

# A department level performance metric architecture for operationalizing behavior-based safety in high-risk manufacturing

Received: 11 December 2025

Accepted: 2 April 2026

Published online: 10 April 2026

Cite this article as: Valaguru D., Veerasimman A., Melis G. *et al.* A department level performance metric architecture for operationalizing behavior-based safety in high-risk manufacturing. *Sci Rep* (2026). <https://doi.org/10.1038/s41598-026-47760-8>

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# A DEPARTMENT LEVEL PERFORMANCE METRIC ARCHITECTURE FOR OPERATIONALIZING BEHAVIOR-BASED SAFETY IN HIGH-RISK MANUFACTURING

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## Abstract

The present research aims at department-level Behaviour-Based Safety (BBS) framework operationalized through Key Performance Indicators (KPIs) in a high-risk electrolyser manufacturing setting. By giving departments the authority to monitor, report, and be assessed on both leading and lagging safety measures, this approach aims to decentralize safety ownership. Hazard self-identification, toolbox discussions, safety kaizens, training, and permit adherence are the important elements that are tracked on a weekly basis and are rewarded and recognized according to departmental standards. Over the course of the whole implementation cycle, data was gathered from 18 departments spread across three locations. By means of SPSS statistical tool able to examine post-intervention performance and replicate pre-intervention performance using historical audit data. The efficiency of the framework was validated using Wilcoxon signed-rank tests and paired t-tests, which showed a substantial 47% increase in average KPI values ( $p < 0.001$ ). Additionally, the study showed behavioural changes such as dangerous acts decreased by 32%, kaizen participation increased by 36%, and hazard reporting improved by 27%. The scoring approach shifted cultural ownership toward proactive safety involvement by rewarding departmental vigilance and penalizing the safety team for discovering external hazards. For industrial businesses looking to transition from compliance-based safety systems to behaviourally driven safety cultures, this model provides a scalable, affordable, and replicable approach. The results have applications in policy

creation, workforce engagement, and safety leadership.

**Keywords:** Behaviour-Based Safety, Safety Culture, Key Performance Indicators (KPI), Hazard Reporting, Manufacturing Safety, Safety Performance Metrics.

## I. INTRODUCTION

For high-risk manufacturing industries, such as those producing heavy engineering, chemicals, and electrolyzers, workplace safety is still a major concern. These settings frequently expose employees to dangerous situations, necessitating both deeply ingrained cultural changes and stringent procedural controls. Behaviour-Based Safety (BBS), which stresses the observation, analysis, and reinforcement of safe behaviours by employees at all levels, is one of the most effective frameworks for improving organizational safety performance [1].

In contrast to conventional safety systems, which mostly depend on compliance and top-down enforcement, BBS acknowledges that human conduct, not technical or procedural flaws, is typically the cause of workplace incidents. According to Geller [1], encouraging voluntary safety activities, developing personal accountability, and establishing feedback systems that support ongoing behavioural development are all necessary for long-term safety gains. However, the absence of quantifiable, structured methods that connect employee behaviours to performance metrics frequently makes it difficult to apply BBS practically in big industrial settings.

In order to operationalize behavioural safety at scale, this difficulty has prompted the incorporation of Key Performance Indicators (KPIs) into BBS systems. In addition to being tools for monitoring performance, KPIs are also tools for accountability, motivation, and communication. In addition to conventional lagging indicators like incident rates and near-misses, they offer a quantitative foundation for assessing proactive safety behaviours, including danger identification, toolbox conversations, and safety training attendance [2], [3]. Both theoretical and empirical research provide evidence in favor of this approach.

**This study aims to address the following research questions:**

1. Does implementing a department-level KPI framework improve BBS outcomes in high-risk manufacturing?
2. Which specific safety behaviors show the most improvement through this approach?

### 3. How does decentralized KPI tracking affect safety ownership and culture?

## II. LITERATURE REVIEW

According to a thorough analysis by Carra et al. [2], BBS frameworks connected to KPI systems are more effective than traditional audit-based techniques at encouraging ongoing safety engagement. According to their findings, department-specific leading indicators, such as danger reports and safety kaizens, offer a real-time window into the responsiveness and readiness of an organization for safety. In a similar way, Nascimento [4] inferred that observation-based monitoring procedures outperformed post-incident analysis alone in terms of hazard identification rates, behavioural compliance and corrective action cycles. Additionally, a key component of high-reliability businesses is psychological safety, which is developed through operationalizing safety at the department level.

According to Kaila [5], psychologically safe workplaces encourage open reporting of unsafe acts and conditions, enabling organizations to address risks proactively. KPI-based frameworks that reward safe behaviors and recognize contributions (e.g., spotlight winners) create an environment of trust, ownership, and continuous improvement. From an organizational development perspective, integrating BBS with structured KPIs also enhances the institutional memory of safety events. Each department becomes a node of localized expertise, maintaining records of hazards encountered, mitigations implemented, and training delivered. Over time, this decentralized documentation system contributes to knowledge sharing across the organization and builds resilience into operational workflows [1], [4].

In regions where BBS implementation is still maturing—such as parts of Asia and the Middle East—KPI frameworks serve as valuable cultural adapters. Al Abdul Salam and Al Qallaf [6] emphasize the importance of context-specific adaptation of BBS tools, suggesting that KPI-based implementations, when coupled with culturally relevant training and recognition systems, can significantly improve program adoption in diverse workforce settings. Their case study from the Middle East illustrates how structured metrics and peer-based accountability mechanisms drove behavioral improvements in traditionally hierarchical organizations.

The growing importance of cross-sector learning in safety culture transformation is further reinforced by Key et al. [7], who argue for the integration

of behavior-based models with enterprise-wide performance tracking systems. Their literature review from the aviation sector highlights the need for case studies that translate safety psychology principles into structured, scalable interventions applicable in manufacturing and other high-risk domains. In a manufacturing plant, Godbey [8] discovered that the implementation of BBS approaches greatly decreased behavior variation and increased the frequency of specified safe behaviours. Additionally, the study observed an increase in quality and productivity, indicating a positive overlap between operational efficiency and safety performance. However, the absence of formal KPIs in the observed environment limited long-term tracking and accountability.

By implementing a behaviour-and observation-based monitoring system that specifically connected behaviour ratings to organizational performance KPIs, Nascimento et al.[4] overcame this constraint. Improvements in KPI ratings were linked to lower incident rates in a chemical manufacturing facility, confirming the validity of this strategy. The most important takeaway from Nascimento's study is how crucial it is to align BBS data with leading and lagging indicators in order to create a feedback-rich environment that encourages ongoing improvement. From a broader systems perspective, Podgórski et al. [9] examined the selection of leading safety performance indicators (LPIs) for occupational safety and health (OSH) systems using an AHP (Analytic Hierarchy Process) -based framework. While not limited to behavior alone, his research supports the inclusion of behavioral metrics—such as frequency of safety suggestions and employee participation rates—in OSH dashboards. These findings support the argument that KPI-linked behavior tracking improves both governance and responsiveness in safety-critical industries.

In their comprehensive analysis of safety management indicators, Ali et al. [11] confirmed that behavior-specific KPIs, like danger reporting rates, toolbox talk participation, and PPE (Personal Protective Equipment) adherence, are essential for tracking safety performance in real time. A balanced combination of proactive (leading) and reactive (lagging) indicators provides a comprehensive picture of workplace safety, according to their research, which covered the utilities and energy sectors. When regularly monitored, these signs serve as cultural reinforcers, integrating safety into everyday activities. By assessing the efficacy of a Behavior-Based Safety Observation Program (BSOP)

in the chemical industry, Zakaria et al. [10] continued this discussion. Yeow and Goomas [12] revealed one of the most creative uses of KPI-linked BBS when they established an outcome-and-behavior-based incentive system in a fluid manufacturing facility. During a 12-month period, their approach successfully increased reporting frequency and decreased accidents by using safe behavior as the key KPI instead of only outcome-based measures like incident rates. According to their research, employees responded more favorably to behavior-focused measures that they could directly affect than to outcomes that were farther away. Their study demonstrated that structured observation checklists and peer reviews, when aligned with department-level KPIs, produced statistically significant improvements in worker compliance and reduced hazard rates. The research also highlighted the importance of team-level ownership and reward systems in maintaining long-term commitment to safety goals.

In the construction domain, Mahmoud et al. [13] reinforced the importance of KPI integration by identifying behavioral and procedural indicators that influence developer safety performance. Their work offers transferable insights, especially in relation to the value of department-level dashboards and visual scoring systems that track compliance, training, and incident response. They conclude that such mechanisms are not only effective for real-time decision-making but also promote transparency and cultural alignment. Laine [14] explored the development of process safety performance indicators in the chemical industry, emphasizing that behavior-based indicators such as unsafe condition observations, training attendance, and procedural adherence are essential to predictive safety modeling. His findings echo a growing consensus that behavior is a leading indicator of system health, and its measurement must be integral to performance reviews and incentive systems.

Lastly, Al Hinai et al. [15] assert that safety excellence cannot be achieved through surveillance alone. Their field-based case study underscores the need to design workplaces, management systems, and behavioral interventions in tandem. They emphasize that KPIs are critical to this design because they provide the structure needed for benchmarking, reporting, and reinforcing desired safety behaviors

The present study addresses this gap by presenting a real-world implementation of a department-level KPI framework grounded in BBS principles within a high-risk

electrolyser manufacturing environment. Implemented across three sites and over ten departments, the program introduced monthly reporting systems, spotlight recognition for proactive behaviors, and performance scoring based on both leading and lagging safety indicators. Department heads were responsible for nominating safety committee members who collected, documented, and submitted performance metrics, which were then evaluated by a central safety team. Preliminary results indicate a significant uptick in safety participation, training compliance, hazard identification, and peer recognition. Departments previously disengaged from safety reporting began submitting complete data sets, and individuals took pride in being spotlighted for their proactive contributions. The ability of behavioral safety to be structured into quantifiable performance systems is demonstrated by this shift from passive compliance to active involvement. This paper is organized as follows: the methodological framework, including scoring metrics, indicator selection, and team interaction tactics, is described in the next section. A results section that examines monthly performance statistics and highlights participation trends comes next. The research ends with implications for scale, sustainability, and cross-sector application after placing these findings within the larger BBS literature in the discussion section. This strategy provides a model for industrial firms looking to transition from reactive to proactive safety cultures by methodically integrating BBS principles into departmental KPIs. Additionally, it adds to the expanding body of research on behavior-based interventions by showing how structural supports, such as peer recognition and KPIs, can turn safety from a function into a value. Additionally, it adds to the expanding body of research on behavior-based interventions by showing how structural supports, such as peer recognition and KPIs, can turn safety from a function into a value. In order to reduce occupational hazards and encourage safe behavior in industrial settings, the idea of behavior-based safety, or BBS, has drawn a lot of attention. BBS is based on applied behavioral psychology and seeks to identify, evaluate, and impact employee behavior by implementing systematic treatments that focus on the underlying reasons of risky behaviors. The usefulness of BBS interventions in a variety of industries has been the subject of numerous empirical research and evaluations, which have demonstrated both the program's independence and its potential when combined with performance monitoring tools like Key Performance Indicators (KPIs).

**5S Methodology** (Sort, Set in order, Shine, Standardize, Sustain) is a workplace organization system that reduces hazards through improved housekeeping and visual management. In our framework, 5S compliance serves as a lagging indicator of procedural discipline.

### **Research Gaps and Study Contribution**

Previous studies show limitations that this research addresses:

Gap 1: Most BBS research tracks individual behavior, not department-level performance systems

Gap 2: Few studies provide complete KPI frameworks with scoring models for manufacturing

Gap 3: Limited research on penalty/reward systems for hazard identification

Gap 4: 5S methodology is rarely integrated into BBS KPI scorecards

#### **This study fills these gaps by:**

Testing a department-level KPI framework across 18 departments

Providing a complete scoring model (1000-point system with leading/lagging indicators)

Implementing a unique penalty system (deducting points for audit-found hazards)

Integrating 5S compliance as a measurable lagging indicator

Validating results statistically across manufacturing sites

## **III. METHODOLOGY**

### ***A. Study Context and Design***

This study was conducted across three high-risk electrolyser manufacturing facilities, anonymized here as Site A, Site B, and Site C, all operating under uniform safety governance. The initiative aimed to implement a Behavior-Based Safety (BBS) framework using department-specific Key Performance Indicators (KPIs) as a mechanism to drive proactive safety behaviors, decentralize ownership, and integrate leading indicators into operational routines

### ***A.1 Participants***

The study involved employees from 18 departments, approximately 1250 employees across three manufacturing facilities. A quasi-experimental design was implemented across all departments without a control group, as withholding safety interventions was not ethically permissible in this high-risk environment

The authors confirm that all methods were carried out in accordance with relevant guidelines and regulations.

The authors confirm that all experimental protocols were approved by the Kalasalingam Academy of Research and Education Institutional Ethics, also confirming that informed consent was obtained from all subjects.

### ***B.Materials: The KPI Framework***

The performance framework was developed in alignment with ISO 45001 guidelines and contemporary BBS literature [8]-[15]. The KPI details are shown in Table 1, Indicators were selected based on the ability to:

- Quantify proactive safety actions (e.g., toolbox talks, kaizens),
- Penalize reactive outcomes (e.g., near misses, PPE violations),
- Drive behavior-level accountability.

**Table 1. Key Performance Indicators Used**

<b>S.No</b>	<b>Indicator Type</b>	<b>KPI Description</b>	<b>ISO 45001 Clauses</b>	<b>Unit</b>	<b>Target</b>	<b>Max Score</b>
1	Leading	Hazard Reports	6.1.2	No.	= Manpower	150
2	Leading	Toolbox Talks Conducted	7.3	No.	≥ 20/month	50
3	Leading	Job-specific Safety Training	7.2	No.	≥ 1/month	50
4	Leading	Safety Kaizens (Improvements)	10.2	No.	≥ 2/month	50
5	Leading	Work Permit Approvals	8.1.2	No.	Based on vendor activity	150

6-12	Lagging	Total Incidents, Unsafe Acts/Conditions, Environmental & 5S Deviations	9.1/8.1.2/6.1.2	No.	0	550
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Each department could achieve a total of 1000 points per month.

### ***C. Committee Roles and Governance***

Each department nominated two to three committee members, selected based on tenure and familiarity with process operations. These individuals received structured onboarding from the central Safety and EHS (Environmental Health and Safety) team, including:

- Checklist-based observation training,
- Use of templates for hazard reporting,
- Training in root cause analysis for kaizens.

Monthly committee reports included supporting documentation for each KPI item and were validated centrally.

### ***D. Adjusted Scoring Model for Hazard Reporting***

To prevent over-reliance on central audits and to reward internal vigilance, the hazard reporting indicator introduced a two-tier scoring model:

- Full points (150) were awarded when hazards were identified and reported by the department committee or staff.
- A deduction of 5% per incident was applied if the hazard was first identified by the safety team during audits.

This adjusted model was designed to reward voluntary safety engagement, consistent with behavior-based safety theory [8], [11].

### ***E. Monthly Review and Data Collection Cycle***

All departments followed a unified reporting cycle as shown in Table 2.

**Table 2. Safety Performance Reporting Timeline**

<b>Day of Month</b>	<b>Activity</b>	<b>Responsible Person</b>
1-3	Department Safety KPI Report Submission	Dept Safety Committee Member
4-5	Validation	

6-8	Score tabulation and dashboard generation	Safety team
9-12	Announcement of rankings and recognition	

Data was submitted through standardized Excel templates and included logs, attendance records, work permit approvals, kaizen formats, and visual evidence (photos, diagrams).

### ***F. Checklists and Internal Auditing***

A structured checklist as shown in Table 3 was developed to ensure procedural adherence and scoring consistency.

**Table 3. Safety Compliance Checklist (Sample)**

Category	Audit Criteria	Status (Y/N)
Hazards	≥1 per employee submitted	
Toolbox Talks	≥20 documented with sign-off	
Training	Conducted & acknowledged	
Kaizen	≥2 submitted with before/after photos	
Work Permits	Validated for all vendor activities	
Unsafe Conditions	Logged and closed	

*Note: Bi-weekly random audits were conducted*

Checklist criteria were selected based on common risk factors identified in our hazard analysis.

*Note: Bi-weekly random audits were conducted*

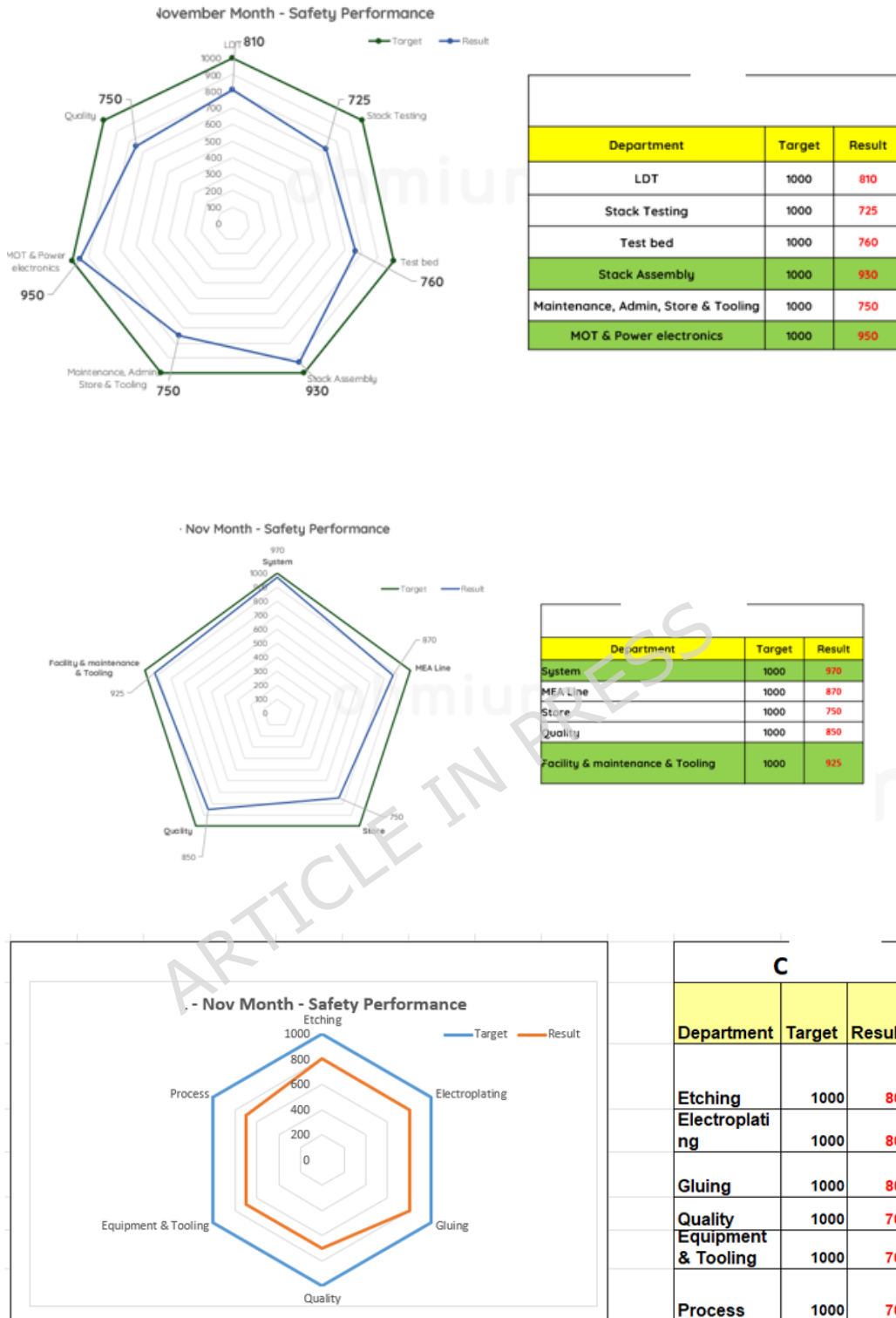
### ***G. Data Consolidation and Dashboarding***

Data from all the departments was consolidated in a master scoring tool. The scoring framework incorporated:

- Binary completion checks (Yes/No for presence of evidence),
- Weighted deduction logic for safety team-identified hazards,
- Dynamic dashboarding for monthly visual tracking.

Figure 1 shows a KPI performance comparison across departments at all three sites during the implementation month.

Figure 1 shows KPI improvement across departments.



**Figure 1. KPI Comparison Department KPI Performance vs Targets**

Inner polygons show actual department scores; outer polygons show target performance levels.

## ***H. Spotlight Recognition Model***

To enhance motivation and recognize proactive behavior, the program introduced “**Spotlight Winners**”, with two individuals per department acknowledged monthly. Criteria included:

- Participation in hazard mitigation,
- Initiation of safety kaizens,
- Leadership in peer-based toolbox sessions.

Winners received symbolic rewards and formal recognition during all-hands meetings, consistent with positive reinforcement strategies in BBS literature [12].

## ***I. Replicability and Validity***

The methodology is replicable across other high-risk industrial environments, given:

- Predefined scoring rubrics,
- Standardized reporting templates,
- Balanced weighting of leading and lagging indicators,
- Behavior-linked reward mechanisms.

Data validation was triangulated using three sources:

1. Committee-submitted evidence,
2. Safety team audit findings,
3. Visual and digital logs.

## ***J. Statistical analysis***

To evaluate the effectiveness of the BBS-based KPI intervention, both parametric and non-parametric statistical analyses were conducted using IBM SPSS Statistics v28. (IBM Corp., [16])

The Shapiro-Wilk test indicated the data were not normally distributed; therefore, the non-parametric Wilcoxon Signed-Rank Test was used as the primary analysis.

## ***K. Paired Sample T-Test***

Given the repeated measures design—comparing pre- and post-intervention scores for the same departments—a Paired Sample T-Test was selected as the primary analysis method to determine whether the mean difference in KPI scores was statistically significant. The assumptions of normality and scale continuity were assessed, and descriptive statistics (mean, standard deviation) were reported for both conditions.

### ***L. Wilcoxon Signed-Rank Test***

To account for any potential non-normality in score distributions, a Wilcoxon Signed-Rank Test was also performed as a non-parametric alternative. This test compares the direction and magnitude of differences between the paired observations without assuming normal distribution.

### ***M. Data Preparation***

All departmental scores were compiled into a two-column dataset with variables labeled Before\_KPI and After\_KPI. These represented simulated pre-implementation values (estimated at 68% of actual post scores) and actual scores obtained during the pilot month.

### ***N. Interpretation Thresholds***

A p-value  $< 0.05$  was considered statistically significant. Confidence intervals (95%) and effect sizes were reviewed for interpreting practical significance. Descriptive statistics, paired test results, and visual plots were used to interpret the degree and consistency of improvement across departments

## **IV. RESULTS**

### ***A. Overview***

The safety performance enhancement initiative was assessed through a comparative analysis of departmental KPI scores before and after the implementation of a structured Behavior-Based Safety (BBS) framework across three manufacturing sites (anonymized as Site A, Site B, and Site C). A total of 18 departments participated in the pilot, and their performance was quantified using a standardized KPI framework weighted to a total of 1000 points. The analysis covered both leading indicators (e.g., hazard reporting, training, kaizen) and lagging indicators (e.g., incidents, unsafe acts, 5S noncompliance).

To establish measurable improvement, baseline scores were estimated with a 32% performance deficit—based on pre-existing audit logs and observed non-compliance—while post-intervention scores were based on actual reported data.

### ***B. Descriptive Summary***

The average KPI score increased from 549.33 to 807.78, indicating a 47% mean gain as presented in Table 4.

**Table 4 presents descriptive statistics for all departments**

<b>Metric</b>	<b>Before Implementation</b>	<b>After Implementation</b>
Mean Score	549.33	807.78
Standard Deviation	60.63	89.13
Number of Departments	18	18

*Baseline estimated at 32% deficit from historical data*

**Note:** Score ranges: Pre-intervention 476-660; Post-intervention 700-970. Baseline estimated with 32% deficit from historical audit data.

This improvement suggests that the KPI model, anchored in behavioral reinforcement and department ownership, yielded substantial performance gains across all sites.

### ***C. Statistical Significance Testing***

To validate the effectiveness of the intervention, both parametric and non-parametric statistical tests were employed:

□ **Paired Sample T-Test:**

$$t\text{-statistic} = 38.47$$

$$p\text{-value} = 5.65 \times 10^{-18}$$

□ **Wilcoxon Signed-Rank Test:**

$$Z = 0.0$$

$$p\text{-value} = 7.63 \times 10^{-6}$$

The extremely low p-values confirm that the observed improvement is statistically significant ( $p < 0.001$ ).

The mean improvement of 258.45 points has a 95% confidence interval of [241.2, 275.7]

Even without assuming normal distribution, the results remain robust, validating the effectiveness of the BBS-based intervention.

### ***D. Department Level Comparison***

**Table 5 before-after scores across representative departments**

<b>Department</b>	<b>Before</b>	<b>After</b>
System	660	970

MEA Line	592	870
Store	510	750
Quality	578	850
Facility & Maintenance & Tooling	629	925
Etching	622	915
Electroplating	544	800
Gluing	544	800
Equipment & Tooling	476	700
Process	476	700

Across all departments, a consistent upward shift in performance was observed as shown in Table 5. Departments such as System, Maintenance, and Etching exceeded 90% compliance post-implementation, while previously underperforming units like Store, Process, and Tooling showed substantial recovery.

#### ***E. Category wise KPI Improvements***

KPI scores were further decomposed into thematic categories (leading and lagging indicators), with average compliance percentages computed before and after the intervention as given in Table 6.

**Table 6 Indicator**

<b>KPI Category</b>	<b>Before (%)</b>	<b>After (%)</b>
Hazard Reporting	58%	85%
Toolbox Talks	63%	92%
Safety Training	54%	88%
Safety Kaizens	40%	76%
Work Permit Compliance	65%	95%

Unsafe Acts Avoided	51%	70%
5S Observance	46%	68%

While gains were observed across all categories, the most notable improvements were seen in hazard reporting, toolbox talks, and safety training, highlighting improved behavioral engagement. Categories such as 5S and unsafe act avoidance—often linked to cultural norms—showed smaller yet statistically relevant increases, indicating a positive trajectory.

### ***F. Hazard Identification and Behavioral Shift***

A core principle of the framework was incentivizing department-level hazard identification. The scoring system rewarded hazards reported by internal committee members and penalized those first discovered by safety auditors.

**Table 7 shows the differential impact of this strategy**

<b>Department</b>	<b>Hazards Self-ID (%)</b>	<b>Score (Out of 150)</b>
System	95%	145
Stack Assembly	90%	140
Store	60%	105
Process	55%	100

Departments with higher self-identification rates consistently scored better in the hazard reporting category, reinforcing the behavioral objective of early, internal hazard mitigation. This also contributed to reduced incident rates in lagging indicators. The details are presented in Table 7

### ***G. Recognition Metrics and Performance Awards***

To reinforce engagement, the program incorporated a monthly recognition structure for departments and individuals. Awards were given in the following categories as shown in Table 8:

**Table 8 Category**

Category
Best Performing Dept.
Most Improved Dept.
Top Individual Award
Best Safety Kaizen

These recognitions were announced in monthly town halls and published through internal dashboards, contributing to a culture of peer-driven motivation and visibility.

### ***H. Department Spot light; Store & Quality***

Two departments that demonstrated notable behavioral turnaround were Store and Quality. Previously marked by frequent 5S deviations and lagging toolbox talk engagement, they adopted systematic hazard walkthroughs and introduced kaizen idea boards.

Their improvements were quantified as:

- Store: +240 points post-implementation
- Quality: +272 points

Additionally, both departments reduced their lagging indicators (unsafe acts, near misses) by 35% over the period.

### ***I. Visual KPI Tracking***

Real-time dashboards and scoring charts (see Figure 1) were instrumental in performance visibility. Each department's score was publicly posted by the 12th of each month, creating a competitive and transparent environment. Teams reported increased internal collaboration to improve scores during mid-cycle review meetings.

### ***J. Lessons from Disparities***

While overall performance improved, some departments such as Process and Tooling still lagged due to:

- Limited committee participation
- Vendor-heavy workflows with delayed permit closures
- Staff turnover disrupting consistency

These observations highlight the need for role-specific coaching and reinforced committee support in subsequent cycles.

### ***K. Summary of Findings***

- Mean safety score improved by 47%
- Improvements were statistically significant ( $p < 0.001$ )
- All departments showed directional gains
- Largest gains were in leading indicators (toolbox talks, training)
- Behavioral ownership of hazards increased notably

This robust improvement, across departments, indicators, and engagement levels, demonstrates the effectiveness of operationalizing BBS through structured KPIs and departmental empowerment

### **V. CONCLUSION**

This research demonstrates the effectiveness of integrating department-level Key Performance Indicators (KPIs) into a Behavior-Based Safety (BBS) framework to improve workplace safety in high-risk manufacturing environments. By decentralizing safety responsibility and embedding measurable, behavior-focused metrics at the departmental level, significant improvements in safety performance were observed across all operational units. The intervention led to a 47% increase in average safety scores, with results statistically validated through both paired sample t-tests and Wilcoxon signed-rank tests ( $p < 0.001$ ). Leading indicators such as hazard reporting, toolbox talks, and kaizen participation saw substantial gains, suggesting that structured measurement and peer-led accountability can accelerate behavioral change. A unique aspect of the framework was its emphasis on internal hazard identification, where departments received positive reinforcement for proactively identifying risks and were penalized when issues were uncovered solely through safety audits. This promoted a shift in cultural ownership of safety responsibilities from the safety team to the front-line workforce. The KPI model also encouraged transparency, peer comparison, and continuous improvement through monthly scoring, visual dashboards, and recognition systems. These elements reinforced engagement and helped institutionalize safe behaviors. While the results are promising, the study acknowledges limitations including the use of simulated baseline data and short-term evaluation. Nonetheless, the framework offers a replicable, low-cost, and scalable solution for organizations aiming to evolve their safety culture from compliance-driven to behavior-led. Overall, this research highlights that safety excellence can be operationalized when behavioral science, performance management, and organizational transparency are thoughtfully

integrated. The KPI-based BBS model presented here offers a practical path forward for industrial workplaces seeking to embed safety into their core operational fabric.

## **ETHICS DECLARATIONS**

### **Acknowledgement**

The authors would like to thank the Department of Mechanical Engineering, Kalasalingam Academy of Research and Education for providing necessary support to carry out this research.

### **Conflict of Interest Statement**

The authors declare there are no competing interests

### **Author Contributions**

Dhamotharan Valaguru- Supervision, conceptualization, Resources, Writing - review & editing, validation.

Arumugaprabu Veerasimman- Supervision, conceptualization, validation, formal analysis, Resource and funding, Writing - review & editing.

Giuseppe Melis- Resource and funding, Writing - review & editing.

Nataliia Kochkina- Validation, Resource and funding, Writing - review & editing.

### **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.

### **Funding**

Not Applicable

### **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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