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Article

Behavior-based safety to improve safety culture in a public construction project in Huánuco, Peru

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Abstract: Unsafe worker behavior is one of the main causes of accidents in the construction sector, one of the most hazardous industries worldwide. This study aligns with Target 8.8 of Sustainable Development Goal 8, which promotes safe and secure working environments, and aimed to determine how Behavior-Based Safety (BBS) improves safety culture in a public works project located in Huánuco, Peru. An applied study was conducted using a quantitative approach, explanatory level, and pre-experimental design with pretest and posttest measurements in a single group. The unit of analysis was the observable behavior of operational workers, recorded through structured observation and documentary analysis over 32 weeks (10 pretest weeks, 12 intervention weeks, and 10 posttest weeks), with 10 weekly measurements before and after the implementation of the BBS program. Safety culture was assessed using ratio-scale indices that integrate three dimensions: psychological, behavioral, and organizational. After the intervention, the overall safety culture index increased from 51.92% to 93.03%, representing an improvement of 41.11 percentage points ($t=30.24$; $df=9$; $p<0.001$). The psychological dimension increased from 49.00% to 86.33% (+37.33 points; $t=9.64$; $p=0.01$), the behavioral dimension from 55.50% to 96.25% (+40.75 points; $t=21.32$; $p<0.001$), and the organizational dimension from 51.25% to 96.50% (+45.25 points; $t=39.50$; $p<0.001$), all with statistically significant differences according to Student's t-test for related samples. The results indicate that BBS is an effective strategy for strengthening safety culture in public works in high-altitude Andean contexts; however, studies with quasi-experimental or experimental designs and comparison groups are needed to confirm causality and assess the generalizability of these findings.
Keywords: behavior-based safety; safety culture; occupational safety and health; construction; public works.

1. Introduction

Workplace accidents in the construction industry are frequent and can generate serious consequences, which is why this sector is considered one of the most dangerous worldwide, with loss of human lives in many cases. One of the main causes of these events is unsafe worker behaviour (EU-OSHA, 2022); this is compounded by poor safety management resulting from inadequate planning and the limited integration of preventive measures into the execution of works (NIOSH, 2024). In this context, Sustainable Development Goal 8, focused on decent work and economic growth, establishes in its target 8.8 the promotion of safe and risk-free work environments for all workers (UN, 2015). Similarly, the International Labour Organization recognizes safety at work as a fundamental principle that protects workers' health and contributes to strengthening a culture of safety in organizations (ILO, 2023).

Globally, around 330,000 deaths from occupational accidents are recorded each year (ILO, 2023), which is equivalent to approximately 904 deaths per day. In the European Union, 22.9% of fatal occupational accidents occur in the construction sector (EU, 2022). In Latin America, 11.1 deaths per 100,000 workers have been documented

(Herrera-Brunett, 2024) and, in São Paulo, Brazil, 373 deaths attributable to occupational accidents were reported, with construction being the most affected sector (Demirkol, 2024). In Peru, during 2023 this sector reported 3,322 non-fatal accidents and 18 fatal accidents (MTPE, 2024); in 2024, fatal incidents reached 31, which represented an increase of 72% compared to the previous period (MTPE, 2025), in a context aggravated by high informality and the limited commitment of some employers to occupational safety standards. In the Huánuco region, construction represents 5% of the economically active population (INEI, 2020) and in December 2024, five deaths due to occupational accidents were recorded in this area (MTPE, 2025). The main causes are associated with work at height and falls at different levels, often related to human error, such as overconfidence, improper use of personal protective equipment, negligence in dangerous situations and insufficient training.

Behavior-Based Safety (CBS) is defined as a systematic and participatory process aimed at identifying critical behaviors related to injury prevention, observing their occurrence in real work, providing immediate feedback and positive reinforcement, and eliminating organizational barriers that hinder the execution of safe behaviors (Ariza & Stubenberg, 2019). This methodology makes it possible to identify and analyze unsafe behaviors in the work environment in order to promote positive changes in behavior through direct, continuous, and timely feedback (Fang et al., 2020; Martínez Oropesa, 2015). Its application is especially useful when workers have the necessary skills and knowledge to perform their tasks safely, but still adopt unsafe behaviors (Meliá, 2007). On the other hand, safety culture is understood as the observable expression of safety management in an organization, and integrates psychological assumptions and attitudes, habitual behaviors at work and organizational management systems, norms and practices, through which decisions are made, priorities are established and risks are acted upon; in addition, it can be diagnosed and improved through instruments that encourage participation, feedback, and continuous learning (Ariza et al., 2023). Likewise, the behavior of owners and managers has a decisive influence on the appearance of unsafe behaviors in construction workers (Zhang et al., 2023).

International evidence supports this approach. Recent studies in the construction sector show that the implementation of Behavior-Based Safety (SBC) is associated with improvements in safe behaviors, especially when there is commitment from senior management and active participation from supervisors; however, difficulties have also been identified in sustaining changes over time and risks of consolidating a culture of blame. Likewise, a positive relationship has been observed between the size of the company and safe culture and behavior, although a gap between management policies and operational reality persists. Similarly, it has been reported that a favorable safety climate in small construction companies is related to lower levels of anxiety, burnout, and depression, as well as greater commitment and job satisfaction. Along the same lines, SBC programs have been developed based on standardized observation, immediate feedback and positive reinforcement that constitute replicable models of intervention, as well as participatory educational strategies that have demonstrated effectiveness in workers with low educational level.

At the national level, several studies report favorable results from the implementation of Behavior-Based Safety (SBC). Bracamonte Sunción (2025), in five civil works in Lima with a population of 456 workers, found that better implementation of the SBC is associated with a lower rate of occupational accidents. In mining, Celis (2024) managed to reduce accidents and incidents at the Raura mining company by 73% over a two-year period, along with an 89.4% increase in safe behaviors and a 10.7% decrease in risky attitudes. Similarly, Cabanillas (2022) evidenced a decrease in unsafe behaviors from 6.98% to 3.32% and a reduction in the accident rate from 392.6 to 0 after the intervention. Barriga and Puma (2021), in the Quellaveco mining project, recorded a decrease in unsafe behaviors from 107 to 18 in six months, as well as an increase in safe behaviors from 13 to 110. Finally, Huaman-Mendoza and De Lama Morán (2024), in a systematic review of SBC in the construction industry, reported that in 90% of cases a significant increase in safe behaviors was achieved, highlighting the importance of integrating psychosocial factors and safety climate as variables that modulate behavioral change.

However, although the SBC has been applied in various sectors at the national and international level, its implementation is still scarce in public works in high Andean areas such as Huánuco. This knowledge gap justifies the scientific, social and practical relevance of this study, as it provides systematic and replicable evidence on the effectiveness of this methodology in a local context that is little researched and with a direct impact on the safety of public project workers. In this framework, the research answered the following question: how does the implementation of a Behavior-Based Safety program improve the safety culture in a public work located in Huánuco during the year 2025?

The general objective was to determine how Behavior-Based Safety improves the safety culture in a public work located in Huánuco, Peru, during the year 2025. The specific objectives were to determine how the SBC improves the psychological dimension, the behavioral dimension and the organizational dimension of the safety

culture in this work. Accordingly, it was formulated as a general hypothesis that behavior-based safety improves the safety culture in a public work in Huánuco during 2025, and as specific hypotheses that such intervention improves, respectively, the psychological, behavioral, and organizational dimensions.

2. Methodology

The research adopted a quantitative approach, because numerical data were collected, objective measurements of the observed behavior of personnel in the workplace were carried out, and statistical analysis was applied to determine the effect of the SBC program on the safety culture. It was of an applied type, because it sought to generate useful knowledge to prevent serious or fatal accidents in a public work through the intervention of the SBC program, and of an explanatory level, aimed at evaluating the impact of the intervention on the dependent variable and establishing verifiable cause-and-effect relationships. The design was pre-experimental in a single group with pre-test and post-test measurements: an initial evaluation was carried out, the SBC program was implemented and then a final measurement was made to quantify the change attributable to the intervention. This design constitutes a viable methodological alternative when it is not possible to form equivalent groups, although it presents limitations to establish firm causal inferences.

The independent variable, Behavior-Based Safety, was operationalized through three dimensions: critical behaviors, feedback, and positive reinforcement (Ariza & Stubenberg, 2019). The dependent variable, safety culture, was evaluated through the psychological, behavioral, and organizational dimensions (Ariza et al., 2023). The corresponding indicators, expressed on a ratio scale, are presented in Table 1.

Table 1. Operationalization of variables: dimensions and indicators.

Variable	**Dimension**	**Indicator**
Behavior-Based Security	Critical behaviors	Critical Behaviors Index: ICC = (TCCI/TCE) × 100
	Feedback	Feedback Rate: IR = (TAR/TAP) × 100
	Positive reinforcement	Positive Reinforcement Rate: IRP = (TCP/NTC) × 100
Safety Culture	Psychological	Voluntary Participation Rate: IPV = (CAV/NTT) × 100
	Behavioral	Safe Behavior Index: ICS = (TCS/TCO) × 100
	Organizational	Standard Procedure Compliance Index: ICPE = (TPC/TPE) × 100

Note. ICB: total critical behaviors identified; TBI: total established behaviors; TAR: total actions performed; TAP: total scheduled actions; TCP: total positive behaviors; NTC: total number of behaviors; CAV: number of voluntary shares; NTT: total number of workers; TCS: total safe behaviors; TCO: total observed behaviors; TPC: total procedures completed; TPE: total standard procedures. Own elaboration.

The unit of analysis was constituted by the observable behavior of the workers in public works, understood as an external, recordable and objectively assessable manifestation of labor behavior; in observational studies, the unit of analysis may focus on codifiable behaviors rather than on the subjects per se (Anguera, 1991). The population was made up of the set of observable critical behaviors performed by workers during the execution of their work over 32 weeks, distributed in three phases: 10 weeks of pre-test, 12 weeks of intervention and 10 weeks of post-test. The sample was composed of 10 weekly measurements in the pre-test and 10 in the post-test, selected through non-probabilistic sampling for convenience, appropriate when a phenomenon is observed in natural contexts and the unit of analysis corresponds to recordable behaviors or events (Supo, Zacarías, & Camayo, 2024).

Structured observation and documentary analysis were used as data collection techniques; such as instruments, behavioural observation sheets and occupational health and safety records consolidated on a weekly basis, prepared based on the indicators and dimensions of the variables. The instruments were validated through expert judgment,

who evaluated their relevance, internal coherence, and clarity, in accordance with the methodological guidelines for the validation of instruments in applied studies (Supo, Zacarías, & Camayo, 2024; Corral, 2022).

The intervention consisted of the application of an SBC program structured in a cycle of continuous behavioral improvement, which included: a) the survey of the baseline and the organizational diagnosis; b) the preparation of the inventory of critical behaviors and the sheet of behavioral observation procedures; (c) training staff in the principles of the SBC, with attendance registration and knowledge assessment; (d) systematic monitoring of behaviour through cards and checklists; e) immediate verbal and graphic feedback, aimed at correcting or reinforcing behaviors; f) positive reinforcement through recognitions of the safe worker of the week and the corresponding record; g) safety walks and behavioral audits with corrective action plans; and (h) monitoring through an SBC scoreboard. In the pre-test phase, critical behaviors were recorded weekly before the application of the program and, in the post-test phase, the measurement was repeated under the same dimensions, in order to estimate the variations attributable to the intervention.

The data analysis included descriptive statistics to synthesize the results of the observed behaviors and inferential statistics to estimate the magnitude of the change. The normality of the data was verified using the Shapiro-Wilk statistic, appropriate for samples of less than 50 observations, and hypothesis testing was performed with Student's t-test for related samples, with a significance level of 5%, using IBM SPSS Statistics software. Regarding ethical aspects, the research was framed in the principles of scientific integrity and confidentiality of information, in accordance with current institutional regulations; Since the unit of analysis was the conduct and not the people, no personal data of the workers were collected, and the authorization of the executing entity was obtained to carry out the observations on site.

3. Results

In the descriptive analysis, the safety culture index (SCI) went from 51.92% in the pre-test to 93.03% in the post-test, which represents an improvement of 41.11 percentage points. Regarding the dimensions, the voluntary participation rate, corresponding to the psychological dimension, increased from 49.00% to 86.33% (+37.33 points); the index of safe behaviors, corresponding to the behavioral dimension, went from 55.50% to 96.25% (+40.75 points); and the index of compliance with standard procedures, corresponding to the organizational dimension, increased from 51.25% to 96.50% (+45.25 points), the latter being the one with the greatest positive variation and the psychological one with the lowest increase, although equally favorable. Table 2 and Figure 1 summarize these results.

Table 2. Descriptive pre-test and post-test statistics of safety culture and its dimensions (n = 10 weekly measurements)

Variable/Dimension	Media pre (%)	OF pre	Media pos (%)	OF POS	Improvement (pp)
Safety Culture (ICS)	51.92	6.21	93.03	4.83	41.11
Psychological dimension (IPV)	49.00	8.54	86.33	7.12	37.33
Behavioral Dimension (ICS)	55.50	6.85	96.25	3.95	40.75
Organizational Dimension (ICPE)	51.25	7.24	96.50	3.18	45.25

Note. SD: standard deviation; pp: percentage points. Prepared by the author from the field records processed in IBM SPSS Statistics.

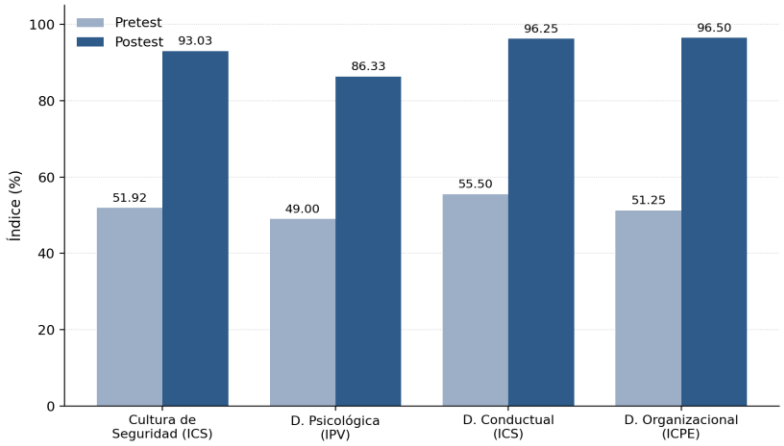

Figure 1. Indices of safety culture and its dimensions in the pre-test and post-test. Own elaboration.

Prior to hypothesis testing, the assumption of normality was verified using the Shapiro-Wilk statistic (n = 10). As can be seen in Table 3, all significance values were greater than 0.05; therefore, the pre-test and post-test data of the variable and its three dimensions show normal distribution. Consequently, Student's parametric t-test was selected for related samples.

Table 3. Shapiro-Wilk normality test of pretest and post-test measurements

Variable/Dimension	**Measurement**	**Statistician**	**gl**	**Say.**
Safety culture	Pretest	0.960	10	0.833
	Postest	0.967	10	0.606
Psychological dimension	Pretest	0.920	10	0.440
	Postest	0.927	10	0.206
Behavioral dimension	Pretest	0.950	10	0.690
	Postest	0.957	10	0.406
Organizational dimension	Pretest	0.880	10	0.119
	Postest	0.895	10	0.406

Note. GL: Degrees of freedom. Significance values > 0.05 indicate normal distribution. Source: IBM SPSS Statistics.

ScientificArticleScientificArticleArticleScientificArticleScientificArticleArticleThe contrast between the general hypothesis and the three specific hypotheses is presented in Table 4. For safety culture, the difference in paired means was 41.11 points (95% CI: 38.03–44.19; t = 30.24; df = 9; p < 0.001), so the null hypothesis was rejected and it was concluded that SBC significantly improves safety culture. In the psychological dimension, the difference was 37.33 points (95% CI: 28.58–46.08; t = 9.64; df = 9; p = 0.01); in the behavioral dimension, 40.75 points (95% CI: 36.43–45.07; t = 21.32; df = 9; p < 0.001); and in the organizational dimension, 45.25 points (95% CI: 42.65–47.85; t = 39.50; df = 9; p < 0.001). In the four contrasts, the bilateral significance value was less than 0.05, which confirms that Behavior-Based Safety significantly improved the safety culture and each of its dimensions in the public works studied.

Table 4. Student's t-test for paired samples (post-test – pretest)

By (pre – pos)	Diff. Of socks	OF	IC 95 % (inf. – sup.)	t	gl	Sig. (bilateral)
Safety culture	41.11	4.30	38.03 – 44.19	30.24	9	0.0001
Psychological dimension	37.33	12.25	28.58 – 46.08	9.635	9	0.01
Behavioral dimension	40.75	6.04	36.43 – 45.07	21.32	9	< 0.001
Organizational dimension	45.25	3.62	42.65 – 47.85	39.50	9	< 0.001

Note. Diff.: difference; SD: standard deviation of the difference; CI: confidence interval; GL: Degrees of freedom. Level of significance $\alpha = 0.05$. Source: IBM SPSS Statistics.

4. Discussion

The purpose of the study was to compare the results of the before and after implementation of Behavior-Based Safety, reflected in the safety culture, and this comparison evidenced the expected change. In relation to the general objective, the safety culture index went from 51.92% to 93.03%, which represents a statistically significant increase of 41.11 percentage points ($t = 30.24$; $p < 0.05$). This finding is consistent with Al-Bayati (2021), who found a positive correlation between safe behavior and safety culture, although modulated by organizational size, and with Galindo, Moreno, and Ospino (2022), who demonstrated the effectiveness of a participatory educational strategy based on SBC, especially in contexts with workers with a low level of education, a frequent characteristic in regional public works workers. The result is also theoretically supported by Fang et al. (2020), who point out that SBC is a comprehensive methodology aimed at identifying unsafe behaviors and modifying them through direct feedback.

In relation to the first specific objective, the psychological dimension, measured through the voluntary participation index, increased from 49.00% to 86.33% (+37.33 points; $p < 0.05$). This result is consistent with Celis (2024), who reported a 73% reduction in accidents and incidents, an 89.4% increase in safe behaviors, and a 10.7% decrease in risky attitudes after implementing the SBC at the Raura mine; it also coincides with Huaman-Mendoza and De Lama Morán (2024), who found that in 90% of the cases reviewed, a significant increase in safe behaviors was achieved, highlighting the role of psychosocial factors as modulators of change. Similarly, it is related to Christino (2020), who argues that the SBC strengthens the daily behaviors of workers and leaders by monitoring unsafe acts and requires dynamic and proactive teams that promote continuous improvement. In this sense, the observed increase in voluntary participation suggests a greater active involvement of personnel in security actions.

As for the second specific objective, the behavioral dimension, expressed through the safe behaviors index, went from 55.50% to 96.25% (+40.75 points; $p < 0.05$). These results are consistent with Cabanillas (2022), who evidenced a significant decrease in unsafe behaviors, from 6.98% to 3.32%, and the reduction of the accident rate from 392.6 to 0 after applying an SBC program based on recording and continuous feedback; they also agree with Barriga and Puma (2021), who reported a decrease in unsafe behaviors from 107 to 18 and an increase in safe behaviors from 13 to 110 in six months, with reductions of up to 74% in incidents. The theoretical support for these findings is provided by Martínez Oropesa (2015), who points out that behavior-based safety management reduces observable unsafe acts and allows risky behaviors to be anticipated through real-time feedback.

Regarding the third specific objective, the organizational dimension, measured by the index of compliance with standard procedures, registered the greatest variation: from 51.25% to 96.50% (+45.25 points; $p < 0.05$). This finding coincides with Celis (2024) and Huaman-Mendoza and De Lama Morán (2024) regarding the effectiveness of continuous training, behavioral monitoring, and positive reinforcement as strategies to consolidate safe behaviors. Likewise, it finds theoretical support in Zhang et al. (2023), who highlight that the behavior of management and the supervision of employees, through direct observation and continuous feedback, are essential to correct unsafe practices, strengthen the organizational climate, and guarantee adequate safety conditions.

Among the strengths of the study are the longitudinal measurement with ten weekly records before and after the intervention, the use of objective indicators on a ratio scale derived from structured observation, instead of self-reports susceptible to social desirability, and the application of the SBC in a poorly documented context, such as a

high Andean public work. However, some limitations must be recognized. The pre-experimental design of a single group, without a control group or random assignment, restricts internal validity and does not allow to completely rule out threats such as maturation, history or the effect of observation; Likewise, the sample size of measurements was small (n = 10 per phase) and, as it is a single work in a specific context, the generalization of the results should be carried out with caution. Future research should replicate the intervention through quasi-experimental designs with a control group, longer time series and multiple public works, and incorporate outcome indicators such as accident rate, as well as the analysis of the sustainability of the improvements once the support of the researchers has been withdrawn.

5. Conclusions

It is concluded that the implementation of Behavior-Based Safety significantly improved the safety culture in the public works studied in Huánuco, evidenced by the increase of the safety culture index from 51.92% to 93.03% (+41.11 percentage points; $t = 30.24$; $p < 0.05$).

The SBC significantly improved the psychological dimension of the safety culture, increasing the rate of voluntary participation from 49.00% to 86.33% (+37.33 percentage points; $p < 0.05$), evidencing greater voluntary involvement of personnel in preventive activities.

The intervention significantly improved the behavioral dimension, increasing the index of safe behaviors from 55.50% to 96.25% (+40.75 percentage points; $p < 0.05$), confirming the effectiveness of behavioral observation, immediate feedback, and positive reinforcement.

Finally, with respect to the third specific objective, the SBC significantly improved the organizational dimension, registering the greatest variation, with an increase of 45.25 percentage points in the index of compliance with standard procedures, from 51.25% to 96.50% ($p < 0.05$). Consequently, it is recommended to give continuity to the program under the responsibility of the organization's OHS area, with the allocation of the necessary resources to sustain and expand the improvements achieved and move towards a sustainable preventive culture in public works in the region.

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Contribution of the authors. Both authors were involved in conceptualization, methodological design, data collection and analysis, writing the original draft, and reviewing and approving the final version of the manuscript.

Ethical approval. The research was carried out respecting the principles of scientific integrity and confidentiality of information. Since the unit of analysis was observable behavior and not people, no personal data of the workers was collected. Likewise, the executing entity was authorized to make the observations on site.

Informed consent. It was not applicable, because no personal data or sensitive information of the workers was collected.

Data availability. Data supporting the study's findings are available in the manuscript and observational logs developed during the research; any further inquiries can be channeled to the authors.

6. Declarations

Conflict of interest. The authors declare no conflicts of interest.

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