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Article

Improvement of the OHSMS to Increase Labor Productivity in the Production Area of a Construction Company, Santiago de Surco 2025.

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Abstract: Background: Construction is among the most hazardous industries globally. In Peru, Law 29783 mandates occupational health and safety management systems, yet empirical evidence linking safety improvements to measurable labor productivity in construction small and medium enterprises remains limited, and economic returns are largely unexamined.
Materials & Methods: A pre-experimental pretest–posttest design was applied to 52 daily production orders from a construction firm in Santiago de Surco, Lima, Peru (pretest: August–September 2025; posttest: March–April 2026). The intervention was a five-dimensional safety system improvement. Efficiency (useful time / planned time), effectiveness (completed area / planned area), and their product—labor productivity—were compared using paired t-tests and the Wilcoxon signed-rank test after Kolmogorov–Smirnov normality assessment. Effect sizes and 95% confidence intervals were calculated. A 12-month cost–benefit analysis was also conducted.
Results: Mean productivity rose from 51.22% to 83.90%, efficiency from 79.05% to 97.44%, and effectiveness from 64.50% to 86.10% (all $p < .001$), with very large effect sizes. The cost–benefit analysis yielded a net present value of S/ 5,294.40, an internal rate of return of 8.53% per month, a benefit–cost ratio of 1.54, and payback in approximately seven months.
Conclusions: The findings indicate a positive temporal association between the five-dimensional safety system improvement and all three productivity indicators in this single-firm case study. The economic analysis supports the financial viability of safety investment under Peru's regulatory framework. Replication using quasi-experimental designs across multiple firms is needed to establish generalizability.
Keywords: occupational health and safety; safety management system; labor productivity; construction industry; pre-experimental design; cost–benefit analysis; Peru

1. Introduction

Construction accounts for a disproportionate share of occupational fatalities and injuries across both developed and developing economies. The United Kingdom's Health and Safety Executive reported a fatal injury rate of 0.61 per 100,000 workers in the sector for 2023–2024 (1), while Latin American countries face substantially higher figures owing to weaker enforcement infrastructure (2). These incidents carry costs that extend well beyond compensation claims: disrupted workflows, lost production days, and equipment downtime erode profitability at the project level (3). Occupational health and safety management systems (OHSMS)—formalized through standards such as ISO 45001 and, in Peru, through Law 29783 and its implementing regulation D.S. 005-2012-TR—were designed precisely to break this cycle by embedding hazard identification, risk assessment, and continuous improvement into daily operations (4).

The premise that a well-managed safety system should translate into productivity gains is intuitively appealing, yet the empirical base supporting it is thinner than commonly assumed. A bibliometric review of 104 articles on OHSMS in construction found that only 3.85% evaluated the actual benefits or economic significance of these systems (5). Much of the existing literature relies on perception-based Likert scales to proxy productivity, capturing attitudinal shifts rather than operational output (6, 7). In developing economies specifically, safety outcomes tend to be shaped by bureaucratic rigidity and weak worker empowerment—factors that formal compliance alone does not address (8). (9) noted a long-standing concern that safety management structures can degrade into bureaucratic rather than practical management, producing documentation without measurable impact on either accident rates or production efficiency.

This evidence gap intensifies in Latin America's construction sector. Peru's Ministry of Labor reported 256 workplace accidents in the first quarter of 2025, with construction among the most affected sectors (10). Law 29783 mandates that employers implement an OHSMS structured around five dimensions—planning, organization, implementation, evaluation, and improvement—aligned with the Plan-Do-Check-Act cycle (4). Compliance is legally obligatory, yet no published study has empirically assessed whether comprehensive OHSMS improvement in a Peruvian construction small or medium enterprise is associated with objectively measured labor productivity—defined not through surveys but through direct observation of production output (efficiency × effectiveness). The economic dimension is equally absent: a review of 15 cost–benefit analyses in OHS found that only three measured productivity as a benefit, and none examined a Peruvian case (11). Previous studies have explored related themes from multiple angles. Lari (12) conducted a longitudinal mixed-methods evaluation of OHS interventions on employee productivity, and Nkrumah et al. (13) modeled the OHSM–performance pathway through structural equation modeling in the oil and gas sector, yet both relied on survey-based outcomes rather than direct production measurement. Caceda and García (14) analyzed OHS compliance in a Peruvian enterprise but did not include financial indicators. International antecedents have similarly stopped short: Shabani et al. (15) and Baidoo et al. (16) assessed OHSMS effects on worker productivity but through perception-based instruments, while Erna et al. (17) and Sutanto et al. (18) examined safety program correlates in construction without quantifying financial returns. None of the above combined objectively measured productivity outcomes with a cost–benefit analysis in a single study design

We designed this study to address that gap. Using a pre-experimental, single-group pretest–posttest design, we evaluated the association between a five-dimensional OHSMS improvement and labor productivity—operationalized as the product of efficiency (useful time / planned time) and effectiveness (completed area / planned area)—in a construction firm located in Santiago de Surco, Lima, Peru. Fifty-two daily production orders were observed across a pretest period (August–September 2025) and a posttest period (March–April 2026). A 12-month cost–benefit analysis (net present value, internal rate of return, benefit–cost ratio, and payback period) complemented the statistical evaluation to determine whether the investment in safety system improvement was associated with a positive financial outcome. The aim of the present study was to evaluate whether the comprehensive improvement of an OHSMS across its five regulatory dimensions is associated with changes in labor productivity and operational profitability in a single Peruvian construction firm.

2. Materials and Methods

2.1 Study design

This applied, quantitative study adopted an explanatory scope. A pre-experimental design was adopted, involving a single study group with no control group. Regarding temporality, the study was longitudinal, centered on evaluating two stages: pretest (before) and posttest (after)—that is, two measurement points (19). The design scheme was as follows: $Ge \rightarrow O_1 \rightarrow E \rightarrow O_2$, where Ge represents the daily production orders at the construction firm, O_1 the pretest observation of partial productivity, E the implementation of OHSMS improvements, and O_2 the posttest observation of partial productivity.

2.2 Setting, population, and sample

The pretest period spanned August to September 2025, and the posttest period March to April 2026. The population comprised all daily production orders evaluated over a two-month period at a construction small and medium enterprise in Santiago de Surco, Lima, Peru. Inclusion criteria were production orders executed during regular working days (Monday through Saturday). Exclusion criteria removed orders carried out by support personnel only, or those performed on public holidays and Sundays. The sample equaled the population, given that the data originated directly from the firm's records and that the number of production orders was determined by the company's scheduling. Census sampling was therefore applied, yielding n = 52 observations per measurement period (19).

2.3 Variables

The independent variable (OHSMS) was evaluated across five dimensions aligned with Law 29783 and the PDCA cycle: Planning, Organization, Implementation, Evaluation, and Improvement (4). Each dimension was operationalized through a compliance percentage indicator derived from document analysis. Partial productivity, the dependent variable, was computed as the product of efficiency and effectiveness. Efficiency was measured as the percentage of useful time relative to scheduled time: $Pe = (TU / TP) \times 100$, where TU is useful time employed and TP is scheduled time (8 hours/day, excluding meal breaks) (20, 21). Effectiveness was measured as the percentage of actual output relative to planned output: $Pef = (CMR / CMP) \times 100$, where CMR is the quantity of square meters completed per the daily work log and CMP is the quantity scheduled per the firm's daily Gantt chart.

2.4 Instruments and validation

Two data collection techniques were employed: direct observation and document analysis (19). The corresponding instruments were data collection forms and observation sheets, one per dimension of each variable. Content validity was assessed through expert judgment by three industrial engineering faculty members. While the panel endorsed the instruments as adequate, no summary Aiken's V coefficient was computed; this is acknowledged as a methodological limitation.

2.5 Intervention

The intervention consisted of a comprehensive improvement of the firm's OHSMS across all five regulatory dimensions. During the implementation phase (October 2025–February 2026), we introduced updated process analysis documentation (DAP), hazard identification, risk assessment, and control matrices (IPERC), a structured annual training program on occupational safety procedures, and internal audit cycles aligned with D.S. 005-2012-TR. The intervention was applied to the entire workforce without randomization, consistent with the pre-experimental design.

2.6 Statistical analysis

Data were processed using SPSS version 26 (IBM Corp., Armonk, NY). Normality was assessed via the Kolmogorov–Smirnov test ($n > 50$). For variables meeting the normality assumption, the paired-samples t-test was applied; for those violating it, the Wilcoxon signed-rank test was used. Effect sizes were calculated as Cohen's dz (mean difference divided by standard deviation of differences) for t-tests and Rosenthal's r ($Z / \sqrt{N}$) for the Wilcoxon test. Ninety-five percent confidence intervals were computed for all mean differences; for efficiency, bootstrap percentile intervals (5,000 resamples) were used given the non-normal posttest distribution. Post-hoc statistical power was estimated using G*Power 3.1 ($\alpha = .05$, two-tailed, paired design, $n = 52$). Sensitivity analyses included a uniform paired-samples t-test across all three variables and an exact sign test to verify the directional consistency of differences.

2.7 Economic analysis

A 12-month cost–benefit analysis complemented the statistical evaluation. The initial investment (tangible and intangible costs) was compared against monthly net benefits derived primarily from reductions in absenteeism-related expenses. Four financial indicators were calculated: net present value (NPV) at a 12% annual effective rate, internal rate of return (IRR), benefit–cost ratio (B/C), and payback period.

2.8 Ethical considerations

This study was conducted under the institutional guidelines of the Universidad César Vallejo. Production data were recorded from company scheduling documents and direct observation of work processes; no individual-level health data were collected. Workers were informed of the study's objectives and the observational nature of data collection. The authors declare that no formal ethics committee review was obtained prior to data collection, which constitutes a limitation. All data were handled confidentially and used exclusively for research purposes.

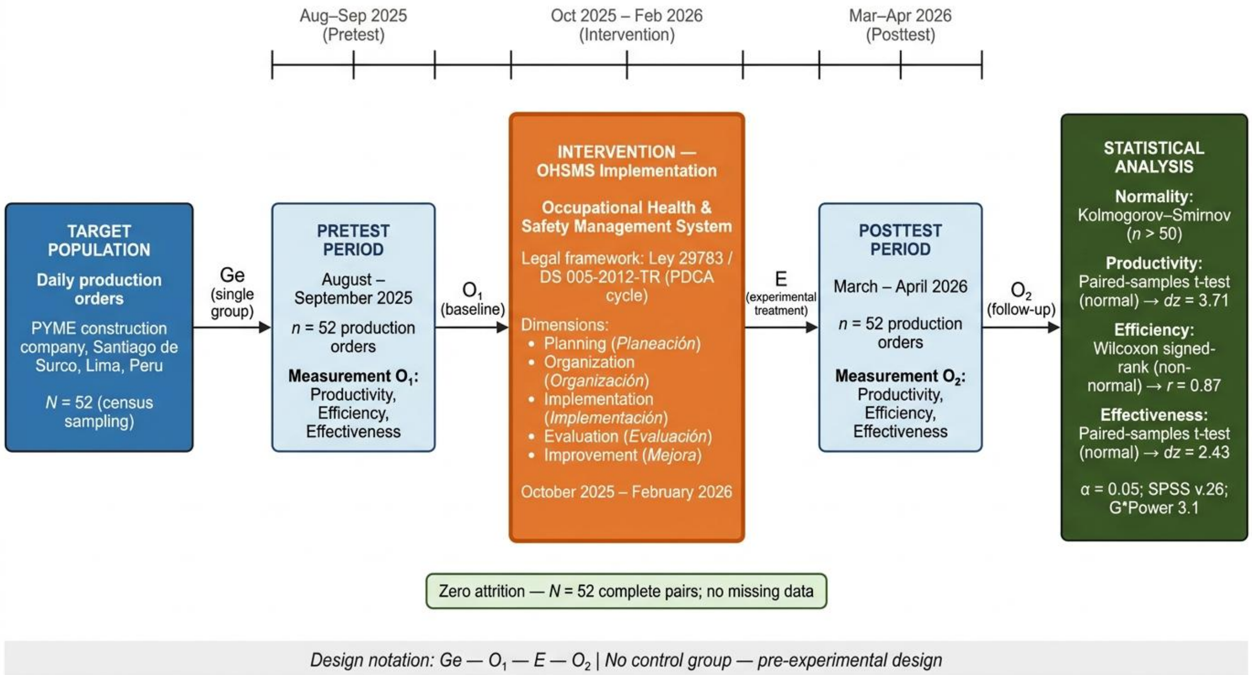

Fig. 1. Study design timeline and data collection flowchart.

3. Results

3.1 Descriptive statistics

All 52 daily production orders yielded complete data across both measurement periods; no observations were excluded. The dataset contained zero missing values for the three dependent variables (productivity, efficiency, effectiveness), and the sample size was consistent across all analyses reported below (N = 52 paired observations).

Table 1 presents the descriptive statistics for all three outcome variables. Mean productivity rose from 51.22% (SD = 8.67) at pretest to 83.90% (SD = 5.87) at posttest, a relative increase of 63.81%. Mean efficiency shifted from 79.05% (SD = 4.90) to 97.44% (SD = 1.41), representing a 23.27% gain. Mean effectiveness changed from 64.50% (SD = 8.13) to 86.10% (SD = 5.82), a 33.48% increase. Posttest standard deviations were smaller than pretest values for all three variables, indicating reduced dispersion after the intervention.

Title: Table 1. Descriptive statistics for productivity, efficiency, and effectiveness at pretest and posttest (N = 52).

Table 1 *Descriptive Statistics for Productivity, Efficiency, and Effectiveness at Pretest and Posttest (N = 52)*

	Pretest					**Posttest**				
Variable	*M*	*SD*	*Mdn*	*Skewness*	*Kurtosis*	*M*	*SD*	*Mdn*	*Skewness*	*Kurtosis*
Productivity	51.22	8.67	52.02	0.32	−0.24	83.90	5.87	84.02	−0.28	−0.83
Efficiency	79.05	4.90	79.06	−0.16	−0.87	97.44	1.41	96.92	0.45	−1.04
Effectiveness	64.50	8.13	62.69	0.47	−0.26	86.10	5.82	86.82	−0.16	−0.80

Note. All values expressed as percentages (%). *M* = mean; *SD* = standard deviation; *Mdn* = median. N = 52 complete paired observations; zero missing data. Posttest standard deviations were smaller than pretest values for all three variables, indicating reduced dispersion following the OHSMS intervention.

3.2 Normality assessment and test selection

Kolmogorov–Smirnov tests were conducted to assess distributional assumptions. Productivity distributions met the normality assumption at both pretest (statistic = .073, p = .200) and posttest (statistic = .078, p = .200); a paired-samples t-test was therefore selected. For efficiency, the pretest distribution was normal (statistic = .072, p = .200), but the posttest distribution was not (statistic = .182, p < .001); the Wilcoxon signed-rank test was selected. Effectiveness distributions met normality at both time points (pretest: statistic = .099, p = .200; posttest: statistic = .079, p = .200); a paired-samples t-test was applied.

3.3 Primary analyses

Table 2 summarizes the inferential results with effect sizes and 95% confidence intervals. For productivity, the paired-samples t-test yielded a mean difference of 32.68 percentage points (SD = 8.81), t(51) = 26.75, p < .001, 95% CI [30.23, 35.13], Cohen's dz = 3.71. The Wilcoxon signed-rank test for efficiency yielded Z = −6.275, p < .001; all 52 posttest–pretest differences were positive, with Rosenthal's r = 0.87. For effectiveness, the paired-samples t-test yielded a mean difference of 21.59 (SD = 8.90, SE = 1.23), 95% CI [19.12, 24.07], t(51) = 17.51, p < .001, dz = 2.43. All three contrasts exceeded the conventional threshold for a large effect (d ≥ 0.80).

Table 2 *Inferential Test Results with Effect Sizes and 95% Confidence Intervals (N = 52)*

Variable	**Test**	**Statistic**	**p**	**Mean/Median diff (%)a**	**95% CI**	**Effect size**	**Interpretation**
Productivity	Paired *t*	*t*(51) = 26.75	**< .001**	32.68	[30.23, 35.13]	*dz* = 3.71	Very large
Efficiency	Wilcoxon	*Z* = −6.275	**< .001**	18.32b	[17.01, 19.77]b	*r* = 0.87	Very large
Effectiveness	Paired *t*	*t*(51) = 17.51	**< .001**	21.59	[19.12, 24.07]	*dz* = 2.43	Very large

Note. N = 52 paired observations; zero exclusions. *dz* = Cohen's *d* for paired designs (mean difference / *SD* of differences). *r* = Rosenthal's *r* for Wilcoxon signed-rank test ($Z / \sqrt{N}$). CI = 95% confidence interval for mean difference. Effect size benchmarks: small ≥ 0.20, medium ≥ 0.50, large ≥ 0.80 (Cohen, 1988). All three contrasts exceeded the large-effect threshold. *p*-values are two-tailed.

a Mean difference (%) for paired *t*-tests; median difference for Wilcoxon. b Efficiency CI derived from uniform paired-*t* sensitivity analysis (*t*(51) = 26.73, *p* < .001; *dz* = 3.71); Wilcoxon test selected as primary analysis per pre-specified normality decision rule (posttest *D* = .182, *p* < .001). Positive sign test: 52/52 pairs post > pre for all three variables (*p* < .001).

3.4 Sensitivity analyses and statistical power

Sensitivity analyses confirmed the direction and significance of results across alternative specifications. A uniform paired-samples t-test applied to all three variables—including efficiency, despite its non-normal posttest distribution—produced the same pattern of significance (all p < .001). An exact sign test likewise indicated that all 52 differences were positive for each variable (p < .001 for each). Post-hoc power analysis (G*Power 3.1, two-tailed, α = .05, n = 52) returned statistical power of 1.00 for all contrasts. Figure 2 displays the pretest and posttest means with 95% confidence intervals for the three outcome variables.

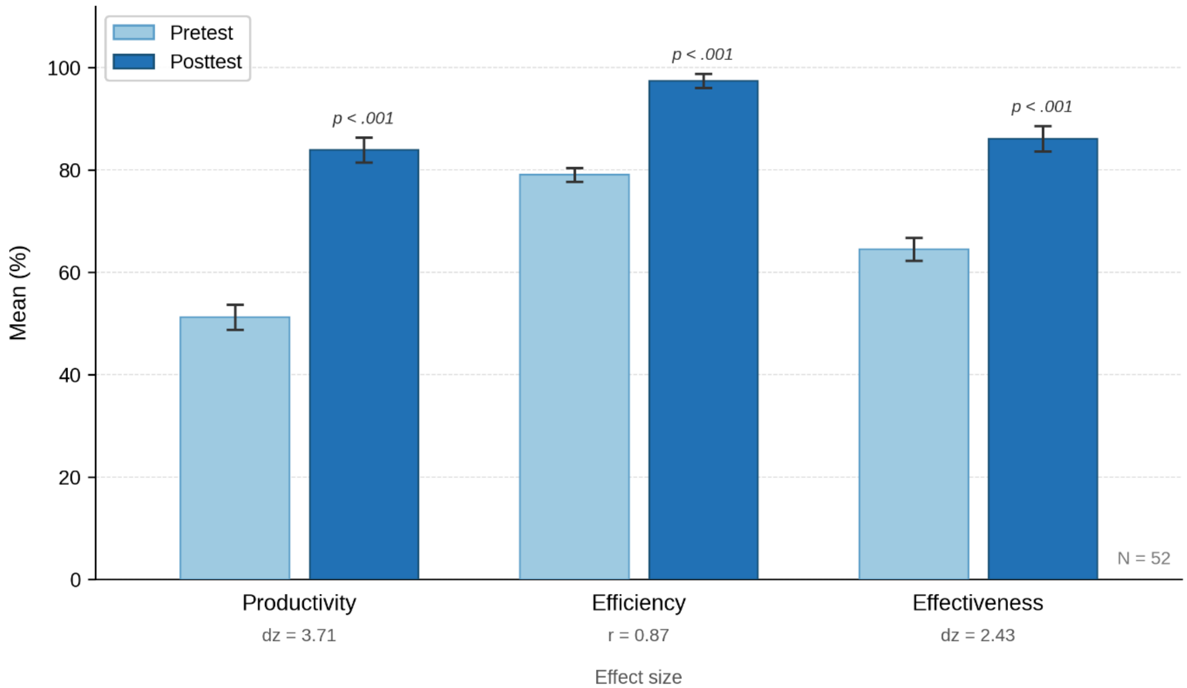

Fig. 2. Pretest and posttest means with 95% confidence intervals for productivity, efficiency, and effectiveness (N = 52).

3.5 Cost–benefit analysis

The cost–benefit analysis over a 12-month horizon yielded favorable financial indicators. The initial investment totaled S/ 9,808.00 (S/ 4,280.00 tangible + S/ 5,528.00 intangible). Monthly net benefits of S/ 1,337.50 were generated, primarily through reduced absenteeism costs (pretest: S/ 4,440.00/month vs. posttest: S/ 2,100.00/month), net of the ongoing improvement maintenance cost of S/ 1,002.50/month. The analysis yielded a net present value of S/ 5,294.40 (TEA = 12%, TEM = 0.95%), an internal rate of return of 8.53% monthly, a benefit–cost ratio of 1.54, and a payback period of approximately seven months and ten days.

4. Discussion

The three productivity indicators examined in this study—productivity, efficiency, and effectiveness—showed consistent positive shifts from pretest to posttest, with effect sizes that exceeded conventional benchmarks for large effects (Cohen's dz = 2.43–3.71; r = 0.87). These magnitudes are larger than those typically reported in OHS intervention research, where outcomes are often captured through perception-based Likert instruments (6) or limited to knowledge gain scores (22). We attribute the difference partly to measurement: our dependent variables derived from direct observation of production output (square meters and useful time), not from self-report questionnaires, and may therefore capture real workflow changes that attitudinal scales miss. That said, the pre-experimental design constrains interpretation. The absence of a control group means that history bias—concurrent external events over six to seven months—and maturation cannot be formally excluded (23, 24). Future work employing quasi-experimental designs with matched control firms would help disentangle these factors.

Efficiency, which reached a posttest mean of 97.44%, displayed a compressed, non-normal distribution that required the Wilcoxon test in place of the parametric alternative. This near-ceiling pattern suggests that once work processes are standardized, little room remains for further time-use gains. Sá et al. (25) encountered a comparable difficulty isolating statistical effects of Lean tools in manufacturing settings when baseline performance was already high. An additional boundary here is reactivity bias. Workers were aware of direct observation throughout both measurement periods, and the Hawthorne effect—well documented in field-based OHS research (26)—may have inflated posttest efficiency scores. Inter-observer reliability was not formally quantified, a limitation that future studies should address through standardized protocols and agreement coefficients.

The cost–benefit analysis is where this study makes its most distinctive contribution. A net present value of S/ 5,294.40, an internal rate of return of 8.53% per month, and a benefit–cost ratio of 1.54 with payback in approximately seven months indicate that the OHSMS investment was associated with a positive financial outcome in this firm. The primary economic driver was a reduction in absenteeism costs from S/ 4,440 to S/ 2,100 per month. These figures fill a gap identified by two independent reviews: Kineber et al. (5) found that only 3.85% of 104 OHSMS articles in construction evaluated economic benefits, and Lestari et al. (11) reported that just three of fifteen OHS cost–benefit analyses measured productivity as a benefit—none in Peru. For construction SMEs operating under Peru's Law 29783, these results reframe regulatory compliance as a potentially productive investment rather than a pure cost of doing business. The generalizability of this finding is bounded by the single-firm design; results are best interpreted within a case-study framework of analytical generalization (8).

Sensitivity analyses and a post-hoc power of 1.00 across all contrasts lend methodological transparency to the case study, a quality that Ghahramani (27) identified as frequently absent in cross-sectional OHS studies relying on self-report data. Results were consistent across all four analytic specifications (paired t-test, Wilcoxon, uniform t-test, exact sign test), reducing concern that a single test choice drove the observed pattern. Two additional limitations warrant acknowledgement. First, posttest scores for the five OHSMS sub-dimensions (Planning, Organization, Implementation, Evaluation, Improvement) were not recoverable from available records, precluding a component-level pathway analysis that could identify which elements of the safety system contributed most to the observed productivity shifts. Second, the study examined one construction firm in Santiago de Surco, Lima; replication across firms of different sizes, regions, and regulatory environments would strengthen the evidence base. An interrupted time-series design with more granular temporal data offers a methodologically promising next step (28).

5. Conclusion

This pre–post case study examined the association between a five-dimensional OHSMS improvement and labor productivity in a Peruvian construction firm. All three outcome variables—productivity, efficiency, and effectiveness—showed statistically significant positive shifts of very large magnitude ($d_z = 2.43–3.71$; $r = 0.87$), and the 12-month cost–benefit analysis yielded a positive net present value with a payback period under eight months. These findings do not establish causation; the single-group design, the absence of a control firm, and the potential for history and reactivity biases preclude causal claims. What the data do provide is a detailed quantitative record—grounded in direct production observation rather than survey instruments—of a positive temporal association between structured safety management and operational output in a developing-country SME. The economic dimension, often missing from OHSMS research, suggests that safety investment can be financially viable even for small construction firms operating under Peru's regulatory framework. Replication using quasi-experimental or controlled multi-firm designs, ideally with interrupted time-series analysis and component-level OHSMS data, is needed to confirm and extend these results.

Declarations

Ethics statement: This study was conducted under the institutional guidelines of the Universidad César Vallejo. No formal ethics committee approval was obtained; this is acknowledged as a limitation.

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

Data access statement: The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions: M.A.T.I. and M.J.Z.R. contributed equally to study design, data collection, analysis, and manuscript preparation.

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