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International Journal of Clinical Case Reports and Reviews

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Research Article

The Application of a Behavior-Based Safety Program at Power Plant Sites: A Pre-Post Study

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Received Date: December 23, 2024 | **Accepted Date:** January 03, 2025 | **Published Date:** January 07, 2025

Citation: Jeongmo Yang, PhD. (2025), The Application of a Behavior-Based Safety Program at Power Plant Sites: A Pre-Post Study, *International Journal of Clinical Case Reports and Reviews*, 22(1); **DOI:10.31579/2690-4861/664**

Abstract:

Objective: This study aims to apply the behavior-based safety (BBS) program to workers at five power plants nationwide and determine the impact on workers' observed safety behavior and recognized safety behavior.

Background: It is necessary to apply a behavior-based safety (BBS) program to prevent at-risk behavior. An effective BBS program requires the implementation of not only behavioral definitions and a customized critical behavior checklist (CBC) but also observations of behavior, coupled with customized interventions at power plants.

Material and method: In this study, a customized CBC and behavioral definition were developed through a review of five different sites that previously used a CBC. The rules of observation, flow, and target were established to initiate the observations. Customized interventions were selected to increase safe behaviors. CBC scoring was used to evaluate observed safe behaviors for three years. Recognized safe behaviors were evaluated with a questionnaire that included four items each for conformity and participation behaviors and were then analyzed through a factor analysis and a t-test. The questionnaires were conducted three months before and after the implementation of the BBS program.

Results: The customized CBC, behavioral definition, and interventions were effective, such that observed safe behaviors and the levels of workers' recognized safe behaviors increased.

Key words: behavior-based safety; critical behavior checklist; behavioral definition; intervention; safe behavior

1.Introduction

Behavior-based safety (BBS) management based on a culture of safety is necessary, as rule violations and mistakes made by workers cause many accidents (Health and Safety Executive, 2007). Programs that encourage workers to change their behaviors, based on measures regarding facility safety and the safety management system, help in establishing a safety culture (Holstvoogd et al., 2006). Moreover, a behavioral intervention program based on safety technology and the safety management system is necessary (Turney and Alford, 2003). When proper evaluation, execution, and review processes are in place, the BBS program can be applied more effectively. The evaluation process may include conducting interviews and surveys regarding the site's safety management system and identifying and analyzing the on-site accident history. The execution process can be comprised of the following: preparing observation checklists and reviewing the critical behaviors on them; providing training for the committee, and observers; conducting a start-off meeting; carrying out observation activities; analyzing collected data; and applying interventions for improvement. In the review process, the progress of the entire program is assessed. It is important to establish proper intervention measures based on an analysis of checklists (Wirth and Sigurdsson, 2008; Myers et al, 2010; Cooper, 2006).At a milk processing plant, safety observations and feedback processes were conducted for 26 months during the application of a BBS program. The results showed that the accident rate declined to 42% in the 24th month and by 33% in the 26th month (Yeow and Goomas, 2014). In another study, the BBS program was applied to 229 workers in 73 companies for five years. In the initial year, the occurrence of accidents to the initial year declined to around 26%, and after five years, the results showed a reduction of approximately 69% (Krause et al., 1999).Additionally, a cement plant's accident rate was lowered to operate a safety observation card system; when more cards were issued, fewer accidents occurred (Nunu et al., 2018).The purpose of the BBS program in this study is to develop a customized critical behavior checklist (CBC) and behavioral definition for observing the behaviors of five power plants, This is expected to increase safe behaviors through the implementation of appropriate interventions.

2. Material and method

2.1 Sample

The sample comprised 136 hired maintenance and operation workers and contract workers at five power plants, observed over three years.

2.2 Development of CBC

It is vital to develop a checklist to identify the risks associated with worker behavior. Additionally, conducting safety observations using the developed checklist can reduce at-risk behaviors and prevent accidents (Mangan, 2015). To effectively develop a customized CBC for this study, CBCs used at five different sites were reviewed: Department of Energy, six observation categories and 28 observation items (Department of Energy, 2002); Takula Oil Field, seven observation categories and 36 observation items (Agraz-Boeneker et al., 2005); ENSCO Drilling Site (2011), six observation categories and 44 observation items (Karish, 2011); Marathon Petroleum Company Michigan Refining Division, five observation categories and 33 observation items (Marathon Petroleum Company, 2017); Dow Chemical, eight observation categories and 26 observation items (Construction Owners Association of Alberta, 2008). As shown in Table 1, a CBC, containing 6 observation categories and 23 observation items, was developed for this study by analyzing the main points of the previously used CBCs and accident cases of our company and other companies.

Category	Observation item	Safe	At-risk
PPE	Head		
	Eyes		
	Ears		
	Face		
	Hand		
	Feet		
	Breathing/ Respiratory Protection		
	Fall protection		
Body position	Caught in between		
	Dangerous position		
	High temperature		
	In contact with material		
	Electric shock		
	Toxic Material Handling		
	Falling		
Tool/equipment	Suitability for work		
	Adequate use		
	Safe condition		
Safe procedure	Existing procedure		
	Adequate procedure		
Arrangement	Executed arrangement		
	Slip		
Electric cart	Move safe route		

Table 1: Development of the customized CBC

2.3 Development of the Behavioral Definition

The behavioral definition guides the observer in understanding the CBC observation categories and items. The behavioral definition was developed based on both a customized CBC and an appropriate example of behavioral definition (Marathon Petroleum Company, 2017). Table 2 shows an example of the customized behavioral definition developed for this study.

Classify	Item	Critical Behavioral Definition
PPE	Head	Are you wearing a hard hat? Is in good condition?
Body position	Caught in between	Contact with rotating parts of equipment
Tool/Equipment	Suitability for work	Is the tool/equipment appropriate for the purpose of the job?

Safe procedure	Existing procedure	Is the work subject to the establishment of work procedures? Are working procedures established?
Arrangement	Execute arrangement	Are there foreign objects in the workplace? Is garbage left in the workplace? Are there any materials that impede passage?
Electric cart	Safe movement	Do you go through a designated passage? Do occupants wear seat belts in electric carts

Table 2: An example of the customized behavioral definition

2.4 Training

A BBS training curriculum must contain the observation skill method, the feedback skill, the introduction of the CBC, and a discussion of at-risk behaviors (Fleming and Lardner, 2001). Additionally, it must include the following: observation skills, intervention, process of observation, and feedback (Jasiulewicz-Kaczmarek et al, 2015; Geller, 2001a).According to these recommendations, the training content of this study comprised accidents and impacts, operating guidelines, the approach toward accident prevention, the theory of BBS, an introduction to the CBC and definitions, the method of observation, and feedback. The training was implemented 12 times; at each site, the investigator performed training and received constructive feedback regarding the BBS program.

2.5 Setting Observation Goal and Flow

The effects of voluntary and forced observation were investigated in 31 in-depth group interviews for 629 participants. Voluntary observation was a method in which the observer participated without an observation goal for a few observations. Conversely, forced observation may be considered coercive because the observer is forcibly assigned an observation goal for a high number of observations. A previous study found that safety behavior increased as safety observation increased; therefore, forced observation was considered more effective in improving behavior (DePasquale and Geller, 2000). Furthermore, it is believed that at-risk behavior can be improved if work behavior is observed daily (Cooper, 1998). The headquarters' BBS committee agreed with the use of the forced observation method in this study. The number of observations was set through discussion with the management, safety manager, and supervisor. The manager conducted one or more observations in a month, while the supervisor and safety manager conducted three.According to the protocol, the observer went to the applicable working place, greeted the workers, explained the goal of the behavioral observation, and then observed the workers' behaviors for approximately five to ten minutes, depending on the situation. In cases of high risk, such as workers not connecting the safety lanyard to the point, work was suspended, and at-risk behavior was improved. However, in cases without high risk, the observer spoke positively, giving praise for wearing basic personal protective equipment. The observer provided feedback to improve at-risk behavior, filled out the CBC, and entered the data into the reporting system. The observation and feedback processes are shown in Figure 1.

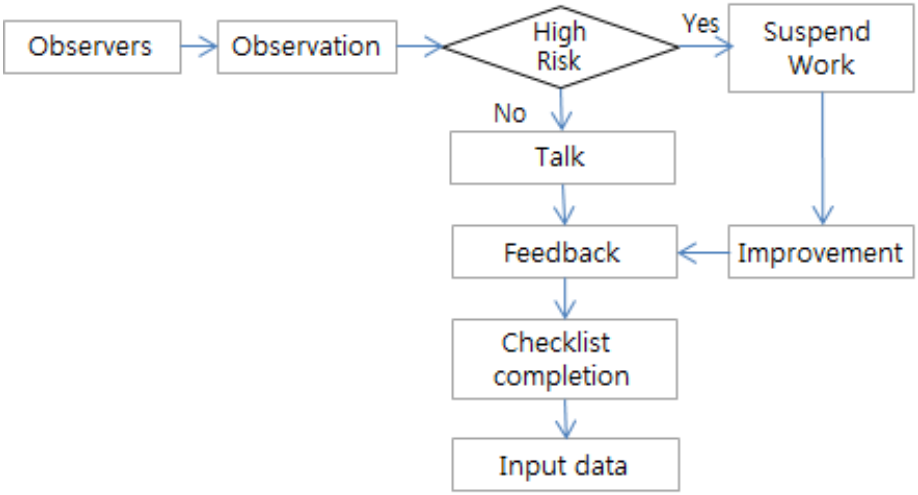

Figure 1: Observation and feedback process

2.6 Intervention

The ABC procedure increases safe behavior and improves at-risk behavior. In this procedure, an antecedent stimulus (A) event induces a behavior (B), which further leads to a consequence (C). Consequences are divided into three categories: temporal factors (soon/later); certainty (certain/uncertain); and behavioral consequences (positive/negative). They are more influential in improving safe behavior than antecedents (Fishwick et al, 2004; Geller, 2001b; Krause and Hidley, 1990). Human behavior can be altered through observational goal-setting and feedback. Improvements in goal-setting and feedback, management's visible commitment, and multiple, detailed interventions have been shown to increase safety behaviors (Cameron and Duff, 2007;Ludwig and Geller,

2000; Geller and Lehman, 1991; Geller, 1990; McAfee and Winn, 1989).Improvement measures, such as banner posting, monthly committee meetings, safety behavior trend posting, and a monthly compensation system, were implemented for 9,000 workers at four steel and mining sites in India; safety behaviors increased from 60% to 96% (Kaila, 2014). Thus, safety-related compensation and incentive systems are recommended to improve safety behavior continuously (McSween, 2003).The BBS committee in this study decided to apply four interventions: observation feedback display charts, behavior observation training, observation awards, and the committee.

2.6.1 Observation feedback display charts

Observation feedback display charts were posted on a bulletin board at the entrance of the main gate and in the cafeteria every month at each power plant.

2.6.2 Behavior observation training

Supervisors are required to perform safety training, called "Tool Box Meeting," about the data on the observation feedback display charts.

2.6.3 Observation awards

The existing monthly award categories are "best near-miss reporter" and "best reporter to improve the unsafe condition." The "best observer" award was added to induce autonomous observation of the existing awards. The site head could award up to four people per site.

2.6.4 Committee meetings

The committee members included the site manager, supervisors, and safety manager and convened once a month. The major agenda item included intervention measures for safe and at-risk behaviors, unsafe conditions or facilities found on site, and related issues.

3. Data management

3.1 Development of an IT Reporting System

A reporting system was developed to handle the enormous amount of observational data collected from each site. This reporting system was added to the existing plant IT reporting system for operation and maintenance. It comprised the name of the observer, the date of observation, and the CBC observation categories and items.

3.2 Evaluation of Behaviors

Both observed and recognized behaviors were reviewed and tested to evaluate safe behaviors.

To measure the observed safe behaviors in this study, the observers used the CBC and calculated the ratio of safe behaviors over three years. The ratio was calculated by dividing the safe behavior score by the sum of the safe and at-risk behaviors and multiplying this value by 100.To measure the recognized safe behaviors in this study, the questionnaire proposed by Griffin and Neal (2000) was used. The questionnaire comprised four items each for conformity and participation behaviors, presented on a five-point Likert scale. A factor analysis and t-test were conducted on eight questions pertaining to recognized safe behaviors. The questionnaire addressed the three months before and after the intervention. Table 3 shows the questionnaire on the recognized safety behaviors of conformity and participation.

Variable	Contents
Conformity behavior	1. I do things in a safe manner. 2. I always use the necessary safety device when I work. 3. I work according to the exact safety procedures. 4. I make sure I work in the safest condition.
Participation behavior	5. I actively participate in organizational safety programs. 6. I personally try harder to improve the safety of the workplace. 7. I help my colleagues work safely when they do harmful or dangerous work. 8. I voluntarily participate in the workplace safety improvement work.

Table 3: Questionnaire for recognized safety behaviors

4. Results

4.1 Intervention

4.1.1 Observation feedback display chart

The monthly display chart shared with employees included the following: the number of observation targets versus the results for the site; the monthly best observers; behavior patterns of safe and at-risk behaviors; and the top three safe and at-risk behaviors. Figure 2 shows the observation feedback display chart for August (2020).

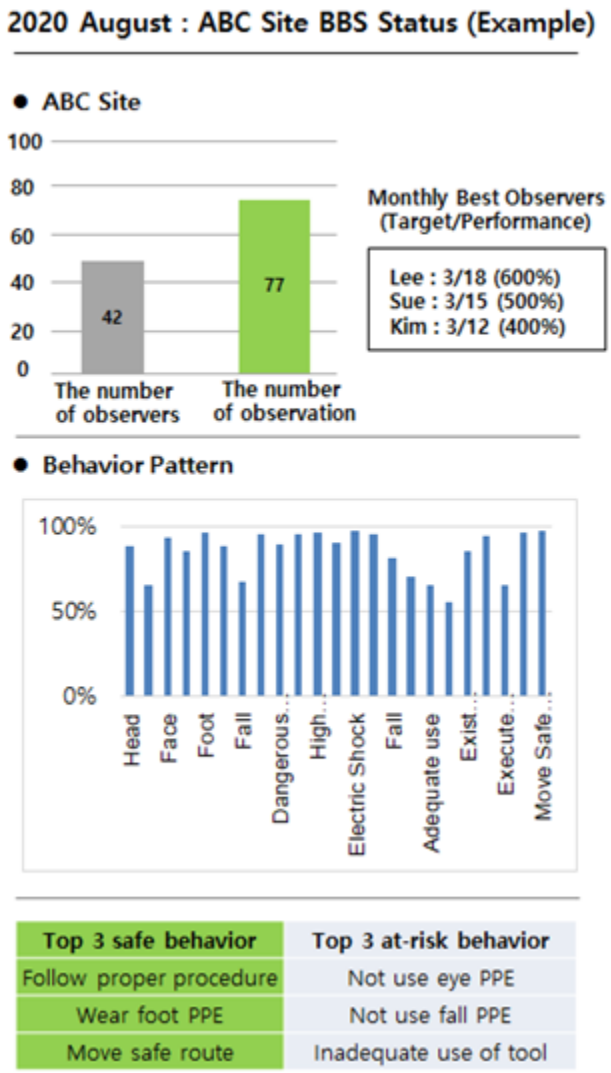

Figure 2: Observation feedback display chart

4.1.2 Behavior Observation training

Supervisors shared the status of behavior observation and trained workers prior to work. Workers were required to leave signatures on the form stating that they understood the contents of the top three safe and at-risk behaviors. Figure 3 shows an example of the behavior observation training record document.

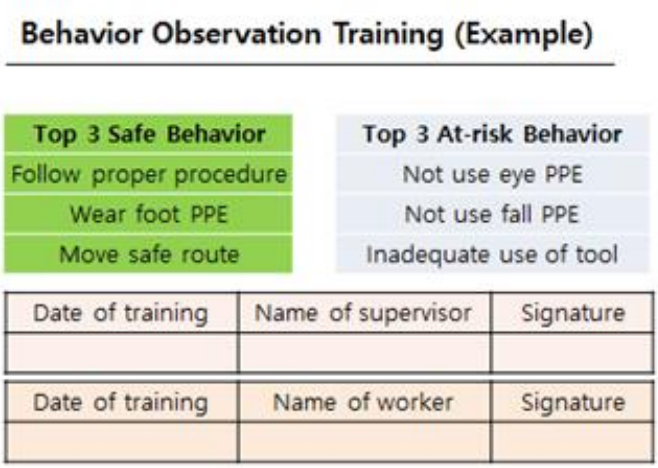

Figure 3: Behavior observation training record document.

4.1.3 Observation award

The on-site safety manager reviewed and analyzed the performance of the best near-miss reporter, best reporter to improve the unsafe condition, and best observer every month. To select the best observer, the safety manager analyzed each observer's observation goals and performance and selected the observer who exceeded the observation goal. The safety manager then prepared a written proposal for the awardee, and the on-site head gave the final approval. The fee (42 dollars) was awarded through payroll. The best observer awards from the five sites were as follows: 1,444 US dollars to 36 people in 2018; 1,134 US dollars to 27 people in 2019; and 714 US dollars to 16 people in 2020.

4.1.4 Committee meetings

Monthly-based site committee meetings were conducted, and the site manager, supervisors, safety manager, and workers participated in these meetings. Agenda items included the number of observation targets versus the results, safe and at-risk behavior items, improvement discussions about safety improvements such as the installation of a permanent lifeline, electric shock prevention methods, PPE preparation at the entrance to the electrical room, appropriate rack installation inside the warehouses, and other items.

4.2 Behavior

4.2.1 Observed safety behaviors

In total, 12,334 observations were conducted from 2018 to 2020, for which the target observations numbered 9,573. Table 4 shows the number of observations across three years.

	2018	2019	2020	Sum (means)
Target	2,981	3,205	3,387	9,573
Result	3,658	4,144	4,532	12,334
Performance rate	123%	129%	134%	(129%)

Table 4: Number of observations across three years

The total number of safe behaviors was 212,256, and that of at-risk behaviors was 12,044 over three years. Table 5 shows the number of safe and at-risk behaviors over three years.

	2018	2019	2020	Sum
Safe	59,448	72,493	80,315	212,256
At-risk	4,962	3,567	3,515	12,044
Sum	64,410	76,060	83,830	224,300

Table 5: Number of safe/at-risk behavior for three years

The rate of safety behaviors (more safe behaviors and fewer at-risk behaviors) increased across three years (2018: 92%, 2019: 95%, and 2020: 96%).

4.2.2 Recognized safety behavior

Questionnaires were received before and after intervention for 136 workers at five sites. A t-test was conducted on eight questions pertaining to recognized safe behaviors. The factor analysis of the questionnaire demonstrated decent reliability. Conformity and participation behavior increased (from 4.35 to 4.51). Consequently, the interventions (observation feedback display chart, Behavior observation training, observation award and committee meetings) and observation were effective to improve recognized safe behavior. Table 6 shows the analysis of the questionnaire for recognized safety behaviors.

Variable	Before		After		t	p
	M (SD)	N	M (SD)	N		
Conformity behavior	4.36 (0.554)	136	4.56 (0.441)	136	-3.45	0.001*
Participation behavior	4.33 (0.577)	136	4.45 (0.495)	136	-1.89	0.061
Total	4.35 (0.525)	136	4.51 (0.423)	136	-2.88	0.005*

* p<.05

Table 6: Analysis of the questionnaire of recognized safety behaviors

5. Discussion and Limitations

Using the customized CBC and behavioral definition, the observed safe behaviors of five power plants were assessed for three years. Recognized safe behaviors were evaluated using a questionnaire. As a result of applying the customized intervention suitable for the power plant, the observed and recognized safe behaviors increased. However, for the BBS program to be more effective, the following improvements are required.

5-1 CBC and Behavioral Definition

A customized CBC and behavioral definition were developed to observe workers' behavior effectively over three years. However, the number of observation items in the CBC that need to be minimized with a review of

risks and behavior trends for over three years must be determined. Additionally, there were requests from the sites to minimize the number of observation items.

5-2 Setting the Observation Goal and Reporting System

The forced observation method was selected for this study to increase the number of observations compare to the initial study. The number of observation times was set as one of the sites' key performance indicators, and newly hired employees were designated as observers at each site. Consequently, 12,334 observations (129%) were achieved, exceeding the observational goal of 9,573 times over three years. Nonetheless, as the forced observation method can have a detrimental effect on the observers, it is necessary to convert it to an autonomous observation method (Latham and Locke, 2006). Autonomous observation methods allow for mutual observation and feedback among fellow workers engaged in active care (Roberts and Geller, 1995). Therefore, this will result in benefits such as intrinsic motivation, greater interest, less pressure and tension, more creativity, more cognitive flexibility, and high self-esteem (Deci and Richard, 1987).After observing the behavior of the workers, the observer writes the observation result on the CBC, returns to the office, and enters the result into the IT reporting system. Sometimes, observers enter the results directly into the IT reporting system without writing the CBC at the site. Therefore, the preference for observing behavior using mobile application programs must be reviewed (Guo et al,, 2015).

5-3. Interventions

An observation feedback display chart is a good communication method to inform workers about observation performance, safe and at-risk behavior trends, and the top three safe and at-risk behaviors (Chatterjee et al., 2005). In this study, at the end of every month, the safety manager at the site conducted observational analysis, printed the results, and posted them to a safety bulletin board at the entrance of the cafeteria and the central control room. However, a monitor-type display chart could communicate the importance of participation effectively by removing the need to display a document on a bulletin board every month.The behavior observation training was conducted before work as part of the Tool Box Meeting, and signatures were obtained. Consequently, workers became aware of safety and at-risk behaviors, and this was found to be a factor in increasing safety behaviors (Jeschke et al., 2017). However, the effectiveness of the behavioral observation training needs further validation.As a result of implementing the observation award, the observation performance exceeded the observation goal. However, in one instance, the same observer received the award for several months consistently. Although the monetary award received a good response during the initial operation, the number of awardees was limited. Therefore, a mileage program, in which many people can receive awards, and other measures to replace cash payments are needed (Cameron and Duff, 2007).The number of safety observations and safety behaviors increased through the monthly committee meetings hosted by the safety manager. Moreover, many unsafe situations and facilities were improved. However, the meetings, which were actively conducted at the beginning of the BBS program, tended to decrease in importance over time. Therefore, a company-wide committee, led by a CEO with a high level of safety culture, would aid in reinforcing the importance of the program (Pęciłło, 2012).

5-4 Safe Behavior

The observed safe behavior of each category and item increased over three years (2018: 92%, 2019: 95%, and 2020: 96%). The five most increased safe behaviors are as follows: "eyes," "head," and "fall protection" in PPE; "falling" in body position; and "safe condition" in tool/equipment.

6. Conclusion

The behaviors of power plant workers were observed effectively using customized CBC and behavioral definitions. Interventions were effective in increasing participation in observations and increasing safe behaviors. The application of the BBS program was found to increase the observed and recognized safe behaviors (Choudhry, 2014; Tholén et al., 2013; Cooper, 2002; Krause et al., 1999; Laitinen et al., 1999; McAfee and Winn, 1989).Therefore, the program applied to this site can help increase safe behaviors at other identical or similar sites, as well as prevent accidents, which also corresponds with the results of prior studies.

Conflict of interest

I confirm that there are no conflicts of interest associated with this publication and that there has been no significant financial support that could have influenced the outcome of this study.

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DOI:10.31579/2690-4861/667