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# Proactive behavior-based safety management for construction safety improvement

Heng Li [a,d,*], Miaojia Lu [b], Shu-Chien Hsu [b], Matthew Gray [c], Ting Huang [a]

[a] Department of Building and Real Estate, Faculty of Construction and Environment, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
[b] Department of Civil and Environmental Engineering, Faculty of Construction and Environment, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
[c] Schools of Earth, Environmental and Biological Sciences and Civil Engineering and the Built Environment, Faculty of Science and Engineering Faculty, Queensland University of Technology, Gardens Point Campus, Australia
[d] Honorary Professor, Faculty of Design, Architecture and Building, University of Technology Sydney, NSW 2007, Australia

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ABSTRACT

Construction is one of the most hazardous industries due to its dynamic, temporary, and decentralized nature. The Hong Kong Commissioner for Labor identifies worker behavior as the root cause of construction accidents. Behavior-based safety (BBS) is one effective approach in managing employee safety issues. However, there is little research on the application of BBS in the construction industry. This research proposes an extension of the BBS approach, proactive behavior-based safety (PBBS), to improve construction safety. PBBS integrates the theory of BBS with the technology of Proactive Construction Management System (PCMS). The innovations of PBBS are: (1) automatically monitoring location-based behaviors; (2) quantitatively measuring safety performance; (3) investigating potential causes of unsafe behaviors; and (4) improving the efficiency of safety management. A pilot study of a Hong Kong construction site practicing PBBS was conducted. The experiment results showed that PBBS performed well on construction accident prevention and the Safety Index (SI) of the two project teams, with increased improvements by 36.07% and 44.70% respectively. It is concluded that PBBS is effective and adaptable to construction industry.



## 1. Introduction

Approximately 80% of all accidents on construction sites are caused by unsafe human behaviors, with the majority of fatalities being due to workers falling from heights, striking against or being struck by moving objects, or being struck specifically by moving vehicles (Hong Kong Special Administrative Region, Labour Department, 2012). In Hong Kong, construction is ranked as the most dangerous industry, with 24 fatalities in 2012. That is 26.3% higher than the average of the five previous years (HKSAR, Labour Department, 2013), thus indicating that the situation is deteriorating. In recent years, with the introduction of 10 major projects by the HKSAR Government, the industry has experienced a shortage of labor, which has forced many companies to employ people with insufficient relevant work experience. As a result, ensuring the safety of the workforce is becoming increasingly more challenging and complex, and thus, it has become more important to control and manage human behavior on construction sites. One effective method used to modify unsafe behavior is behavior-based safety (BBS) (Chen and Tian, 2012). BBS has been widely used in many industries in Europe and North America for over 20 years, including the petroleum industry (Zohar and Luria, 2003; Fleming and Lardner, 2000; Ismail et al., 2012), the manufacturing industry (Ray et al., 1997; Chandler and Huntebrinker, 2003), the nuclear power industry (Cox et al., 2004), the transport industry (Olson and Austin, 2001; Glendon and Litherland, 2001), and occasionally, the construction industry (Zhang and Fang, 2013; Laitinen et al., 1999; Lingard and Rowlinson, 1998).

Construction is quite different from other industries because of several unique characteristics, including complicated construction processes, temporary organizational structure, changing work locations (Building, 1987), complex work environments (Fang and Wu, 2013), and the characteristics of worker behaviors, which are not as standardized as those in manufacturing factories (Geller, 2001a,b). In addition, because of decentralization, construction workers usually work on separate sites and must make their own decisions when facing specific problems (Olson and Austin,

* Corresponding author at: Honorary Professor, Faculty of Design, Architecture and Building, University of Technology Sydney, NSW 2007, Australia. Tel.: +852 27665879; fax: +852 27645131.
*E-mail addresses:* heng.li@polyu.edu.hk (H. Li), emily.lu@connect.polyu.hk (M. Lu), mark.hsu@polyu.edu.hk (S.-C. Hsu), m2.gray@qut.edu.au (M. Gray), huang.ting@polyu.edu.hk (T. Huang).

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2001). Thus, the construction industry needs a safety system that is capable of monitoring and dealing with novel, variable, real-time risks and hazards. The four basic steps of the BBS approach are (1) identification, (2) observation, (3) intervention, and (4) review (or follow-up observation) and monitoring (Ismail et al., 2012). However, on traditional construction sites, individual observation, review and monitoring may consume many more hours of safety management staff time than they do in other settings (such as a factory) because workers are likely to roam on job sites and therefore be difficult to identify and track (Zhang and Fang, 2013).

This paper proposes an extension of BBS for construction called *proactive behavior-based safety* (PBBS), which combines traditional BBS management with novel information technology called the Proactive Construction Management System (PCMS), which was developed by the authors and the construction virtual prototyping laboratory (CVPL) of the Hong Kong Polytechnic University. PBBS provides a qualitative (BBS management) and quantitative (PCMS location-based behavior observation) way to improve construction safety. Similar to BBS, PBBS includes four well-defined steps. These are (1) baseline observation, (2) safety training, (3) follow-up observation, and (4) feedback and reinforcement. Due to advances in building information modeling (BIM) technology, virtual construction is now the norm for most large construction projects (Zhang et al., 2013; Ding et al., 2011; Li et al., 2012). Simulating construction in virtual models enables the project participants to find and fix the biggest problems before they start building (Li et al., 2012; Ding et al., 2011). The Proactive Construction Management System (PCMS) proposes location-based virtual construction by integrating the Virtual Construction Simulation System (VCS) (Li et al., 2003; Guo et al., 2013) with a real-time location system (RTLS). Using PCMS technology, the real-time location-based behavior data from workers provide safety supervisors automatic and immediate observations, which can decrease safety management costs and improve management efficacy. Through PCMS, workers are provided real-time warnings when they are exposed to risky situations and post real-time analyses when they may have behaved unsafely. PCMS can identify the location of workers, provide proactive warnings and monitor unsafe worker behaviors related to location as distinguished from other unsafe behaviors that are not location related, such as electric shock and nonstandard operations. With respect to the BBS approach, leader-based verbal coaching serves as safety training in formal and informal settings (Kines et al., 2010), and causation analyses conducted through in-depth interviews are used to investigate the basic reasons for workers' unsafe behaviors (Olson and Austin, 2001). A Safety Index (SI) change trend chart is established and used to evaluate safety behavior and change trends. By implementing the PBBS approach, workers and safety managers become armed with objective data regarding potentially unsafe behaviors. Safety managers are better able to impress upon workers just how unsafe their behaviors actually are and can thereby increase the uptake of safer behavior.

In this study, which focuses particularly on the construction industry, both conceptual and actual on-site trials of the PBBS approach have been conducted. This paper describes the origins of PBBS, reports on the findings of these trials to date, and examines the benefits and limitations of the PBBS approach.

## 2. Literature review

### 2.1. Behavior-based safety

Behavior-based safety (BBS) is an effective method for accident prevention that has been widely applied in Europe and North America since the 1980s. BBS became increasingly popular in industrial settings from then on and subsequently throughout the world. There is a significant amount of literature on this approach, including multiple books on BBS that have been published to explicate the principles and procedures involved in the implementation of the BBS process (McSween, 1995; Geller, 2000; Geller, 2001a,b; Krause et al., 1997; Sulzer-Azaroff, 1998; Geller, 1998). Cox et al. (2004) defined BBS as an integrated management process (Hurst and Palya, 2003) that focuses on people. BBS theory emphasizes observing human behavior without presuming knowledge of the thought processes of human beings (DSR, 2003) and usually involves four well-defined steps. The steps are the (1) identification unsafe behaviors; (2) the observation or sampling of identified behaviors over a period of time; (3) application of feedback to increase desired behaviors and decrease undesirable behaviors through coaching and mentoring; and (4) presenting of feedback regarding performance to the relevant audiences within the organization (Ismail et al., 2012). In the field of psychology, such a process is regarded as reinforcement (Chen and Tian, 2012). BBS can realize a change in the target of the safety performance index, such as safety audits, safety climate assessments, and hazard identification and analyses, from a dragging indicator to a leading indicator (Flin et al., 2000; Grabowski et al., 2007). Furthermore, BBS provides a structural and quantitative approach to establish long-term safety management and safety production gains. BBS principles affirm that as human safety consciousness and safety habits are not innate, they can be improved with training (Pearson, 1995), and the evidence of success of the BBS approach appears significant (Cruthirds and Pittman, 1996). For example, Cox et al. (2004) concluded that this model of safety intervention is effective for improving employee safety performance, while Lingard and Rowlinson (1998) studied the application of BBS in Hong Kong's construction industry and found that the approach is reliable in the category of site housekeeping (environment). However, there is some contention among researchers with respect to the best theoretical approach to safety. Some have argued that the BBS process is flawed because it is based on the theory of behaviorism, which claims that all human behavior is driven by external consequences [30]. This is in contrast to other theories such as the theory of planned behavior (Ajzen, 1991), which holds that behavior is derived from both intrinsic and extrinsic factors as well as from social norms. Other authors have argued that safety is derived from culture not from behavior (Smith, 1999; Cox et al., 2004; Elsberry, 2003; Choudhry et al., 2007a,b; DeJoy, 2005). It has also been suggested that these two approaches are complementary rather than antagonistic (Smith, 1999). The purpose of this study is not to settle this argument, however. It is sufficient that BBS approaches are associated with a systematic application of a psychological approach to human behavior that focuses on the identification and modification of critical safety behavior as a lever to reduce workplace injuries and losses. The aim of this set of safety management techniques is to encourage employees to make safe behavior habitual whereby individuals perform safely without thinking.

The above systematic reviews provide case studies of companies and workers that have successfully experienced BBS, and they provide solid evidence for the success of BBS in casualty prevention (DePasquale and Geller, 1999; Grindle et al., 2000; McAfee and Winn, 1989; Petersen, 1989; Sulzer-Azaroff and Austin, 2000). However, BBS has received limited systematic and quantitative study in the construction industry.

### 2.2. Proactive Construction Management System

The PCMS is a comprehensive and proactive system integrated with multiple information technologies such that safety-related information (positioning tracking, machine maintenance, health and safety investigation, safety training, site hazards, danger detection, etc.) is effectively communicated to safety officers or safety