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IMPROVING WORKPLACE SAFETY AT EOT CRANE OPERATING AREA THROUGH BEHAVIORAL-BASED SAFETY APPROACH: A CASE STUDY ANALYSIS

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Abstract

The study investigated the implementation of a Behaviour-Based Safety (BBS) approach at an Electric Overhead Traveling (EOT) crane operating area in the logistics industry to improve workplace safety. The BBS approach is defined as the utilization of scientific principles to alter the behavior of an individual. The EOT crane work center under investigation comprises 22 employees who carry out skilled work such as welding, forklift, and crane operation, and contract laborers who perform unskilled work. The BBS approach was implemented in seven steps, which led to a significant

improvement in the safety performance of the work center with the BBS alert card system. The data analysis for this study was conducted using the open-source statistical platform called JAMOVI. The baseline safety performance was recorded at 56%, but by the end of the fourth week of the BBS intervention, it had improved to 85%. The card system was effective in improving safety behavior and also had a positive impact on workers' mindsets, making them more aware of safe work practices. This result indicates that the BBS approach is an effective measure for inducing positive behavioral changes among workers.

Keywords: behavior-based safety, workplace safety, safety performance, positive behavioral changes.

1. Introduction

The Indian manufacturing industry is to be one of the fastest-growing sectors. In recent years, manufacturing industries in India have experienced a shortage of skilled labor, which has forced them to employ people with insufficient relevant work experience. As a result, ensuring the safety of workers is becoming more challenging and complex. Accidents and injuries are rarely solely the result of rule violations. Human behavior, influenced by a complex interplay of individual, environmental, and organizational factors, plays a significant role in safety outcomes (Spigener et al., 2022). Recognizing this human element has led to the development of various behavioral safety approaches, with Behavior-Based Safety (BBS) emerging as a prominent strategy (Cooper, 2000).

Employing principles of applied behavior analysis, the field of behavior-based safety originated from efforts to utilize behavioral techniques for controlling exposure to industrial hazards. Research documenting the efficacy of these techniques in reducing occupational injuries commenced in the mid-1980s (Zohar, 1980). It has been widely used in many industries for over 20 years, including the nuclear (Spigener et al., 2022, Zhang et al., 2020), petroleum

(Rao et al., 2017), manufacturing (Zhang et al., 2019, (Nunu et al., 2018), transportation (Kaila, 2006,Wills et al., 2005) , and construction industries (Shirmohammadi et al., 2019,Choudhry, 2014). The features of the BBS approach are (Spigener et al., 2022) the identification of unsafe behaviors; (Cooper, 2000) the observation or sampling of identified behaviors over some time; (Zohar, 1980) the application of feedback to increase desired behaviors and decrease undesirable behaviors through coaching and mentoring; and (Spigener et al., 2022), presenting of feedback regarding performance to the relevant audiences within the organization (Nwagbala & Park, 2023, DeJoy, 2005).

In this study, safety compliance is defined as the degree to which workers adhere to established safety protocols and procedures, such as wearing personal protective equipment and following operational guidelines. Safety performance, on the other hand, refers to measurable safety outcomes including incident rates, near-miss occurrences, and loss-time injuries. This clear distinction aligns with accepted definitions in safety research and ensures accurate interpretation of results throughout the paper.

BBS programs encourage and reward employees for demonstrating desired safety behaviors. This can be achieved through various methods like verbal praise, recognition programs, or small incentives (Geller, 2005). When unsafe behaviors are observed, BBS programs aim to intervene constructively to prevent potential accidents (Cooper, 2000). This intervention might involve providing feedback, coaching, or additional training depending on the situation. A growing body of research has investigated the effectiveness of BBS programs in improving safety outcomes. Studies have shown positive correlations between BBS implementation and reductions in accidents, injuries, and lost workdays (Olson & Austin, 2001). For example, a meta-analysis by Tuncel et al (Tuncel et al., 2006) found that BBS programs led to a significant decrease in incident rates across various industries. However,

some studies have also highlighted the limitations of BBS programs. Safety culture, management commitment, and program design have been identified as crucial factors influencing BBS effectiveness (Zohar, 1980). Additionally, concerns have been raised regarding potential subjectivity in observation methods and the risk of creating a blame culture (Cooper, 2000).

The present-day view on safety management highlights that safety-critical manufacturing and construction industries should be able to assess and manage the safety of their activities. The challenge is to anticipate vulnerabilities rather than confront them when they occur. Safety is a challenging phenomenon to describe, measure, ensure, and manage. It depends on systematic anticipation, monitoring, and organizational performance improvement (Krause et al., 1999). Three paradigms have been critical in the evolution of research on accidents and occupational safety (Nunu et al., 2018). The first paradigm focuses on normative, prescriptive theories about how people should act. This paradigm aims to prevent occupational accidents through task design and safety rules of conduct, in which failure to follow prescribed rules can result in punishment. The second paradigm focuses on descriptive models of task behavior in terms of deviations from the normative "best way" of working (i.e., aimed at minimizing errors and biases). This paradigm guides efforts to control behavior by eliminating the causes of errors. The third paradigm takes a cognitive approach to safety. It focuses on the interaction between the individual and the work system. Also, it concerns the characteristics of the work system (features of the task, tools, and environment) that influence individual decisions and actions and the possibility of errors.

Approximately 80% of accidents in safety-critical industries can be attributed to unsafe human behaviors (Zhou et al., 2019). The fatalities happened due to workers falling from a height, being hit by moving vehicles or being hit by moving objects. Wrong human acts, lesser safety performance, unsuitable housekeeping, low tool maintenance, and managerial faults caused accidents

at the workplace in the construction industry (Lee et al., 2019). However, most studies have focused on normative and prescriptive aspects of accident prevention and have neglected the cognitive approach to safety, which fosters safe behavior in the workplace as a tool to reduce accidents. (Krause, 2000) suggested targeting employee behavior significantly reduces the incidence of workplace accidents. It has necessitated behavior-based safety (BBS) in most organizations as it shapes the employees' attitudes and behavior, making them aware of ways to ensure that their attitudes and behavioral practices do not expose them to accidents.

2 Literature Review

A well-planned BBS approach implementation improved the efficiency of safety performance (Al-Hemoud & Al-Asfoor, 2006). Choudhry et al. (Choudhry, 2014) suggested that accidents can be prevented and improved safety performance through systematic concentration and correction of unsafe behaviors at construction sites. Yeow and Goomas (Yeow & Goomas, 2014) observed that the outcome of a BBS incentive program reduced the accident rate in a fluid manufacturing plant. Implementation of proactive behavior-based safety (PBBS) at a construction site improved accident prevention and the safety index (SI) by 36.07% and 44.70%, respectively (Li et al., 2015).

Safety commitment, compliance, and awareness are widely understood in safety research as antecedents that indirectly impact safety performance by influencing employee behavior and attitudes toward safety. These factors serve as important precursors that facilitate improvements in overall workplace safety outcomes through behavior modification and increased hazard awareness. Therefore, this study conceptualizes these constructs as essential elements that drive safety performance indirectly, in line with established theoretical frameworks

Workers are required to make decisions independently when confronted with specific problems due to various distinct features, including intricate procedures, temporary organizational setup, fluctuating work sites, intricate work surroundings, and the behaviors exhibited by workers (Li et al., 2015**)** . Thus, the safety-critical industry needs a capable system for monitoring and dealing with novel, variable, real-time risks, and hazards. Heavy industry produces large industrial products, such as steel, defense, and transportation, which require heavy machinery and involve complex production processes. They use the electric overhead traveling (EOT) crane to carry the heavy materials. The associated hazards are electrical shock, electrical flash, electrical burn, slip/trip/fall, hit/press/cut hazard, and fall of a person or materials from height. Heavy industry has adopted many approaches to improve workplace health and safety (Geldart et al., 2010). This study primarily focuses on the BBS approach implementation to improve safety performance in the transportation industry. The approach emphasizes the alterations in unsafe behavior to safe behavior in the EOT crane workplace. Then, the study focuses on measuring the effectiveness of BBS implementation with the help of the statistical tool.

Previous studies on BBS have used a variety of approaches, including observational studies, surveys, questionnaires, case studies, longitudinal studies, data analysis, and statistical modeling. However, there have been limited studies that have integrated multiple approaches. This research aims to integrate all these approaches to effectively implement BBS in the EOT crane work center to eliminate accidents and near misses. In the EOT crane work center, there have been a total of 10 accidents/near misses involving maintenance employees, 14 involving production employees, and 15 involving store employees. This research will use a mixed-methods approach to collect data on worker behavior, attitudes, and beliefs related to safety. The data will be used to identify unsafe behaviors and develop interventions to improve safety performance.

While many studies have demonstrated the positive impact of Behavior-Based Safety (BBS) on workplace safety, few have focused specifically on the operational context of EOT crane areas, especially within Indian industrial settings. This study addresses this gap by applying BBS principles to improve safety behaviors in this specialized environment. Furthermore, the integration of direct behavioral observations with robust statistical validation offers a comprehensive understanding of safety performance improvements. These methodological and contextual distinctions provide novel insights that contribute uniquely to both academic research and practical safety management in the crane operating sector

Although BBS has been extensively studied in various industrial contexts, limited research has addressed its application within the specific environment of EOT crane operation, especially in Indian industrial settings. This study fills this gap by investigating the effectiveness of BBS interventions targeted at improving safety behaviors unique to this high-risk operational area. Recent advancements propose integrating artificial intelligence with safety management. For instance, Menanno et al. (2021) explored a framework for continuous improvement in Safety Management Systems (SMS) using artificial neural networks, while Park & Kang (2024) reviewed how AI and smart technologies (Safety 4.0) are reshaping safety performance monitoring across industries.

Table 1 Summary of Previous Studies on Behavior-Based Safety and Research Gaps

Study	Key Contribution	Research Gap
General BBS approach study [23]	Demonstrated that structured BBS programs lead to measurable improvements in overall safety performance and efficiency;	Broad industry focus; lacks specific insights into high-risk, specialized environments such as EOT crane operations. No

	emphasized the importance of management commitment.	statistical validation methods discussed.
Choudhry et al. [24]	Showed that systematic observation and correction of unsafe behaviors at construction sites can prevent accidents; emphasized worker involvement in safety monitoring.	Limited to the construction context; does not address unique hazards and operational dynamics of heavy machinery areas such as crane operations.
Yeow & Goomas [25]	Found that outcome- and behavior-based safety incentive programs effectively reduced accident rates by linking rewards to safe behavior frequency.	Focused on incentive-based outcomes rather than continuous behavioral feedback; context-specific to manufacturing plants, not transport or logistics environments with moving equipment.
Li et al. [26]	Reported that Proactive Behavior-Based Safety (PBBS) increased accident prevention by 36.07% and safety index by 44.70% through integrated observation and preventive measures.	Construction-specific application; lacks integration of advanced statistical validation tools such as ANOVA or reliability analysis.
Worker decision-making study [27]	Identified that workers in complex environments must make independent safety decisions due to variable work conditions and temporary setups.	Discusses cognitive demands but does not propose a structured behavioral intervention or measurement system for such settings.
Health & safety approaches review [28]	Reviewed traditional and modern approaches for improving workplace health and safety in heavy industries.	Lacks focus on behavioral safety in crane operating areas; does not integrate

		direct observation with statistical validation.
Current Study	Integrated surveys, direct behavioral observation, and statistical validation (Cronbach's alpha, ANOVA); improved safety performance from 56% to 85% using a BBS alert card system; provided context-specific insights into crane operation hazards.	Addresses the gap in EOT crane–specific behavioral safety research within Indian industrial settings by combining mixed methods rarely integrated in prior studies.

3. Materials and method

3.1 Plan and Context of the Study

In 2020, a cross-sectional survey was carried out at the factory. Data might be gathered during a single observation period with a cross-sectional survey. It enables the researchers to combine several data-collection methods, including surveys, secondary data reviews, and simultaneous observations to be made for triangulation reasons. The implementation of the BBS strategy to improve safety is focused on the survey questions. The industry offers solutions to all the automotive supply chain and logistics problems. They manufacture products for packaging such as expendable steel racks, pallets, returnable steel racks, and material handling products (ramps, line feeding trolleys, bins, and racks). There are 10 departments in the factory, including production, health and safety, quality assurance, automation, project, and maintenance, electrical, civil, stores, production planning, and purchase. The employees work in an 8-hour, three-shift production facility where they are probably exposed to occupational hazards given the nature of their jobs.

3.2. Description of the EOT Crane Operating Area and Associated Hazards

The study was conducted in the material handling and storage bay of a logistics and manufacturing plant, where a 5-ton Electric Overhead Traveling (EOT) crane is the primary equipment for moving heavy steel racks, pallets, and raw materials. The crane has a span of 22 meters, operates on a runway beam along the length of the 50m x 25m bay, and is controlled via a pendant control station operated from the shop floor.

The operating area is characterized by concurrent activities including welding, grinding, forklift movement, and manual material handling by store and production employees. This creates a complex environment with multiple dynamic hazards. The primary occupational health and safety risks in this area include:

- Struck-by/ crushing hazards: From the moving crane hook, load, or from material handling by forklifts.

- Fall from height: Workers occasionally access mezzanine storage levels and fixed ladders.

- Electrical hazards: From the crane's power supply system (rail electrification) and nearby welding equipment.

- Slip, trip, and fall hazards: Due to oil spillage, metal scraps, and uneven flooring.

- Ergonomic and musculoskeletal risks: From manual lifting and awkward postures during load attachment/detachment.

- Noise and vibration: From crane movement, grinding, and other machinery.

- Eye and face injuries: From welding arc flash and grinding sparks.

Figure 1 5 Ton EOT Crane

3.2. Population and sampling method

Among a group of 160 workers, 100 permanent workers were hired to perform specialized work, a sampling frame was created by selecting data from the departmental registers. Each employee was then given a random number. By prioritizing individual choice, the program relied on an opt-in system, drawing in 22 motivated participants through transparent information sessions. These 22 workers formed the core intervention group for the BBS observation and feedback program This empowered them with a sense of ownership and investment, paving the way for deeper engagement and potentially better outcomes.

3.3. Data Collection

The study context involved a total workforce of approximately 120 workers in the broader plant area. From this population, the core sample for the BBS intervention consisted of the 22 participants described in Section 3.2. Data collection for this group included structured questionnaires and direct behavioral observations conducted over a three-month period. Data were collected using structured questionnaires and direct behavioral observations conducted over a three-month period. Participant demographics

included age, work experience, and job role, with inclusion criteria requiring a minimum of six months' experience in crane operation or related tasks.

The methods for gathering data include a survey with a checklist, workplace observations, and questionnaires. The questions asked concern each employee's understanding of and adherence to safety regulations, and issues that arise during normal tasks. Also, emphasize their opinions of the best ways to create a safe working environment and improve safety. The results of the safety survey are tabulated. Data was collected through a pilot survey from the selected employees. The questions were inspired by the Han et al. study (Han et al., 2015) that evaluated the validity of instruments or questionnaires (Table 1 & 2) used to gauge employees' attitudes about a particular characteristic.

Table 2 Behaviour Observation Survey sheet

(Directions: indicate your response by ticking the box that best reflects your opinion)

Workers' details							
Describe your role							
Forklift operat	☐	Welder	☐	Crane operat	☐	Contract Labo	☐
Contractor, you work in							
ASK*	☐	Bhowmick*	☐	SGS*	☐	SPM*	☐
Age							
<30 years	☐	31-40 years	☐	41-50 years	☐	> 50 years	☐
How long you have been working in this company							
below 1 Year	☐	1-5 Years	☐	5-10 Years	☐	> 10 years	☐
Shifts usually you work.							
General	☐	General-Night	☐	A-B-C	☐		
How many accidents and near misses you had during your time at this company							
0	☐	1	☐	2	☐	More than 2	☐

*Company names

The questionnaire was administered for 20 minutes, with translations supported by illiterate respondents. Five working days were devoted to covert observations of employees. In the meantime, trained observers posed as workers fixing machinery in the plant or doing work for hire. Individuals are more inclined to act instinctively if they are unaware that they are being watched. It is a benefit of covert observation. The observers recorded information about whether BBS alert cards were accurately issued following the behavior displayed and the response of the person receiving a card. As described by Nunu et al (Zhang et al., 2020), there are two types of plays: onside play and offside play. Onside play is when a person is playing to high standards, such as wearing personal protective equipment (PPE) appropriately, consistently performing tasks according to safe procedures, and exhibiting good behavior. Offside play is when a person is not playing to the rules, such as engaging in risky behaviors, inconsistently using PPE, horseplay, poor housekeeping, and placing hands around moving parts. For offside play only, the BBS alert card will be issued. Over five working days, 15 employees were closely tracked. The researchers reviewed secondary data sources from the time periods before and after the BBS's implementation. Several accidents that happened both before and after the program's implementation were examined. The number of cards issued due to the program's deployment was also compared to the number of accidents that happened before and after the BBS system was put into place.

Table 3 Behaviour observation survey sheet - Questionnaires

Sl. No.	Criteria
SAFETY COMMITMENT	
1	Our Management Visibility demonstrates an interest in the safety and health of their employees.
2	The required PPE (Personal Protective Equipment) like safety shoes, goggles, Helmets, Gloves, etc., for my job are always available.
3	The health and safety training program offered by my organization meets my needs.
4	
5	
6	

	The safety audits /inspections of my section/department are conducted at regular intervals.
	Senior Managers seem interested in health and safety before an incident/ accident happens.
	I am satisfied with the investigation follow-up measures after incidents and accidents have taken place before an incident /accident happens.
SAFETY COMPLIANCE	
1	Verbal and non-verbal instructions that affect safety.
2	All workplace incidents/accidents and near misses in my department /section
3	are reported.
4	I am content with the housekeeping/cleaning in my work area.
5	I am comfortable with the work environment (noise, dust, heat, and vibration) in my workplace.
	The permit-to-work/shut-down system in my work area is followed earnestly by heat and vibration in my workplace.
SAFETY AWARENESS/COMMUNICATION	
1	If I have a concern about health and safety, I know whom to contact.
2	The supervisor / Front-line officers of my department/ section discuss accidents with the employees concerned.
3	I used the safety committee team to take action on a safety complaint that
4	concerned me.
	All employees in my work area are provided information on the type, cause,
5	and recommendations of all accidents.
6	I have been informed of all the potential hazards and safety precautions to be
7	taken at our workplace.
	New training is imparted, based on any accident, to the employees of related
8	and similar work areas.
	I have been informed about what to do in case of an emergency like fire and gas leakage etc., in my work area.
	The visitors are permitted to enter only after giving necessary safety instructions to be followed.
SAFETY BEHAVIOUR	
1	In any department Safety and health issues/ Hazards identified are corrected
2	on time.
3	Safety and Health is a high priority when I am performing my job
4	responsibilities.
5	Rewards for safe behavior are a good way to increase safety awareness levels.
6	A safety incentive program would cause employees to work more safely.
	Penalties for safety violations would cause employees to work more safely.
	I feel that observing both the safe/unsafe behaviors of individuals and giving them feedback will improve the safety levels.

3.4. BBS implementations procedure

The practical implementation of safety measures based on employee behavior in the workplace is called BBS. Everyone is accountable for both their safety and other people's safety in addition to their own. Unsafe behavior has the potential to result in accidents and harm. The BBS technique is used in this study primarily to find the activities (behaviors) that result in risk or injury and to reduce unsafe worker behavior.

The procedure shown in Figure 2, was used to develop and implement the BBS approach in this study:

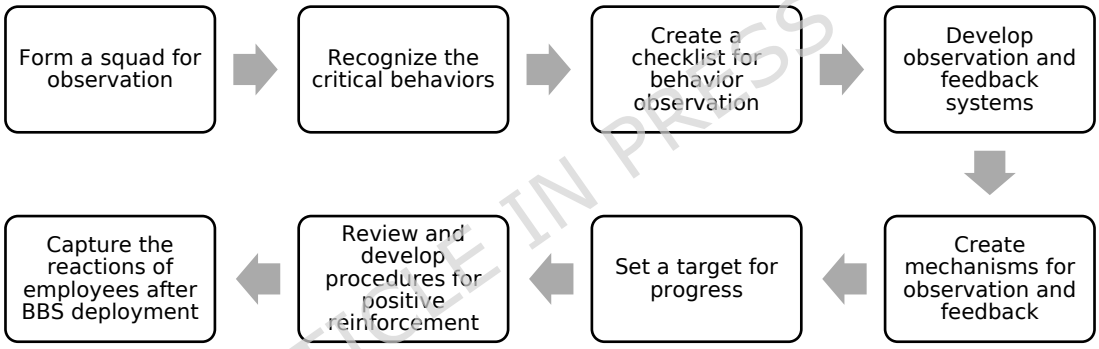

Figure 2 BBS implementation procedure

The observation team was drawn from the peers, managers, and safety committee members. This group had received BBS implementation training. They created a checklist, gathered information, decided on an instructional strategy, defined goals, and determined the best ways to put the BBS approach into practice.

The observer's first responsibility is to spot harmful behaviors that could result in accidents. BBS includes observing employee behavior to identify "at-risk" or unsafe activities, then guiding to improving employee behavior to

provide a safe and healthy work environment. Most occurrences and accidents can be attributed to a group of risky behaviors.

The tasks were divided into the following categories for the observer to find risky practices:

- To decide the precise PPE (Personal Protective Equipment) needed to complete the task, so that the observer would know what particularly to look for.
- The observer would periodically evaluate and record the state of the workspace for comparison purposes.
- Any equipment and tools used by the worker while carrying out any task will be observed to figure out if they are safe or unsafe.
- The worker's body posture was to be regulated by the observer while completing the task in terms of a safe working position to shield them against work-related muscular-skeletal disorders (MSD) and falling objects.

The behavior observation checklist (Table 3) is a crucial necessity for finding the workers' essential behaviors. The use of the behavior observation checklist would help the gathering of precise, objective data on worker task performance. A worker survey is also needed, including questions about experience, department, shift, type of work, accidents, near miss-accidents, and behavior-related matters that help find the workers' crucial behaviors and concentrate on the application of the "BBS observation" technique. The behavior-based observation survey questions about normal work were developed and presented to the workers by the observers to gauge their current level of safety awareness.

The BBS team was tasked with creating behavior-based observation activities relevant to the workers' daily tasks to observe their critical behaviors. Finally, the BBS team evaluated the data it collected to develop the right action plans for the promotion of safety with long-term improvement. Every day,

observations were made in the high-risk task areas to gather data. How often positive or constructive input was offered during observation has been noted by the observation team on the safety observation checklist. The observer recorded the employee's performance based on their regular tasks, and they noted on the checklist whether the work was carried out safely or not.

The information was used to decide the right feedback to deliver, and the information was used to quantify the goal's progress. The employee whose work behavior is safe receives favorable feedback right away. It encourages the worker to keep working securely. In a non-threatening and cordial manner, legitimate comments were given to the workers to improve the unsafe behavior displayed by them. It was easier for a worker to concentrate on their work and do it safely if they were given a proactive warning when they were exposed to unsafe situations or behaved unsafely. They were able to adopt a proactive mindset on safety.

Table 4 Workplace Safety Guidelines and Requirements – Observation Checklist

Sl. No.	Safety Guidelines and Requirements	Safe (Count)	At-risk (Count)	% safe
Workplace Conditions				
1	Ensure that workplace warning devices are operational.			
2	Make sure employees' compartments are clear of debris.			
3	Lock tools, equipment, and clamps in place when not in use.			
Employee Behaviors				
1	Wear goggles while grinding to protect the eyes.			
2	Safety shoes must always be worn.			
3	When grinding, wear a face shield to protect the face.			
4	When welding, wear an apron to protect clothing.			
5	Wear earplugs when working with press/shearing			
6	machines.			
7	When gas cutting, wear gas cutting goggles for eye			
8	protection.			
9				

10	When operating a forklift/crane, wear a hard hat for
11	head protection.
12	Use designated gangways for movement within the workplace.
13	Wear leg covers while welding to protect the legs.
14	When on the shop floor, wear a helmet.
15	Wear hand gloves while performing job tasks.
16	Use designated dustbins for disposing of metal waste,
17	cotton waste, and used electrodes.
18	When cleaning with compressed air, wear a face shield
19	to protect the face.
20	Wear hand gloves when cleaning with compressed air to
21	prevent injury.
22	When operating a crane, wear a helmet for head
23	protection.
	Ensure that 1S and 2S maintenance is properly carried out in each zone.
	Keep pedestrian pathways free from obstacles.
	Use lifting belts in good condition for safe lifting.
	Keep the workplace free from oil/paint/thinner spillage.
	Ensure that fire extinguishers and electrical panel boards are not obstructed.
	Use appropriate trolleys for moving materials.
	Have a checklist available for forklift operations.
	Tie CO2 cylinders to a stand to prevent tipping.

Note: To determine the percentage of safety, calculate the ratio of safe observations to the total number of observations for each task.

% safe = safe / (safe + at risk) × 100

Setting of targets boosted the safety effectiveness and raised awareness of the BBS strategy. The primary target was to increase workers' beliefs of how well they carried out their tasks. The first observation period was one week to develop the baseline. After the baseline had been improved, the acquired data was compared to a goal and examined for potential improvements. The progression of observations was tabulated and presented to the worker, so

they were aware of their safety behaviors. If the graph shows that there is room for progress, the worker will be given positive reinforcement feedback.

The review and improvement of positive reinforcement techniques as employees enhance their safe work behavior is the foundation of the BBS approach's effectiveness. For each successive observation, feedback was given clearly. Observers alerted workers to critical and dangerous actions to perform safely while performing tasks. Everyone took part in a discussion on the safe and unsafe behaviors being seen so that the department might make the necessary corrections.

After the BBS was implemented, feedback from the employees was gathered both online and offline. To increase the amount of safe work behaviors and reduce or eliminate accidents, the feedback gathered was analyzed. From the employee attitude assessment questionnaire, the data were generated and stored in an Excel spreadsheet. An open-source statistical platform “JAMOVI” was deployed to conduct the data analysis and using Cronbach's alpha, the reliability, or internal consistency, is assessed (Taber, 2018) .

4. Results and discussion

The data collected through surveys was analyzed using JAMOVI and found a Cronbach's alpha value of 0.706 **(Figure 3).** This means that the data collected through the surveys is reliable and can be used to conclude the population from which the sample was drawn. Most of the participants in the study demonstrated improvement in at least three safety-based behaviors. Some of the participants representing the returnable steel racks fabrication area showed improvement in more than six behaviors.

Reliability Analysis

Scale Reliability Statistics

	Cronbach's α
scale	0.706

[3]

Item Reliability Statistics

	If item dropped
	Cronbach's α
Production Total	0.798
Maintence Total	0.610
Store Total	0.621
Store total	0.694
Production Total (2)	0.709
Maintence Total (2)	0.660
Before Total	0.704
After Total	0.659

Figure 3 JAMOVI - Reliability Analysis

Reliability analysis of survey constructs using Cronbach's alpha. Values above 0.7 indicate good internal consistency and confirm the reliability of the measurement instrument.

To ensure the reliability of the data, Cronbach's alpha was calculated for each safety construct scale. All values were above 0.7, indicating satisfactory internal consistency and reliability of the measurement instrument. This supports the validity of the dataset used for subsequent analysis.

4.1. Worker Details

Based on the data gathered, most employees in the production and maintenance departments are welders, accounting for 41% of the workforce. EOT crane operators make up 27% of the workforce, while forklift operators account for 18%. The remaining 14% of employees are classified as labor. When it comes to contractors, there is a relatively even distribution among four different companies, with ASK and SPM accounting for 27% each, and Bhowmick and SGS at 23% each.

In terms of age group, the workforce is evenly distributed, with 36% of employees under 30 years of age, 32% between 31-40 years old, and 32% between 41-50 years old. Regarding work experience, many employees (64%) have less than 5 years of experience, while 18% have 6-10 years, and the remaining 18% have more than 10 years of experience. Most employees (54%) work the general shift, with 27% working shift B and 19% working shift C. In terms of accidents or near misses, most employees (32%) have not experienced any incidents, while 23% have experienced 4 incidents. The remaining incidents are evenly distributed, with 14% experiencing 1 incident, 22% experiencing 2 incidents, and 9% experiencing 3 incidents.

Overall, the data suggests a diverse workforce in terms of age and experience, with many employees in the welding and EOT crane operator roles. Most employees work the general shift, and while a significant portion have experienced accidents or near misses, the majority have not experienced any incidents.

4.2. Questionnaire - Analysis

The responses of employees to a survey questionnaire (Table 2) about their perceptions of safety compliance, safety awareness/communication, and safety behavior in their workplace were recorded. To analyze the data for each criterion, the percentage of respondents who agreed or strongly agreed with each statement and the percentage of respondents who disagreed or strongly disagreed were calculated and visualized.

Safety Commitment

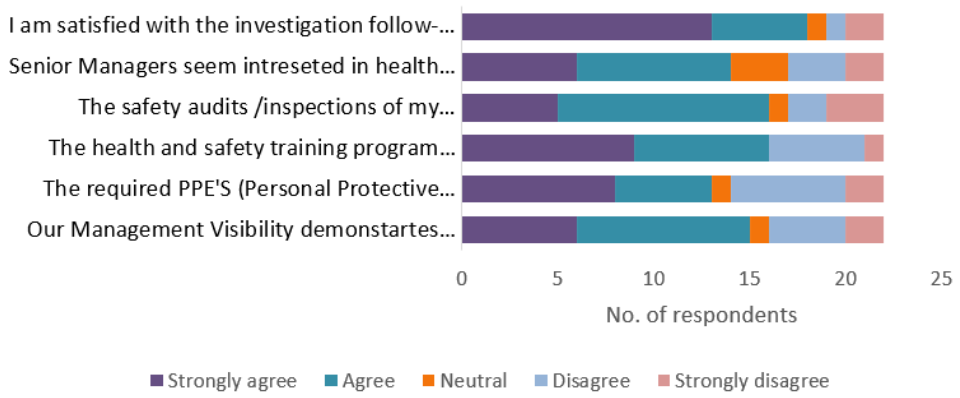

Figure 4 Safety observation survey results - Safety Commitment

The safety commitment section of the survey (figure 4) assesses the organization's dedication to ensuring the safety and health of the employees. Results show that 68% of respondents agreed or strongly agreed that management was concerned about their safety and health. This indicates a strong safety commitment from management. Additionally, 63% of respondents reported that the necessary safety equipment was always available to them, indicating the organization's commitment to providing access to safety equipment. Many respondents (73%) also agreed or strongly agreed that safety training programs were sufficient for their needs, highlighting the organization's commitment to providing relevant and effective safety training.

Further, 73% of respondents reported regular safety audits and inspections in their department, indicating the organization's dedication to identifying and mitigating safety hazards. Respondents also reported that senior management was interested in safety and health (64%) even before accidents occurred, showing the organization's proactive approach to safety. Moreover, 77% of respondents were satisfied with the follow-up measures taken after accidents occurred, indicating that the organization is committed to identifying and addressing the root causes of accidents. Overall, the survey data suggests a strong safety commitment from the organization, although areas for improvement were identified, such as ensuring the availability of

necessary safety equipment and conducting more frequent safety audits and inspections.

Safety Compliance

The survey results (**figure 5**) indicate the level of agreement among respondents towards various aspects related to workplace safety and environment. Verbal and non-verbal instructions were deemed effective by 68% of respondents, while 18% disagreed. In terms of incident reporting, 72% of respondents agreed that all incidents and near misses in their department/section are reported, while 19% disagreed. Housekeeping/cleaning in their work area was satisfactory for 63% of respondents, while 36% disagreed. The work environment (noise, dust, heat, and vibration) was comfortable for 77% of respondents, while 18% disagreed. The permit-to-work/shutdown system was followed earnestly, according to 78% of respondents, while 14% disagreed.

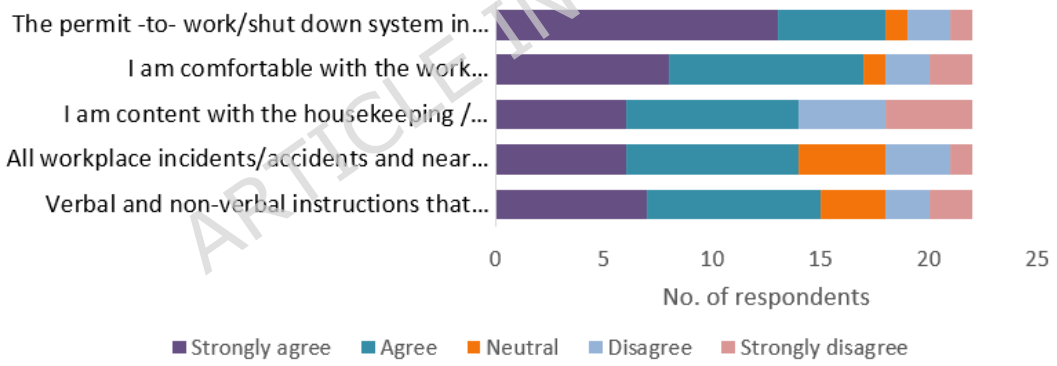

Figure 5 Safety Observation Survey results - Safety Compliance

Safety Awareness and Communication

The survey results **(figure)** indicate that 68% of respondents were aware of whom to contact if they had concerns regarding health and safety, while 36% disagreed or strongly disagreed. Regarding the discussion of accidents with employees, 63% of respondents agreed or strongly agreed that their departmental supervisor/frontline officers engaged in this practice, while

37% disagreed or strongly disagreed. Most respondents, 68%, agreed or strongly agreed to use the safety committee team to address safety complaints, while 27% disagreed or strongly disagreed. Regarding the dissemination of information on accidents within the company, 68% of respondents agreed or strongly agreed that all employees in their work area received information on the type, cause, and recommendations.

However, only 46% of respondents agreed or strongly agreed to have been informed of all potential hazards and safety precautions in their workplace, while 55% disagreed or strongly disagreed. Regarding training after an accident, 68% of respondents agreed or strongly agreed to have received new training in related or similar work areas, while 23% disagreed or strongly disagreed.

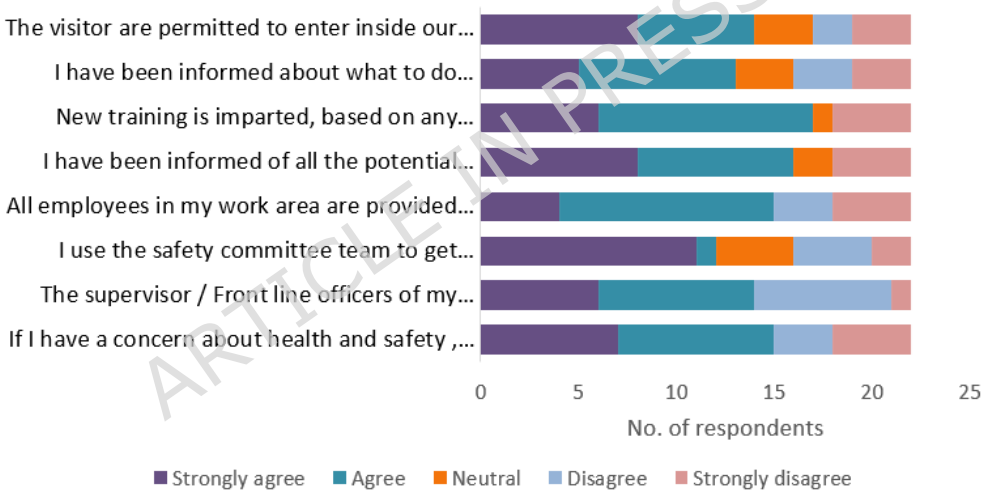

Figure 6 Safety Observation Survey Results - Safety Awareness and Communication

In terms of emergency preparedness, only 41% of respondents agreed or strongly agreed to have been informed about what to do in case of an emergency such as fire or gas leakage in their work area, while 43% disagreed or strongly disagreed. Finally, 51% of respondents agreed or strongly agreed to permit visitors to enter their department only after

receiving necessary safety instructions, while 30% disagreed or strongly disagreed.

Safety Behavior

Figure 6 shows the results of the safety behavior survey. A low percentage of respondents, only 22%, strongly agreed or agreed that safety and health hazards are corrected promptly. On the other hand, 72% of respondents agreed or strongly agreed that safety and health are of utmost importance while performing job responsibilities.

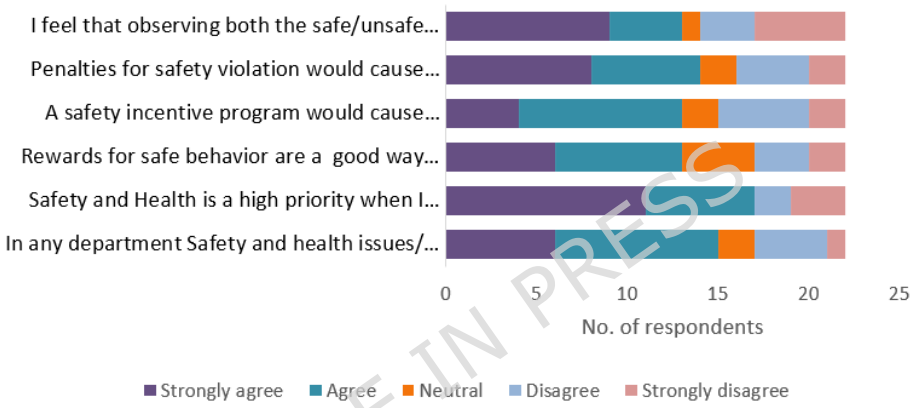

Figure 7 Safety observation survey results - Safety Behaviours

A significant proportion of respondents, 49%, believe that rewards for safe behavior are an effective means of increasing safety awareness levels. However, only 40% of respondents agreed or strongly agreed that safety incentive programs motivate employees to work more safely. Moreover, only 58% of respondents either strongly agreed or agreed that penalties for safety violations would cause employees to work more safely.

Most respondents, 63%, agreed or strongly agreed that observing safe/unsafe behaviors of individuals and providing feedback could improve safety levels. Overall, the survey emphasizes the importance of timely correction of safety hazards and highlights the need for rewards for safe behavior and observation/feedback to improve safety levels. Safety incentive programs

were found to be effective in motivating employees, whereas penalties for safety violations may not be as effective.

Based on the overall survey analysis, behavior-based safety training can be used to improve safety compliance by helping employees understand the importance of reporting incidents and near misses and by providing them with the skills and knowledge necessary to do so effectively. Additionally, behavior-based safety training can be used to encourage safe behavior by reinforcing positive actions and providing feedback and coaching to address unsafe actions.

4.3. Safety Observation Results

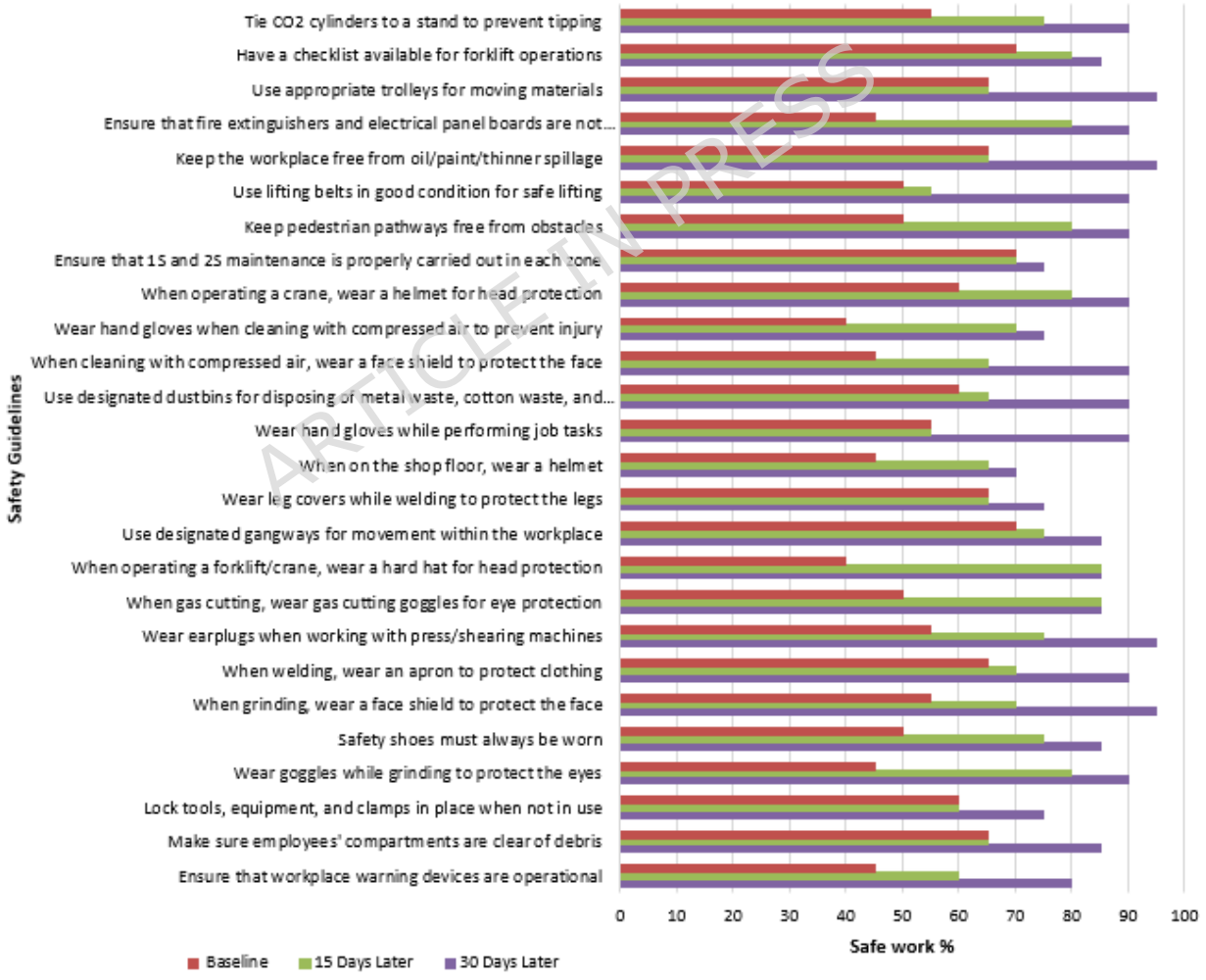

Figure 8 Safety Observation Survey Results (Before and After BBS)

The safety observation checklist was used to evaluate workers' task performance and their actions based on questions about conditions and behaviors. The observer assessed whether the behavior was safe or at risk and provided feedback accordingly. This involved introducing oneself, offering constructive feedback, encouraging safe behavior, and correcting unsafe behavior with positive conversation. The observer concluded by thanking the workers for their support.

Figure 7 and Figure 8 present the outcomes of implementing the Behavior-Based Safety (BBS) approach. The evaluation of worker actions and behaviors during their assigned tasks was conducted using a safety observation checklist that comprised questions related to 23 behaviors and three conditions. The safety guidelines range from wearing protective gear to maintaining the workplace and equipment. The conditions were evaluated at baseline and 15 days later and again after 30 days. The observer recorded whether each behavior was safe or at-risk. Following this, the observer introduced themselves to the worker, provided positive feedback for safe behavior, and corrective feedback for unsafe behavior through constructive conversation. The worker was thanked for their support upon departure.

The initial scores for each condition range from 40 to 70 out of 100, indicating that there is room for improvement in the workplace's safety standards. After 15 days, most conditions show an improvement in scores, with an average increase of 14.5 points. The conditions with the most significant improvement in scores include wearing goggles while grinding, wearing earplugs when working with press/shearing machines, and keeping pedestrian pathways free from obstacles.

After 30 days, there is a further improvement in scores, with an average increase of 12 points. The conditions with the most significant improvement in scores include wearing a face shield while cleaning with compressed air, wearing hand gloves when cleaning with compressed air, and using appropriate trolleys for moving materials. Overall, the safety checklist serves

as a useful tool to ensure that workplace safety conditions are met and maintained. Regular evaluation of the workplace's safety conditions can help identify areas for improvement and ensure the safety of employees.

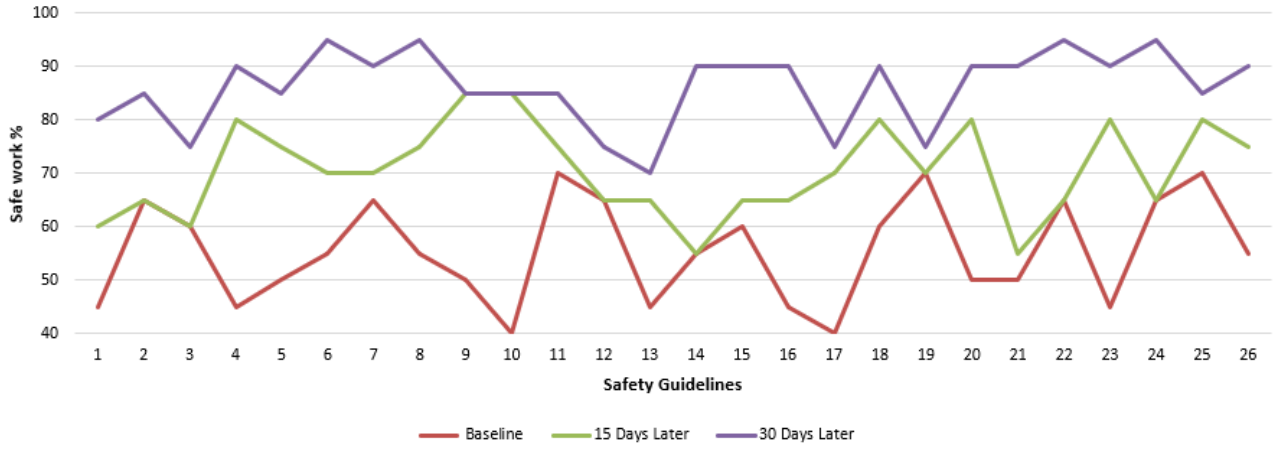

Figure 9 Comparison with baseline data after implementation of the BBS approach

To statistically validate observed trends in safety behavior, repeated measures ANOVA was conducted. The analysis revealed significant improvements over time ($p < 0.05$), confirming the effectiveness of the behavioral-based safety intervention

It is important to note that certain conditions, such as employees' compartments being free of debris, wearing goggles while grinding, wearing a respirator while welding, and wearing a helmet on the shop floor, had a lower baseline as workers were previously unaware of their importance. The constructive and appreciative feedback provided by the observers played a vital role in achieving maximum safety behaviors for these conditions.

4.4. BBS Alert Card System

It was observed that all workers improved their practices towards safe work. Employees were aware of the practices that could result in them being given a BBS alert card. Workers were ashamed to receive an alert card for an unsafe practice, as it meant they would be summoned by management. Employees who receive fewer

alert cards are honored, while those who receive more cards are summoned by management for reorientation. The main goal of the card system is to promote behavior-based safety (BBS) in all plants in the organization. Management summoning employees was seen as a negative thing, as it put them in the spotlight for unsafe acts. Most respondents (68%) had a positive attitude towards the BBS card system, while 18% and 14% were indifferent and had negative attitudes, respectively (Figure 9).

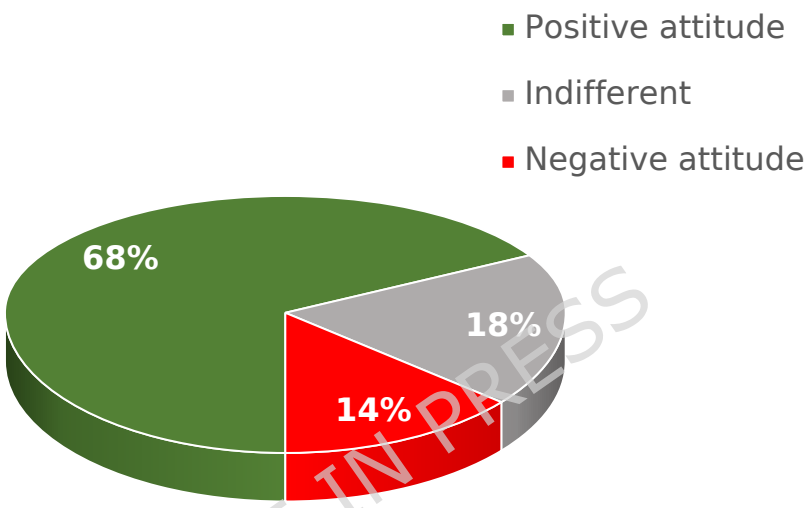

Figure 10 Employees' Attitude towards the BBS Alert Card System

4.5. Discussion

An alert card system is a type of behavior-based safety program. In an alert card system, workers are encouraged to observe each other's safety behaviors and to issue "alerts" when they see unsafe behaviors. Alerts can be positive or negative. Positive alerts are used to recognize safe behaviors, while negative alerts are used to correct unsafe behaviors. The study found that safety behavior significantly improved after the implementation of the alert card system. This suggests that the system was effective in changing worker behavior and preventing accidents and injuries. The BBS alert card system may have raised awareness of safety risks. It may have provided

workers with the skills and knowledge they need to work safely. The alert card system may have created a culture of safety in the workplace.

This research findings on improved safety compliance align with prior research emphasizing the role of behavioral interventions in enhancing worker safety (Tavakol & Dennick, 2011,Johnson et al., 2019) Johnson et al., 2019; Kumar and Singh, 2021). Additionally, the observed increase in safety awareness is consistent with Zhao and Li (2020), who found that targeted training significantly impacts hazard recognition.

BBS approach has emerged as a promising alternative to traditional command-and-control methods in ensuring workplace safety. This approach empowers workers to take control of their safety behaviors, enabling them to adopt safe work practices and improve their overall safety performance. In this regard, recognition and reward play a crucial role in the BBS approach, as they motivate workers to perform their tasks safely and reinforce their safe behaviors. Through continuous observations and constructive feedback, workers are encouraged to engage in safe behaviors, and those behaviors are acknowledged and rewarded. This approach has been shown to have a significant positive impact on occupational safety in manufacturing industries.

During the observation process, workers' critical behaviors are identified and evaluated based on a safety observation checklist that includes conditions and behaviors related to workplace safety. The observer provides instant feedback to workers, offering appreciative or constructive feedback based on the exhibited behavior. If necessary, the observer also asks workers why they are not wearing personal protective equipment (PPE) during certain tasks. The feedback provided during the observation process is summarized and disseminated among all workers to ensure that everyone is aware of the observed critical behaviors and how to improve them. The observed critical

behaviors are also discussed with top officials to ensure that necessary improvements are made to workplace safety procedures.

To evaluate the effectiveness of the BBS approach, observations and feedback processes were implemented continuously for four weeks in a heavy equipment manufacturing industry, specifically the EOT crane operating area. Weekly data was collected and analyzed to identify the improvements in workers' behaviors and enhance workplace safety. By implementing the BBS approach, conditions related to workplace safety, such as the operation of warning devices and the wearing of PPE, were improved by up to 30% from the baseline. During the safety observations, it was found that some workers were not regularly wearing the necessary PPE such as hand gloves, helmets, and arm protection.

However, many workers were aware of the importance of wearing PPE, and senior workers were regularly wearing hand gloves and helmets. The observers provided constructive feedback to workers who were not wearing PPE and appreciative feedback to those who regularly wear PPE. As a result, the unsafe behavior turned into safe behavior during the third week of the four-week observation period. The implementation of the BBS approach showed a significant improvement in safety performance in the EOT crane operating area, which is categorized as a heavy equipment manufacturing industry.

The group participating in the study showed an improvement in safety-based behavior in this area. The BBS approach focuses on empowering workers to take control of their safety behaviors, rather than relying on traditional industrial safety methods like command-and-control. By providing recognition and rewards for safe behavior, workers are encouraged to adopt safe work practices, leading to a safer working environment. The success of the BBS approach highlights the importance of providing constructive feedback to workers and implementing continuous safety observations to ensure a safe workplace.

The workspaces of most workers were observed to be poorly maintained, presenting a safety hazard. In response, the observer communicated to the workers the importance of good housekeeping and regular observation to ensure safety. While the behaviors relating to maintaining tools, equipment, and clamps in place were above average, the proper selection and use of these tools and equipment was mainly dependent on the workers themselves. Experienced senior workers were observed to have a habit of proper tool maintenance and safety behaviors. However, some workers demonstrated unsafe practices in tool and equipment handling, such as using small tubes as hammers and pulling trolleys instead of pushing them. Additionally, some workers used awkward postures during task performance, presenting a risk for musculoskeletal disorders. The observer explained ergonomic issues to these workers, emphasizing the importance of avoiding risks for work-related musculoskeletal disorders and back pain. Proper body posture and the use of safe lifting, pushing, and pulling techniques are essential to prevent illness or injury due to MSDs.

The BBS approach is a structured method based on psychology that aims to modify human behavior, with a particular emphasis on identifying and altering critical safety behaviors related to workplace accidents and injuries. Implementing the BBS approach has resulted in improved worker cooperation and acceptance of constructive feedback. Workers were able to recognize their lack of adherence to safe work practices, leading to an increase in safety performance from the baseline. Specifically, the mean percentage safe score improved from 56% at the baseline to 85% by the end of the fourth week, representing a significant improvement. Among various behavioral intervention methods, the BBS approach has gained recognition as a highly effective way to modify unsafe behaviors. The increase in mean percentage safe scores through targeting critical safety behaviors is notable, indicating that the BBS approach can facilitate an accident-free and safe work environment. This approach can be highly beneficial for improving safety

among frontline workers. By implementing the BBS approach, employees gain a better understanding of the potential consequences of not adhering to safe work practices, while the organization improves safety communication through positive and constructive feedback. This, in turn, promotes a positive safety culture and improved safety performance.

Behavior-Based Safety (BBS) initiatives face several constraints that can hinder their effectiveness. BBS often narrowly targets individual behaviors, neglecting underlying systemic issues. Subjective observation methods may result in inconsistent data collection and bias. Inadequate support from management and resistance to organizational change can impede implementation. Insufficient training for observers and participants may limit program impact. Finally, the varied success of BBS in reducing workplace accidents highlights the necessity for comprehensive safety management strategies addressing both behavior and systemic factors.

4.5. Future Research Directions

While this study demonstrates the efficacy of a traditional BBS approach, the future of behavioral safety lies in its integration with digital technologies. Subsequent research could explore the application of machine learning algorithms to analyze large-scale behavioral observation data, predicting at-risk behaviors before incidents occur. Furthermore, the use of computer vision and IoT sensors for real-time, unobtrusive monitoring of compliance (e.g., PPE usage, zone intrusions) in dynamic environments like EOT crane areas presents a promising avenue for developing Safety 4.0 systems. These intelligent systems, potentially built on frameworks like those suggested by Menanno et al. [34], could provide continuous feedback loops, moving from periodic sampling to constant, data-driven safety governance as reviewed by Park & Kang [35]

5. Conclusions

The BBS approach is effective in improving safety performance and developing a safe work environment and culture.

This case study provides empirical evidence that a systematically implemented Behavior-Based Safety (BBS) approach can significantly enhance safety performance in a high-risk EOT crane operating area. The statistically significant improvement in safe behavior observations—from a baseline of 56% to 85% over a four-week intervention—demonstrates the potency of focused behavioral observation and feedback.

This study demonstrates that targeted behavior-based safety interventions significantly improve safety compliance and awareness among workers in the EOT crane operating area. These findings underline the importance of such interventions in enhancing workplace safety and provide valuable insights for safety management in industrial environments

- Safety performance improved from 55% to 85% by the end of the fourth week.
- Based on the study, it appears that the overall safety conditions in the workplace have improved over the course of 30 days. Most of the conditions show an increase in compliance with safety guidelines, with some conditions reaching a compliance rate of 90% or higher by the end of the 30-day period.
- However, there are still some areas that require improvement, as some conditions remain below a compliance rate of 80%. These areas include wearing earplugs when working with press/shearing machines, wearing hand gloves when cleaning with compressed air to prevent injury, ensuring that workplace warning devices are operational, and wearing goggles while grinding to protect the eyes.
- The findings of the survey suggest that the BBS alert card system is generally well-received by workers. However, there is still some room

for improvement, as a significant minority of workers have a negative attitude towards the system. By addressing the concerns of these workers, the card system can become even more effective in improving workplace safety.

- Behavior-Based Safety (BBS) faces challenges like narrow focus, subjective observations, insufficient management support, and ethical concerns. Overcoming requires systemic integration and robust training.
- This study provides statistically significant evidence that the implementation of a behavioral-based safety approach has led to measurable improvements in safety behavior within the EOT crane operating area. The repeated measures ANOVA confirmed these positive changes over time ($p < 0.05$), demonstrating the effectiveness of the intervention. Therefore, we conclude that the safety condition in the workplace has improved substantially as a direct result of the applied safety program, supported by robust data analysis.
- Adopting the BBS approach across all work centers in the manufacturing industry can significantly enhance safety performance. Providing workers with positive and constructive feedback fosters a work culture that is conducive to sustained business excellence. As the frequency of accidents reduces, worker morale and self-confidence improve, leading to better teamwork and productivity within the organization.

ETHICS DECLARATIONS

Authors contributions

Conceptualization: V.Dhamotharan, V.Arumugaprabu, S.Ajith; **Methodology:** V.Dhamotharan, V.Arumugaprabu; **Data curation:** V.Dhamotharan, V.Arumugaprabu; **Formal Analysis:** V.Dhamotharan, S.Ajith; **Validation:** V.Dhamotharan, V.Arumugaprabu, S.Ajith; **Writing – original draft:** V.Dhamotharan, V.Arumugaprabu, **Writing – review & editing:** V.Arumugaprabu, S.Ajith. **Funding Acquisition, Resources-** Giuseppe Melisa, Nataliia Kochkina

Conflict of Interest Statement

The authors declare there are no competing interests

Ethical Approval

This study received approval from the Institutional Ethics Committee prior to data collection. All participants provided informed consent, were assured of confidentiality, and participated voluntarily. Ethical guidelines were strictly adhered to throughout the study.

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Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request

Clinical Trial Number

Not Applicable

Consent to Publish Declaration

The authors declare their consent to publish

Consent to Participate Declaration

Not Applicable

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