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Behavior-based safety on construction sites: A case study

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ABSTRACT

This work presents the results of a case study and describes an important area within the field of construction safety management, namely behavior-based safety (BBS). This paper adopts and develops a management approach for safety improvements in construction site environments. A rigorous behavioral safety system and its intervention program was implemented and deployed on target construction sites. After taking a few weeks of safety behavior measurements, the project management team implemented the designed intervention and measurements were taken. Goal-setting sessions were arranged on-site with workers' participation to set realistic and attainable targets of performance. Safety performance measurements continued and the levels of performance and the targets were presented on feedback charts. Supervisors were asked to give workers recognition and praise when they acted safely or improved critical behaviors. Observers were requested to have discussions with workers, visit the site, distribute training materials to workers, and provide feedback to crews and display charts. They were required to talk to operatives in the presence of line managers. It was necessary to develop awareness and understanding of what was being measured. In the process, operatives learned how to act safely when conducting site tasks using the designed checklists. Current weekly scores were discussed in the weekly safety meetings and other operational site meetings with emphasis on how to achieve set targets. The reliability of the safety performance measures taken by the company's observers was monitored. A clear increase in safety performance level was achieved across all categories: personal protective equipment; housekeeping; access to heights; plant and equipment, and scaffolding. The research reveals that scores of safety performance at one project improved from 86% (at the end of 3rd week) to 92.9% during the 9th week. The results of intervention demonstrated large decreases in unsafe behaviors and significant increases in safe behaviors. The results of this case study showed that an approach based on goal setting, feedback, and an effective measure of safety behavior if properly applied by committed management, can improve safety performance significantly in construction site environments. The results proved that the BBS management technique can be applied to any country's culture, showing that it would be a good approach for improving the safety of front-line workers and that it has industry wide application for ongoing construction projects.

1. Introduction

What is behavior? Behavior is simply anything someone does or says. Psychologically, behaviors are actions or reactions of persons or things in response to external or internal stimuli. Over the past decade, much research has been conducted on Ajzen and Fishbein's (1980; Fishbein and Ajzen, 1975) theory of reasoned action. According to the theory, behavior is determined by the behavioral intention to emit the behavior. The theory proposed that behavior is affected by behavioral intentions which, in turn, are affected by attitudes toward the act and by subjective norms (Fishbein and Ajzen, 1975). For this research, the behavior means the observable actions, because observable practices are what matters more for workers' safety on construction sites. Behavioral approach addresses how people behave on the job. One can know about someone's attitude by conducting observations of how they behave and what they convey on-site. According to McSween (2003), if we change safety habits of people, their attitudes about safety will follow, especially as their colleagues adopt better safety habits. When we have a group of people with similar habits and attitudes about safety, we begin to talk about people having a common safety culture; then we want to talk about changing the culture, we have to talk about changing people's behavior (McSween, 2003).

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This work presents a case study for using behavior-based safety (BBS) management in construction fields. BBS is the systematic application of psychological research on human behavior to the problems of safety (Cooper, 1994). Heinrich (1959) estimated that 85% of accidents can be attributed to unsafe acts. Blackmon and Gramopadhye (1995) stated that 98% of all accidents are caused by unsafe behavior. HSE (2002) revealed that 80–90% of all workplace accidents and incidents are attributed to unsafe behaviors. Nishigaki et al. (1994) found that most accidents occur because of human-ware failure. Reducing accidents and improving safety performance can only be achieved by systematically focusing upon those unsafe behaviors at construction sites (Choudhry and Fang, 2008; Choudhry, 2012). For example, not holding the handrail when ascending or descending stairs, not storing equipment after completing a task, etc., are all unsafe behaviors. The triggers for behaving unsafely include a wide range of management system faults that are associated with each incident. These triggers commonly include getting the job done, meeting excessive production targets, competing priorities, tight construction schedule, lack of training and lack of availability of equipment or materials. According to Behavioral Safety (2012), other triggers are often in the direct control of front line-management and or employees such as poor housekeeping and using personal protective equipment (PPE).

According to the accident pyramid, Heinrich (1959) proposed that for every 300 unsafe acts there are 29 minor injuries and 1 major injury. In other words, he suggested that the ratio between major injuries, minor injuries and no-injury accidents was 1:29:300. Widespread acceptance of Heinrich's theory of accident causation that unsafe acts lead to minor injuries and over time to a major injury sent safety managers and company presidents in pursuit of unsafe acts under the assumption that if they could control unsafe behavior then the major injury would not occur. With senior management commitment, a good safety program starts by conducting a thorough evaluation and step-by-step Job Safety Analysis (JSA) followed by the development of a written Safe Operating Procedure (SOP) for each construction activity (Hinze, 1997). If JSA and SOPs are poorly developed merely to satisfy administrative requirements of the safety management systems, damage to safety efforts is possible.

1.1. Objective

This work was carried out at a construction site of a construction firm (hereinafter called the company), that is considered a leader in the construction industry of Hong Kong. The company strives to focus on customers' needs and construct high quality buildings and infrastructure projects. The management of the company values its staff and always tries to ensure that their employees are working in a safe and healthy environment. Having achieved a good safety record over the past years, the company management considers that it is the right time to further improve site safety through a bottom up approach namely behavior-based safety (BBS) techniques. In addition, there is no alternate for the company's Health, Safety and Environment Management Systems (HSEMS) whether they are ISO 14001 or Occupational Health and Safety Assessment Series (OHSAS, 18001) standards (Choudhry et al., 2008). The Area Management System was working well for the company's construction projects. So, the company seems committed to continuously strengthening the implementation of its safety systems.

There were numerous subcontractors performing work on all the company's projects. All subcontractors were responsible to plan and conduct their own work. Nonetheless, when a safety lapse occurred resulting in an accident, the accident was charged to the prime contractor, the company. The writer was requested to help the company to devise ways for solving site safety problems. In the present scenario, the research team thought that BBS could offer a better solution to this problem besides improving safety on the company's construction sites. Many manufacturing companies experienced a 40–75% reduction in their accidents rates within twelve months as a direct consequence of implementing the techniques associated with BBS (Behavioral Safety, 2012).

This work is an attempt to adopt and develop existing management techniques for safety improvement for the construction company and to evaluate their effectiveness in a BBS field study on a construction site in Hong Kong. Attempts to improve safety using safety poster campaigns have been attempted. Saarela et al. (1989) revealed that such campaigns did not make a lasting impact on accident and injury rates. Other methods such as incentive and reward systems (McAfee and Winn, 1989) were normally used to speed up the progress of work but usually did not reward safe working procedures. Incentives used to foster safe behavior could be expensive or applicable for the short term and might discourage operatives from reporting accidents and incidents. In this study, operatives mean the front-line workers (including both trades people and general operatives), supervisors, and drafts-people. The use of disciplinary action and punishment were likely not to be effective as those were infrequent, delayed, or of mild intensity. Additionally, construction supervisors were often reluctant to use them because of fear that resentment would lead to lowered morale, lack of cooperation and loss of productivity (Peter, 1991).

On the company's construction sites, serious accidents were relatively rare and non-serious accidents were under-reported, it then made sense to focus on behaviors that could improve construction site safety. McAfee and Winn (1989) demonstrated that safety behavior could be improved by systematically monitoring safety-related behaviors and providing feedback in conjunction with goal setting and training. Goal setting coupled with feedback were better than feedback alone; and participative goal setting was more effective than assigned goal-setting (Duff et al., 1994). Research in other countries was conducted on BBS including goal setting and feedback techniques (Komaki et al., 1978; Chhokar and Wallin, 1984; Duff et al., 1994; Sulzer-Azaroff and Austin, 2000; Geller, 2001, 2005; Svensson and Hyden, 2006). The results indicate that behavioral approaches could be one of the best techniques to improve site safety (Duff et al., 1994). BBS initiatives were useful toward improving safety performance (Al-Hemoud and Al-Asfoor, 2006; Choudhry, 2012). Nonetheless, no attempts have been made to apply BBS techniques for improving construction site safety within the company. Past studies (Duff et al., 1994; Geller, 2005) were done in western cultures and this study was carried out in the Chinese culture providing an insight into the generalizability of BBS concept beyond western cultures. The aim of this research is to find ways for further improving construction site safety at the company's construction projects. Specifically, the following main objectives are included for this research:

1. To develop, and introduce a suitable method of measuring safety performance to help the company to improve construction site safety;
2. To find ways for improving construction safety for the company's subcontractors conducting work on the firm's construction site; and
3. To use a method to assess safety management, based upon proven techniques for changing work behavior thus improving site safety by fostering safe behavior.

2. Background

Safety management by walking around (SMBWA), an intervention based on managers and employees participation was presented by Luria and Morag (2012) to demonstrate the ways in which this practice can improve safety in organizations. Fogarty and Shaw (2010) presented the model highlighting the importance of management attitudes and group norms as direct and indirect predictors of violation behavior. The study concludes that the Theory of Planned Behavior (TPB) (Ajzen, 1991) is a useful tool for understanding the psychological background to the procedural violations associated with incidents and accidents. The effectiveness of a road safety intervention was described in a recent study (Glendon et al., 2014) by measuring attitudes toward unsafe behavior and risk perception. Other studies indicate that safety management practices not only improve working conditions but also positively influence workers attitudes and behaviors with regard to safety, thereby reducing accidents on construction sites (Choudhry et al., 2008; Vinodkumar and Bhasi, 2010).

Within the field of construction, many efforts were made to improve safety on construction sites including legislation (Hinze, 1997; Choudhry et al., 2006), engineering failures (Cooper, 1994), safety awareness campaigns (Saarela et al., 1989), safety training (Cooper and Cotton, 2000; Hale, 1984), and unsafe acts (Duff et al., 1994; Choudhry, 2012). The legislative approach has not made much of an impact because the resources necessary to police construction sites have not always been forthcoming (Choudhry et al., 2006). Engineering approaches have typically focused on designing out the possibility of accident occurrences, which does not match the rapidly changing technologies (Cooper, 1994). Other interventions designed to improve construction safety by raising operative's safety consciousness using safety poster campaigns, and other informational safety campaigns, have not been consistently successful (Saarela et al., 1989). Safety training has been one of the fundamental methods for improving safety (Hale, 1984). This is based on the assumption that safety training in itself is a good thing, those who know what to do will conduct themselves in a safe manner. Nonetheless, this has not always been the case. Despite the view that safety training will cure most ills concerning accidents, evidence exists that it is not always effective (Hale, 1984), which may be related to the variability of the quality of the provided training. This is because both safety training and safety campaigns concentrate upon changing people's attitudes in the hope of influencing their subsequent behavior (Cooper, 1994). Similarly, both engineering and legislative approaches are based on the assumption that influencing a situation will influence people's behavior. To some extent, this is correct, but it is not the whole picture (Cooper, 1994; Wilson, 1989).

Many approaches to improve safety concentrate upon changing people's attitudes, in the hope of influencing their subsequent behavior. The underlying assumption of this approach is that attitudes cause behavior, which is inaccurate (Cooper, 1999). Definitely, attitudes are often expression of how people would like to see them behaving, rather than the behaviors that they actually engaged in (Cooper, 1999). For example, evidence has shown that workers with the most favorable attitudes toward personal protective equipment (PPE) are least likely to use them in practice. Similarly, senior management in many companies expresses the view that safety of its employees is of the utmost importance. Nevertheless, very often these same managers design the overall workflow system, and or the reward system in such a fashion that unsafe practices are inevitably encouraged (Cooper, 1994; Wilson, 1989).

The BBS approach is founded on behavioral science as conceptualized by Skinner (1938, 1953). Experimental behavior analysis, and applied behavior analysis emerged from Skinner's research and the intervention process targets specific behavior for constructive change (Williams and Geller, 2000; Hayes, 2001; Geller, 2005). Peterson (2000) revealed that the concept of safe behavior reinforcement is not new when systematic application of safe behavior in safety was first conducted by Komaki et al. (1978). Behavior modification is based upon the principle that behavior is a function of its consequences and the frequency of desirable behaviors can be increased by positively reinforcing safe behaviors (Lingard and Rowlinson, 1994). Additionally, BBS toward improving safety differs from traditional approaches in two simple ways (Behavioral Safety, 2012). The first is its concentration on observable safety behavior, rather than unobservable attitudes toward safety. The second is its emphasis on the encouragement of safe behavior, rather than the punishment for unsafe behavior.

When non-compliance to legislation or safety rules occurs, management often places an emphasis upon punishment to rectify the situation. This is in contrast to the rewarding of compliance, which will have the effect of increasing the likelihood of compliance. Cooper (1994) revealed that punishment must fulfill two criteria to be effective. It must take place every time the unsafe behavior occurred and as soon as possible after the behavior. One cannot punish everyone immediately and every time one commits an unsafe act. This is because one is not always going to be there to observe it. Encouraging desirable behavior, however, by positively acknowledging safe behavior is more likely to be successful, as it does not have to be given immediately and every time. Evidence indicates that one of the most powerful methods of encouraging desirable behavior is to provide social rewards in the form of praise or recognition (Cooper, 1994). After a period, when the behavior becomes an established part of the individual's repertoire, rewards can be given on a less frequent basis. Additionally, incentives have been used successfully to improve safety behaviors (Peter, 1991) but can be expensive. In addition, material rewards sometimes apt to discourage operatives from reporting accidents and near misses.

Cooper (1994) further explained that in all occupations, we are provided with feedback from many sources that subsequently affect our behavior. For example, when driving our car, we get feedback from the speedometer. If we are breaking the speed limit, we tend to adjust our speed and slow down. In terms of improving the safe behavior of employees as a whole, a powerful behavioral change agent is the public posting of the feedback as to how well employees are doing; in relation to those areas of safety, they are specifically trying to improve (McAfee and Winn, 1989; Cooper, 1994). The advantage of feedback is that all personnel including sub-contractors can tell whether their collective efforts have been successful. This type of feedback is usually in the form of chart posted in a public location (e.g. site canteens or site notice boards). Very often, employees watch actual posting of the weekly performance results. This could result in a focusing of attention and reinforcement of particular aspects of safety by stimulating conversations among employees as to how well they are progressing.

Other effects include raising general level of safety awareness and positively changing attitudes and improving safety because goal setting and feedback provides a direct measure of safety performance (Duff et al., 1994). Based on some 400 laboratory and field studies, goal setting theory (Lock and Latham, 1990) was developed inductively in the industrial/organizational psychology over a period of 25 years. These studies showed that specific, high (hard) goals lead to a higher level of task performance than do easy goals or vague, abstract goals such as the exhortation to "do one's best." As long as a person is committed to the goal, has the requisite ability to attain it, and does not have conflicting goals, there is a positive, linear relationship between goal difficulty and task performance (Lock and Latham, 1990).

Varied results were reported regarding the application of the BBS approach in the construction industry. Lingard and Rowlinson (1998) have reported mixed results of a BBS study in the construction industry of Hong Kong that a significant improvement in safety performance occurred in the housekeeping category but no improvements were observed in the access to heights and bamboo scaffolding categories. Mattila and Hyodynmaa (1988) revealed that a behavioral safety program affected safety positively even in the difficult setting of two building sites in Finland. A review argued that safe behavior programs have been seen as complementary to safety programs aimed at changing organizational culture and proposed a theoretical integration of the two for managing safety (DeJoy, 2005). Hopkins (2006) revealed that BBS programs do not work when the workforce mistrusts the management and argued that the safety program is just another way to hold workers responsible, though, Hopkins certainly sees BBS as an important component of any comprehensive safety management system. Unlike the typical top-down control approach to industrial safety, behavior based safety provides tools and procedures workers can use to take personal control of occupational risks (Geller, 2005). It appears that diversity in the effects of the BBS approach needs further investigation on construction sites particularly in the implementation process of the approach, which is addressed in the present study.

3. Method

This section describes the research method, questionnaires development and data collection process. Both quantitative and qualitative methods were utilized in analyzing the data. The research was divided into four phases: preliminary study phase, data collection phase, data analysis phase, and report writing phase. In the preliminary study phase, appropriate literature was searched from journals and books in order to gather background data. Planning for the research method was completed during this phase along with the research schedule. Questionnaires required to collect safety information from the construction sites were developed. A rigorous BBS management approach and its intervention programs as implemented at the target project were prepared during this phase.

3.1. Categories of safety behavior modifications

An extensive literature review was carried out to introduce a BBS management approach in the company including learning from the UK experience (Duff et al., 1994). Related modifications were incorporated to make an approach suitable for the construction site of the company. Safety management systems, work procedures and site safety plans on a complicated elevated expressway project provided by the company were studied. Being the most risky, five categories of safety behavior modifications were identified and were measured in this case study. These are personal protective equipment (PPE), housekeeping, access to heights, plant and equipment, and scaffolding.

PPE included wearing safety helmets, safety shoes, safety gloves, using ear defenders, or wearing hearing protection in noisy environments, wearing goggles or eye protectors while doing welding or using motorized cutting equipment, and wearing respirators in dusty conditions. Breathing apparatus were made available for use in confined spaces. Fall arresting equipment or a safety harness was an excellent PPE for personnel working at height where it was impracticable to provide a working platform. Reflective waistcoats or vests were made available for personnel involved with operations where good visibility was required. Life jackets or other buoyancy aids were provided for workers liable to fall into water.

Housekeeping included items related to such aspects of site safety as storage and stacking of materials as well as the maintenance of clear access routes. Housekeeping on construction sites included removing nails from the site, keeping floor openings covered or guarded, not throwing objects from heights and providing barricades around open excavations. Improvement in housekeeping was made without the requirement of substantial additional materials or equipment. Everyone on site was required to contribute toward improvements of on-site housekeeping.

Access to height category of work included not using short, broken or defective ladders; also, ladders must be tied or secured. Mobile tower scaffolds and mobile work platforms were required to be used safely and as recommended by their manufacturers.

Plant and equipment category required that equipment was not to be parked near excavations. Operatives do not have to drive equipment too fast and the equipment was not to be loaded insecurely. Equipment was not to be used to carry illegal passengers and workers. Excavators, dump trucks, dumper, cranes and other vehicles were required to be operated safely.

Scaffolding category of work was related to few specialty trades. Frequently additional materials required resulted in increase in cost and the project schedule. For example, if a scaffold was to be fitted with an adequate closely planked working platform, guardrails and toe boards. Good quality timber was required for use as platforms and toe boards.

3.2. Goal-setting meeting

Goal-setting theory hypothesizes that goals are the immediate, though not sole, regulators of human action and that performance can improve when goals are hard, specific and accepted by the employees (Lock and Latham, 1990). The literature on goal setting provided clear guidance on how to operate the theory to good effect (Cooper, 1994; Robertson et al., 1999; Choudhry, 2012). At the target project, goal-setting meeting were arranged on-site with the participation of workers to set realistic and attainable targets of safety performance. Operatives were asked to agree upon a goal that was difficult but achievable for safety improvements in relation to the appropriate base period scores. When consensus was not reached, operatives' suggested goal levels were recorded. Subsequently, all the suggested figures were summed up and averaged to provide a goal on which operatives agreed. When all operatives in each trade agreed upon a goal, the trade goals were summed and averaged to provide the goal for the identified category. This participation process induced commitment to and ownership of to the improvement process. The respective goal-level was then entered as a solid line on each of the feedback charts. After the goal-setting session, feedback on safety performance was provided regularly to operatives since it was the key feature of the BBS initiative.

3.3. Feedback charts

The researches on feedback (Duff et al., 1994; McSween, 2003; Choudhry, 2012) demonstrated that performance was enhanced when management provided clear feedback of performance-related information. Following the goal setting meetings, the feedback charts were posted at appropriate places on the project site where operatives can see them easily. Observations continued at the same rate as that during the base period. The results of weekly observations were posted on the feedback charts every week.

3.4. Observers and behavior observations

Each safety observer was provided a half-day training session in the basic theory and practice of the BBS management approach. The training content included elements of goal-setting, behavior modification, decision making, how to manage resistance from others, the provision of individual feedback, observational techniques and scoring of the operatives checklists. Similarly, part of the training was devoted to practice observations. Any misunderstanding in scoring was identified during this process. Originally, different trades were requested to spare one observer for the training. By

Table 1
List of checklist items for PPE category.

S. No.	Items
1.	What proportions of the site personal on the site are not wearing safety helmets?
2.	What proportions of site personnel are not wearing protective footwear?
3.	What proportions of site personnel are not wearing gloves while handling materials that had sharp edges, hot or could cause skin problems?
4.	What proportions of operatives are not using ear defenders while using noisy equipment?
5.	What proportions of the site personnel on the site are not wearing goggles or other items of eye protectors when using motorized cutting equipment, welding, and cartridge operated tools?
6.	What proportions of operatives are not wearing face masks in dusty conditions?

Table 2
List of questionnaires.

Questionnaire	Description
I	General requirements for behavioral safety
II	Behavior safety assessment survey
III	Participating contractors and subcontractors
IV	Feedback charts
V	Project information for the BBS
VI	Training checklist for safety performance measure
VII	Observer checklist for safety performance measure

this training, observers became comfortable and conversant with their task.

Qualified supervisors of the company with relevant site experience hereinafter called observers were observing behavior. Safety performance observations were taken two times a week. Observations were taken at differing times of the day to overcome any systematic time of day effects and to avoid management expectations affecting the results. Safety behavior measurements involved observing behavior at random to determine safe performance. Following this, observations were taken on-site, and were never taken twice on the same day. For validity issues, two observers always measured the observations independently and simultaneously to avoid any bias and to ensure level of agreement and acceptability. Where possible, these observations were carried out jointly by the research team to minimize bias. Inter-observer reliability (IOR) checks were performed on several occasions when the writer and an observer independently completed a checklist for the same site. Using the percentage agreement method (Komaki et al., 1978), these checks showed 94% agreement between observers.

Following the base period scores, a copy of the checklist was publicly displayed on the health and safety notice board. This was done to make it explicit to the workforce, which behaviors were being monitored by the observers (a sample checklist items for personal protective equipment is shown in Table 1). Checklists were also distributed to all operatives during the goal-setting sessions. Observers were required to submit completed checklists to the writer to compile the results. The writer was responsible for entering these results from the checklist into a computer and for preparing the feedback chart and graphs. Each week's scores were calculated and averaged to provide an overall index of safety performance level.

To provide feedback, it was required to conduct meeting sessions with smaller groups. Copies of checklists were given to all those present in the meeting, to clarify particular behaviors that were being monitored. Base period scores were measured for first 3 weeks on the site in all categories. The results of the base period observations were then presented to operatives in graphical form for their feedback. Observers were asked to visit operatives' respective trades and groups and talk to workers individually, in the presence their line manager in order to minimize interruptions to the site work. These meetings begin with an explanation of the purpose and the philosophy behind the BBS approach. Particular emphasis was placed on the fact that no individual employee is to be identified because of the observations and therefore no disciplinary action was taken against employees who even did not follow the procedures advocated by the BBS technique in the checklists.

3.5. Scoring of the safe behavior

When taking BBS performance measurements, the observer remained on-site from 45 min to 1 h with the amount of time spent at each site was determined by the number of operatives in the crew of a category; more time was spent with larger crews. Normally, no observations were recorded in the first 5–15 min to allow workers to become accustomed to the observers. The number of workers in a crew, the crew type and its number (e.g. scaffolding crew) were noted and observations were recorded. After having base period scores for three weeks, participative safety improvement goals were set on the construction project. During the subsequent intervention period, operatives were requested to adopt the observation checklists for their work area.

Observations were taken for 2 months. Nonetheless, the company intended to continue the process and behaviors recorded as 100% safe are to be removed and replaced with others identified during the observations or obtained from the accident and near-miss records. The company then introduced new observers when the research finished. The new observers were selected and the experienced observers continued to point out non-compliance to their peers. The experienced observers provided a support resource for subsequent observers. In effect, the initiative was constantly refreshed in an attempt to embed the process into normal procedures so that it would not be viewed as a flavor of the 2 months attempt. The company provided all necessary training for the new observers and resources they required.

In the data collection phase, the BBS was introduced at a mega construction project of the company. Base period scores were measured. The behavior-based safety interventions were employed on the project. The company's observers were trained and assigned to take safety performance measurements on the construction project. After base period scores of the BBS were determined, the project management team implemented the designed intervention and the measured safety performance scores were made available to the writer daily. The collected data was entered and analyzed. The writer spent a total of 2 months and 7 days at the target project in Hong Kong for the purpose of data collection and introducing the BBS technique to the company. Based on the field study, a system of measuring, monitoring, and improving safety on the company's construction project is documented in this paper. An observer is a nominated supervisor of the construction company who was trained to take observations during the implementation of BBS management approach specifically for this research.

3.6. Research instrument

Questionnaires were used as the research instrument. Designed set of questionnaires was submitted to the company both in English and Chinese languages well in advance (see Table 2). Questionnaire I contains requirements for behavioral safety research such as participation of the construction sites, research design, safety team of the company, observers' selection, observers' qualification and training, measuring safety by behavioral observations, goal-setting, feedback and charts. Questionnaire II comprises behavioral safety assessment survey which was prerequisite for any project for inclusion in the behavioral safety research. Questionnaire III lists names of all the participating contractors and subcontractors. Questionnaire IV provides information about the feedback charts; their number, sizes, where and when to be placed. Questionnaire V records project information including name of the project, designer, contractor, consultant, and contract amount. Questionnaire VI comprises on the training checklist for safety performance measure. Questionnaire VII provides the observer checklist for safety performance measure. All questionnaires were pilot tested before the data collection period.

The behavior safety assessment survey was carried out. The construction site was selected for the behavior-based safety after reviewing the outcome of the behavior assessment survey. This task was completed during the first visit of the writer. It was the responsibility of the project manager and safety managers to ensure feedback charts were placed and properly updated. Training checklist for safety performance measure (Questionnaire VI) was prepared and observers were asked to read it repeatedly. The questionnaire in the training checklist included 42 questions and 111 training statements. Copies of the training checklist were distributed to all the operatives after the base period measurements. One copy of this checklist was given to every operative attending the goal setting session. This checklist provided information to operatives as to how they could act safely when compared to safety performance measurements. There was no requirement to fill or return this checklist. The observer's checklist for taking safety performance measurement (Questionnaire VII) was mainly adopted from the study of Robertson et al. (1999); modifications were made after incorporating feedback from the project manager, middle managers, engineers, site supervisors, and safety representatives of the company. Safe and unsafe behavior items were identified from the company's safety management systems. The purpose of this process was to foster employee ownership, which is considered vital for the success of this study. Observers were required to take measurements two times a week preferably on Monday and Thursday while visiting the entire construction site. They can choose their own time to take the measurements. Proportional rating scale was used for measuring safety performance, which is more suitable to construction industry environments. Additionally, seven management interviews were conducted with the project managers, safety managers and higher management to collect qualitative data. Qualitative data were also collected from seven semi-structured interviews with operatives. These interviews provided a broad understanding of the industry, operative's issues and their site safety.

3.7. Percentage rating

This research uses the percentage rating scale for measurements as demonstrated by Duff et al. (1994). Other research involving measures of safety performance normally utilized either an "all or nothing" measure of safety performance, i.e. 100% safe or 100% unsafe (Komaki et al., 1978). A proportional rating scale is better suited to deal with construction industry environments. For example, a scaffold with only 75% of the required toe-boards correctly fixed was assessed as 25% unsafe for that particular measurement item, rather than just "unsafe". This method permits changes in safety performance to be measured with increased sensitivity.

In this research, an eleven-point rating (none unsafe, scarcely any unsafe, very few unsafe, a few unsafe, some unsafe, considerable unsafe, a lot of unsafe, a great deal of unsafe, an extreme unsafe, almost entirely unsafe, all unsafe) was used for each individual item while taking measurement. Scores for each category of safety performance, for example, housekeeping are calculated by combining scores for the individual items observed. The "Not Seen" option simply reflects the fact that during a particular observation session, people were not undertaking that specific activity. This allows these items to be discarded from further calculation.

3.8. Workshop and progress meeting

A workshop was held in Beijing with four participants from the company and five researchers. It was agreed that the writer would help in launching the company's BBS program and would monitor the research for at least 60 days in Hong Kong. Following this, the writer visited target project sites for 8 days prior to the data collection period to get information about site activities, to carry out the behavioral safety assessment survey, and to make final adjustments to the questionnaires submitted to the company. Upon arriving in Hong Kong, the writer presented the research program to the company's management before proceeding to the site visits. Seven projects were visited and three were selected for the BBS study after reviewing the outcome of the BBS assessment survey.

Later, a progress meeting was held in Beijing. Top management of the company, the writer and other researchers participated in the meeting. It was agreed that the BBS research shall be carried out on only three projects. It was decided that the company needs to select three observers for each construction site. The writer is to be stationed at project "A", where the detailed case study is to be carried out. It was agreed that due to time constraints the writer is to administer and coordinate the BBS technique for 60 days. Nonetheless, the company desired to continue with the BBS observations by their staff until construction activities are completed. The data were collected from the target construction sites in Hong Kong. More than 15 employees of the company directly supported and participated in the research work including an Executive Director, a Project Manager, a Head Safety Officer, and the Coordinator of this research, 3 Safety Managers, and 9 observers.

3.9. Project information

The BBS was introduced on the three projects in Hong Kong. The three sites are named as Project "A", "B" and "C" and have the workforces from 550, 270 and 400 operatives who were selected to implement the BBS techniques. Project "A" was an elevated expressway contract where this case study was carried out. It covers a four-kilometer dual 3-lane carriageway linking the future Hong Kong–Shenzhen Western Corridor with the Southern Section of the Link located in Yuen Long. According to the tender document, the contract was signed with a contract completion time of 860 days. Project "B" was a dual carriageway tunnel construction for a 3 plus 3-lane roadway into a mountain in Hong Kong. The Project "C" was also a 3 plus 3-lane elevated road but is mostly across the sea including a cable stay bridge that is to connect Hong Kong with Mainland China. The selected construction sites have contract values of HK$1.7 billion for project "A", HK$ 1.5 billion for project "B" and HK$ 2.2 billion for project "C". Both goal-setting and feedback techniques were used to implement the intervention.

Safety management practices on the project included implementation of the company's Health, Safety and Environment Management System (HSEMS) Manual, the Company's HSEMS Operational Control Procedure, and the Site Safety Plan (Choudhry et al., 2008). The entire measurement process was designed for five categories of construction activity and it was implemented simultaneously in all five categories.

3.10. Weekly progress and training

The writer introduced the 60 day research project at a kick-off meeting. After the kick-off meeting, observers were provided a half-day training session to implement BBS on the projects i.e. project

"A", "B" and "C". Observers were trained in theory of goal-setting, about safe and unsafe behaviors, and the scoring of safety performance measures in a classroom setting. In total, nine observers were trained, three from each project. Other training was provided when required. Observers were not required to be engineers. Supervisors of the company, who got training of how to record observations, were asked to collect data. Safety managers of the company were also provided training. Criteria for the selection and qualification of observers were issued in advanced, and were utilized for training and discussions with safety managers and the project management team.

The 60 day research schedule was distributed to all safety managers and observers so that they can understand the daily research activities for the data collection phase. To improve coordination between participants, weekly coordination meetings were held at project site "A" where the writer was residing. Participation of the company's Coordinator for this research project, Safety Managers of the three projects, and all Observers were required to attend these weekly meetings. Participation of senior management and project managers were appreciated at the weekly meetings. The writer prepared the minutes of each weekly meeting and emailed them regularly to every participant including the project management team, safety managers, and observers for their information and follow-up.

The writer visited project site "A" several times during the data collection period. Each visit typically contained an element of training concerning either clarification of the BBS techniques or reinforcement of intervention awareness among observers, supervisors, and operatives. During the weekly meetings, it was stated that data were to be incorporated from project "A" since it was designated as the case study project to explain the research work. Nonetheless, safety managers of project "B" and "C" were requested to pay more attention to the BBS management system on their projects to ensure proper implementation by the company's personnel for comparison purposes. Then on all three projects, both quantitative and qualitative data were collected. Quantitative data covered safety performance measurements and qualitative data collected included management interviews and semi-structured interviews with operatives.

3.11. Data collection

As per the plan, the company implemented the BBS management system with the company's management team and writer was involved in the development of the BBS techniques. The writer supported the launch of the program at the construction projects. A letter was issued to all observers at the beginning of the data collection period. Observers were requested to be honest about their feeling while taking observations. A checklist for safety performance measure was issued to observers for taking safety performance measurements two times a week. Observers were required to visit the entire site when taking measurements. Two questionnaires for participative goal-setting and the training checklist for safety performance measures were distributed to all operatives during the goal-setting session at the three projects. Operatives were not required to complete and return these two questionnaires as they were for their information and recording the explanation of how they need to act safely during conducting their constructions tasks. Trained company's observers were ready to record safety performance scores against the designed checklists. Safety performance measurements were taken in the following five categories:

1. personal protective equipment;
2. housekeeping;
3. access to heights;
4. plant and equipment;
5. scaffolding.

After completing all planning, the practical implementation of the 60 days observations was started. A detailed case study was carried out at one site and the same BBS techniques were implemented on the other two sites for comparison purposes. The safety manager and his team including three observers implemented the BBS research on the three projects. Baseline scores were measured by observers touring the whole site and filing the designed checklists. Goal-setting sessions were arranged on site with the participation of workers to set realistic and attainable targets of performance. These sessions were held at project site "A", after three weeks of measurements. At project site "B", the goal-setting session was held after 5 weeks of measurements. The writer presented goal-setting materials to achieve the set target and to motivate the operatives for improving safety at project "B". The goal setting session was held at project site "C" after taking 4 weeks of measurements. Similarly, the writer presented goal-setting materials to encourage operatives in achieving the set target at project "C". The writer helped in conducting the goal-setting sessions at all three projects.

On the day of the goal setting session for project "A", the company requested that the whole day be taken to conduct a complete safety review. Owing this, everyone was determined to put the safety in order at project site "A". In the goal setting session, site operatives were informed about the measured safety performance level during the last three weeks at project "A". A score of 92% was set as target after participation of the operatives. Operatives agreed that every effort is to be made to achieve the set target within the next 5 weeks. The training checklist for safety performance measure was distributed among site operatives to let them understand what is being measured. The training questionnaire and feedback charts were distributed to the site people. The operatives received feedback of the current week safety performance scores.

Feedback charts were displayed at suitable places so that the operatives can see the current safety scores in relation to achieving their set targets. Consequently, updated feedback charts were displayed on 1st day of every week i.e. on Monday. Feedback charts showing graphically the results of the safety measure were placed in positions where the workforce could see them at least once a day. They were displayed at each check-in point of the operatives' canteen and on the site notice boards. Safety performance as a percentage was plotted against time. Charts of computer printouts were used in great numbers for providing feedback to the operatives.

During the goal-setting meeting, the project manager and safety manager of the project "A" encouraged operatives to achieve the set goal for improving safety. A special review session for improving safety and intervention awareness was held at project site "A" during 6th week. The writer presented the research progress of project site "A". Participants repeated their commitment to achieve the set target of 92%. Subsequently, another review session for improving safety was held at project "A" wherein the writer presented more material on the benefits of BBS to improve site safety. In total, the writer delivered five presentations including the last presentation on progress of the research at the company's Headquarters. In all these sessions, introduction to BBS, what is being a measured, goal-setting material, how to achieve the set target, and benefits of BBS to improve site safety were presented.

After 3 weeks of base period measurement, observers were asked to have discussions with the operatives, visit the site and distribute the training materials, provide feedback and display charts on-site. They were asked to develop awareness and understanding of what was measured in the presence of line managers. In the process, operatives learned how to act safely in conducting their work

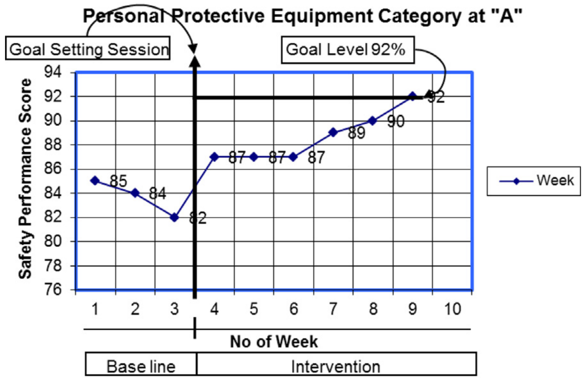

Fig. 1. Safety performance scores for PPE category at project "A".

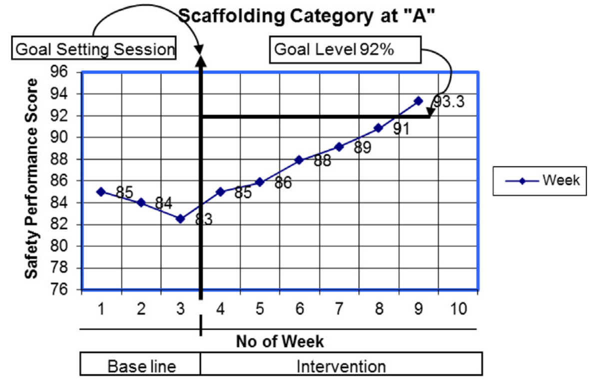

Fig. 2. Safety performance scores for scaffolding category at project "A".

tasks. Additionally, current weekly scores were discussed during site safety meetings as well as in other operational site meetings on how to achieve the set targets. Site management appreciated the BBS technique when they notice a mathematical number indicating improvement of ongoing safety performance levels.

The writer performed inter-observer reliability (IOR) checks at project site "A". During these checks, the writer and observers were scoring the site simultaneously and independently. After calculations, the scores were compared to remove any discrepancies. Using the percentage agreement method, IOR reliability of 94% was recorded. Additionally, qualitative data were collected in a number of ways. First, observers were issued 'diaries' where observations and information about any events relevant to the safety intervention were recorded by observers. Second, weekly progress meetings were arranged and minutes of all meetings were prepared and distributed to all concerned including observers, safety managers and project management team. The writer also kept records of each event and comments were recorded in the minutes of meetings. Third, both management and operatives' interviews were conducted.

The safety performance measure used in this research was comprised on two documents. The first document consisted of a handbook covering the safety issues of each item, which, was distributed free to every operative for their information showing how they were required to perform safely compared with each measured item. The second document contains the observer checklist for safety performance used to calculate percentage scores of safety performance.

4. Results

This section describes results of the BBS research carried out at the project site "A" in all five categories of safety performance measurements. The company observers collected safety performance data each time after visiting the entire site and twice a week. After having three weeks of measurements, a safety intervention was introduced in a goal-setting meeting at project "A". At this point, all site personnel attended the goal-setting session at project site "A", at which safety performance measure was explained, current levels of safety were discussed, and targets for improvement were set. Safety performance measurements continued and each week levels of performance and the targets were presented graphically on feedback charts. Feedback charts were located prominently and were updated weekly.

In personal protective equipment category, the measured scores of safety performance were 82% at the end of the 3rd week when the goal-setting meeting was arranged. The scores had been increasing during the intervention period and approached to 92% in the 9th week (see Fig. 1).

The safety performance score in housekeeping category was 83.7% at the end of 3rd week when the intervention was introduced. The scores had been increasing every week approached to 92.9% during the 9th week, and crossed the set goal of 92% in the housekeeping category.

In access to heights category, the subcontractors were implementing a work-at-height safety campaign and the measured scores were 91% and 93% during week #2 and #3 respectively. An accident occurred during the 4th week, when a worker slipped from the top of a ladder and received serious injuries in his head. Subsequently, all ladders were checked for defective rungs and short ladders were replaced. Operatives were informed to keep correct angle (75°) as one horizontal to four vertical. Operatives were briefed about the access to heights handbook distributed to them during the goal setting session. Within the next weeks, the scores were improved from 87.5% in week #5, to 92.5% at the end of the data collection period.

In plant and equipment category, the measured score of safety performance was 91% when the goal setting session was arranged. The safety performance scores have been increasing and reached to 93.6% during the 9th week, thus crossing the set goal of 92%.

The fifth identified category of behavior modification was scaffolding. Fig. 2 shows that the measured scores for safety performance in scaffolding category were 83% at the end of the 3rd week when the goal-setting meeting was arranged. The scores have been increasing every week during the intervention period, approached up to 93.3% during the 9th week, and crossed the set goal of 92%.

At project "B", the safety performance score during week #5 was 81.5%, which had gone up to 93.5% at the end of week 9. At project "C", the graph shows that the safety performance score during week #6 was 85.8% which had gone up to 91.9% at the end of week 9. The sum of the scores of all categories at project "C" has also shown an improvement in safety performance. The sum of all measured scores of the BBS research at project "A" was presented in a previous paper (Choudhry, 2012). The results shows that the sum or overall all measured scores of safety performance for the BBS was improved from 86% at the end of 3rd week to 92.9% during the 9th week. Thus, the BBS intervention demonstrated large decrease in unsafe behaviors and substantial increase in safe behaviors on the construction project. Additionally, interview conducted revealed that subcontractors were executing more than 70% of the company's work. This indicates subcontractors' operatives' involvement in this research. Measurements in all five categories have shown that safety performance has improved on construction sites in different trades; for example, scaffolding.

5. Discussion

The detailed analysis and results of the case study were presented in the previous section. In this section, the results are discussed for further applicability of BBS management system on the company projects and in the construction industry. In this research, the inter-observer reliability (IOR) for the safety performance measure was over 94%. It was decided that in case IOR is below 90%, the data are to be investigated again for evidence of bias (Choudhry, 2012). The analysis indicated that all observers of the company involved in this case study were able to use the safety performance measures adequately after being trained by the writer.

The primary focus of this research was to devise a way for further improving safety at the company's construction project. When goals were set, operatives focused their attention on improving behavior in relation to the items included in the safety performance measure. Several number of feedback charts were placed at locations where operatives were able to see them. Initially, operatives appeared to be disinterested but then they were keen to see that their safety performance was monitored and reflected on these charts. On site, operatives positively received several versions of the devised feedback charts, which were usually having comments in Chinese by the observers. The recorded safety measure showed progressive improvements in site safety performance. When feedback charts were updated regularly communicating subsequent improvements in operatives' safety, safety performance acted as an encouragement, and reinforced operative efforts to improve their safety goals. Due to the intervention, the graphs showed significant improvements in safety performance in all categories at project site "A".

The findings reveal that the role of project management team was important for the goal setting sessions. It was not easy for the safety managers to arrange a goal setting session without the support of the project management team. It is important to mention that although, many operatives did not pay much attention to the specific scores entered weekly on the feedback charts however, they recognized the presence of these charts and knew that someone was monitoring their safety performance on-site. There was not a single example of rejecting the intervention from any operative. Rather the intervention stressed to both the company's employees and subcontractors that improvement in safety behaviors is an important goal. The intervention seems to have substantial impact on management systems and in increasing safety communication as well as increasing awareness about safe behaviors.

Another benefit of the intervention was that it focused attention on the everyday behaviors that were under the control of the workforce. An additional benefit of the intervention was that new operatives responded to the improved safety climate of their peers. Certainly, the findings of this research appear congruent with Robertson et al. (1999). Operatives worked unsafely if they were tolerated by their supervisors (Choudhry, 2012). Results indicated that the BBS was a good safety campaign in which there was no need to stop work but to take measurements for improving workers safety. Checklists can be modified by replacing stable behavior of workers and concentrating on risky ones. Measurement can be taken by trade, crew or group-wise and or measure the safe and unsafe behaviors of all operatives. For future case studies, the duration can be 8 weeks in length, stop and then start again if safety is degrading. An intervention can continue until the site activity is completed. Site management can obtain a mathematical number showing ongoing safety performance levels.

The BBS approach used in this work have had a positive impact in improving construction site safety and is in line with other researchers (Duff et al., 1994; Blackmon and Gramopadhye, 1995). The BBS results were also in line with Robertson et al. (1999) and Al-Hemoud and Al-Asfoor (2006). The writer postulates that the BBS management system can be applied to any country's culture and it is an excellent technique for improving the safety of front-line workers and operatives on construction sites.

5.1. The company specific recommendations

There is no doubt that implementation of the company's health, safety and environment (HS&E) management system demonstrated an approach (Choudhry et al., 2008), which was largely from top to bottom. HS&E approach requires working with the leadership of the company and it involved more managers for any safety change at lower level. From the site implementation process, the BBS change appears mainly a bottom-up approach that focuses on front-line workers, supervisors and middle managers, wherein critical behaviors were identified and targeted for change. From the site process, it appeared that it was also more helpful in improving safety of subcontractors without spending more company's money. Nevertheless, both the HS&E and the BBS called for a systematic approach to manage safety by continuous improvements. In this particular case, the BBS safety performance measurements can also be called as supervisory observation when the primary contractor's observers were taking the observations. Knowing this BBS research was largely a bottom-up approach, the company can ask its subcontractors to implement the BBS approach and submit records to the prime contractor. Nonetheless, the company can also implement the BBS in part of a project or in one category, for example housekeeping or scaffolding for improving site safety of its subcontractors' employees as is evident from this research.

For improving further the site safety, implementation of the BBS by the company's subcontractors can be beneficial. One of the problems, as revealed by interviewees, was the lack of communication between management and workers, particularly the lack of subcontractor workers' involvement in implementing safety management systems or safety initiatives. There was no justification that subcontractors were not committed to the development and implementation of safety management systems. The writer postulates that worker's involvement is necessary for any site safety endeavor. Another interviewee revealed that there was a multi-layer subcontracting system in the construction industry in Hong Kong. The writer needs to emphasize the importance of implementing the BBS management on subcontractors' works due to the ever-changing nature of construction (not like manufacturing) and particularly the multi-layer subcontracting system in construction. In this situation, the BBS can offer the best solution. Nevertheless, the objective of any such intervention needs to be communicated to the site personnel. The company needs to inform its subcontractors, ideally at the tendering stage about the idea of BBS safety intervention, involving each subcontractor adopting the system and producing their own feedback charts. The process can ensure for the subcontractors to obtain online training for improving the safe behavior of their operatives without stoppage of site construction work.

5.2. Limitation and future directions

Useful findings regarding the practical implementation of the BBS case study were obtained. Nonetheless, the research was limited to three mega-projects and within one company. There was limitation for the writer to spend time on the projects. Many site operatives did not understand mathematical or percentage scores of safety performance that were used to provide feedback. An optimum form of providing feedback scores may be investigated in future. Although this research focuses on practically implementing behavioral safety in Hong Kong, similar studies based on the same methodology can be undertaken elsewhere to investigate how regional and cultural factors influence the findings of this work. Particularly, similar studies are to be conducted in Mainland China so that a strong body of knowledge on improving safety can be documented.

6. Conclusions

In this work, the prime contractor's observers were measuring safety performance, arranging goal-setting sessions and updating the feedback charts after having been trained by the writer. The writer distributed the research schedule to the project management team including the observers for follow-up of the daily research work. Site management showed their commitment that the intervention was to continue, uninterrupted until project completion. The writer remained on-site full time for 68 days to launch the BBS approach and to solve any problems in the implementation of the intervention.

The sum of all measured scores for safety performance at project "A" was 86% at the end of the 3rd week when the goal-setting meeting was arranged. The scores were increasing every week during the intervention period, approached up to 92.9% during the 9th week, and crossed over the set goal of 92%. Interviews conducted showed an increased awareness that improvements in safety behaviors had occurred. Safety performance measurements and the qualitative findings demonstrated that there was a substantial increase in safe behaviors and that these changes took place by the presence of the intervention. Most of the behavior changes, which were reflected in the safety performance, consequently, occurred because of intervention which was based on the goal-setting and feedback charts.

The results clearly indicated that the BBS intervention was useful to increase safe behavior within the construction industry. Because of the intervention, all three sites showed improvement in safety performance scores, and these improvements were significant at the project where the detailed research was carried out. This work demonstrated that safety behaviors can be reliably measured, without excessive use of company's resources; and goal-setting and feedback were useful to produce large improvements in safety performance on construction projects. Although this paper focuses on introducing and investigating the BBS approach on construction projects of a company in Hong Kong, similar techniques may be followed in Mainland China or elsewhere in any culture to improve safety on construction sites.

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