavior is part of worker BBS.
3. Methodology

By doing a literature search on the topic of "behavior-based safety" in the Web of Science database (we selected all databases up to 2017), 458 articles were identified. Through our analysis of the search data, we found that: China was the country with the largest number of publications on this topic (including Taiwan, China), with 123 articles; followed by the United States at 98. After we charted the retrieved data (Fig. 2), we found a general year-over-year increasing trend in the published literature on BBS research, whether in China or other countries. However, the number of studies on safety behavior in China was greater than in any other country. This provides evidence that BBS research has become a research hotspot for safety management scholars in recent years and Chinese safety management scholars are paying significant attention to behavior-based safety research.

Figure 2. Trends in the publication of international behavior-based safety research literature.

4. Literature review

Authors should discuss the results and how they can be interpreted in perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

BBS is one effective way to manage worker safety issues. Depasquale and Geller [8] studied worker safety behavior in 20 industries and the results showed that worker safety behavior training was effective. Lingard and Rowlinson [9] showed that safety behavioral techniques had a significant effect on improving building site management performance. Al-Hemoud and Al-Asfoor [10] summarized the effects of several safety behaviors on accident prevention. Leung et al. [11] showed that the safety behavior of construction workers on the construction site could reduce the risk of accidents. In order to promote safety behavior methods, Li et al. [12] combined safety behavior theory with proactive construction management system (PCMS) technology and proposed proactive BBS (PBBS) to improve construction safety. The focus of foreign worker safety behavior research in recent years is mainly the following areas (Fig. 3): The relationship between safety behavior and standards; The relationship between workers' and supervisors' safety behaviors; The relationship between safety behavior and social cognition; The relationship between safety behavior and safety climate; The relationship between safety behavior and safety intervention; The relationship between safety behavior and other factors such as work demand, work resources, safety climate, and safety environment, respectively.
4.1. Relationship between BBS and standards

Ahn and Lee [13] proposed an empirically supported subject-based modeling approach to study the impact of social norms on employee behavior that could be used to develop policies or interventions to improve worker behavior in specific situations. The proposed method provided a way to simulate worker behavior and develop policies or interventions to improve worker behavior in a group.

In order to better understand the control process of construction worker safety behavior by different social norms, Choi et al. [14] studied the perceived management norm of employee safety behaviors, the perceived workgroup norm, and the role of project identification in different cultural backgrounds and organizational structures. The results showed that there was a significant relationship between social norms and safety behavior.

After investigating the safety behaviors of construction workers in the United States, South Korea, and Saudi Arabia, the research team found that employee safety behaviors were influenced by perceived management norms, perceived workgroup norms, and personal attitudes, while perceived workgroup norms were the intermediary between perceived management norms and safety behavior [15]. In addition, the social identity of the project reinforced the relationship between the perceived management norm and safety behavior, weakening the relationship between the perceived workgroup norm and safety behavior.

These findings provide an explanatory model for how regulation affects worker safety behaviors. The use of social psychology to promote worker recognition of projects and strengthen workers' good social norms is considered an effective means to improve construction safety. Choi et al. [16] showed that the personal standards of construction workers were significantly different from the specifications required by project supervisors for safety behavior and that the personal standards of construction workers' safety behavior were significantly affected by their perceived organizational norm. At the same time, the significant impact of social identity on the organization mitigates the impact of the organization’s norms on the personal standards of the construction workers' safety behavior.

The study indicated that the combination of positive norms within the scope of the project and improved project identification were an effective means of improving the safety behavior of workers on construction projects. These findings suggest new ideas for safety management.
4.2. The relationship between worker BBS and manager BBS
Based on BBS, Gravina et al. [17] explained the role of managers in the safety behavior of workers by establishing a consultant workshop model. This offered another method to improve on site construction safety.

4.3. Relationship between BBS and other factors

4.3.1. Safety behavior and social cognition. To identify different safety behavioral characteristics, Fugas et al. [19] studied the relationship between safety behavior and social cognition. The study concluded that cognitive behavioral control was considered the optimal variable that distinguished the group with safer behavior from the others. Choi and Lee [20] established a social cognitive process model for the safety behaviors of construction workers based on experience and established a social cognitive process of worker safety behavior based on theory and evidence. This model was used mainly to study how the process of social cognition affects safety management interventions and how to influence workers' safety behaviors under low, medium-, and high-risk site conditions.

4.3.2. Safety behavior and safety climate. Zohar [21] first proposed the concept of safety climate based on a survey of 20 Israeli manufacturing companies. Zohar described the safety climate as a summary of employees' attitudes towards the work environment and a reference frame for guiding appropriate and adaptive mission behaviors. Employee perceptions of the safety climate determined their safety behavior since individual behavior was shown to be based on the perception of reality. A large number of studies have supported a positive correlation between safety climate and the safety behaviors of first-line workers in high-risk organizations [22]. Shen et al. [23] studied the factors affecting the psychological safety climate, the operation of the safe climate at the individual level, and the basic elements of a higher climate of safety. The results provided managers with three pathways to a psychological safety climate where: customers actively participate in safety management, the project team creates an employee friendly workplace, and transformational supervisors communicate with employees on safety issues.

4.3.3. Safety behavior and safety intervention. Kines et al. [24] tested the applicability of a combination of safety intervention approaches and safety culture initiatives based on safety engagement behaviors. The integrated approach has broad application value. Zaira and Hadikusumo [25] established a comprehensive safety intervention model that affected worker safety behaviors. They conducted a questionnaire survey of construction companies. The results showed that safety interventions were effective in improving safety behaviors. Further, there were three methods of safety intervention: management, individual, and technical intervention, with technical intervention being the most important factor affecting employee safety behavior. In addition, by applying five important safety measures: workplace safety inspections, personal protective equipment programs, availability and maintenance of safety equipment, safe work practices, and safety permits, worker safety behavior could be improved. Such studies underscore that by identifying the appropriate safety measures and specific interventions that improve worker safety behavior construction management can be facilitated further.

4.3.4. Safety behavior and work characteristics, work resources, safety climate, and safety environment. Gillen et al. [26] studied the perceptions of injured construction workers in terms of variables such as workplace safety climate, job requirements, and the relationship between these and the severity of the injuries. Chen et al. [27] used structural equation modeling to study the role of the Canadian construction industry safety climate and personal resilience in safety performance and work stress. The safety climate was shown to not only directly affect the safety performance of construction workers but also indirectly affect their work pressure. Bronkhorst [28] showed that job characteristics (i.e., work stress), work resources (i.e., supervisor support, peer support), and safety climate were directly related to safety behavior; the safety environment could buffer work characteristics (i.e., work/family conflicts and
unsafe work), which had a negative impact on safety behavior, and enhance the positive impact of work resources (i.e., colleague support) on safety behavior.

5. Results

5.1. Key research issues
The literature review on worker safety behavior pointed to the following issues: From the perspective of influential factors, in addition to focusing on worker safety behaviors and unsafe behaviors, in recent years, there are many studies on safety climate, safety environment, social influence, social identity, psychological capital, system security, safety psychology, safety information, safety knowledge, and work stress, with a particular emphasis on safety climate. From an industry perspective, there are many results on the safety of workers in the construction and coal industries, with a particular emphasis on construction. From the perspective of research methods, structural equation modeling, game theory, and simulation modeling have been used to study the safety behaviors of workers, with a particular emphasis on structural equation modeling. From the perspective of organizational levels, many studies have investigated individual behaviors, management behaviors, and organizational safety behaviors, with a particular emphasis on organizational safety behaviors. From the perspective of enterprise size, many studies have examined the safety behavior of workers in medium-sized and small-sized enterprises. From the perspective of worker demographic characteristics. As the demographics continue to evolve, the older generations of workers will gradually retire from the production line. Therefore, research on the safety behavior of the new generation of workers is an emerging trend in recent years.

5.2. Research characteristics
Through a review of the worker safety behavior literature, we found that worker safety behavior studies have the following characteristics: Extensive research has been conducted on the relationship between worker safety behaviors and different influencing factors, the path, and the mechanism. The research perspective on worker safety behavior is relatively broad, in terms of the perspectives on influential factors, industries, research methods, organizational levels, and enterprise size, among others.

6. Conclusions

6.1. Future need for worker safety
As we have shown, the safety behavior of workers is closely related to the occurrence of accidents. Marx pointed out in the "Collection of Marx and Engels" [29] that only the workers who master the new forces of society can play their roles better. With the help of scientific and technological innovation, social development has accelerated, and all walks of life are constantly influenced by new technologies and new equipment. Workers in the front line of production have direct contact with these new forces, and workers continue to be exposed to unsafe conditions. In China, our society must uphold the dominant position of our citizens and always consider their interests so that every citizen’s sense of happiness and security can be assured [30]. In the process of improving the security of people's livelihoods, strengthening and innovating social governance, it is also necessary to establish a concept of safe development, and carry forward the idea of safety first by improving the public safety system and the system for production safety, while resolutely curbing serious safety accidents and improving the capabilities of disaster prevention, mitigation, and relief.

6.2. Future study possibilities
Based on our literature review, we identified several areas where the research on worker BBS could improve in the future in terms of theory, methods, and perspectives. The prospects for future worker safety behavior research are detailed here. First, further innovation in the research theories of worker BBS. Practically speaking, worker safety behavior is based on the identification of unsafe behaviors. As
it is essentially a cross-disciplinary study of safety science and management science, the theoretical basis of the research comes from numerous theories including traditional accident causal chain theory, modern accident causal chain theory, agency theory, game theory, plan behavior theory, psychological contract theory, social capital theory, social cognition theory, social network theory, and other basic theories of safety science and management science. Among these, there should be room for more innovation in the study of worker safety behaviors as well as improvement in the relevant theory systems. Second, further innovation in the worker BBS research methods. At present, for example, the research on worker safety behavior is conducted through questionnaires on the influential factors, structural equation modeling, game theory, and simulation modeling. Hence, other research methods could be explored. In future studies, safety management scholars could use social science computing experiments to simulate worker safety behaviors and explore natural science experimental methods to conduct demonstrations of worker safety behaviors. Third, further innovation in the perspective of worker BBS. At present, the research on worker safety behavior is rich and diverse from perspectives such as the principal-agent, new-generation workers, criminal psychology, and abusive management. Safety management scholars could continue to conduct in-depth research based on these perspectives in the future and also identify innovative perspectives. For example, they could conduct in-depth and systematic research on worker safety behaviors from the perspectives of system science and spatial and temporal distribution characteristics. The issues of whether workers comply with and participate in safety behaviors, whether their safe behavior is actively or passively observed and promoted, and what are the internal and external causes of compliance and participation are all worthy of further exploration. Such research by safety management scholars will help organizations continue to improve worker safety in the future.

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