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JOURNAL OF MECHANICAL, INDUSTRIAL, ELECTRICAL, AND CIVIL ENGINEERING

THE INFLUENCE OF OCCUPATIONAL HEALTH AND SAFETY (OHS) PROGRAMS ON EMPLOYEE PRODUCTIVITY: EMPIRICAL EVIDENCE FROM A STATE-OWNED ELECTRIC UTILITY IN NORTH SUMATRA, INDONESIA

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Abstract

Background: Occupational Health and Safety (OHS) programs are critical determinants of workforce productivity in high-risk industrial environments. Despite extensive literature on OHS, empirical evidence specifically examining its quantified effect on employee productivity in Indonesian state-owned power utilities remains scarce, constituting a significant research gap.

Objective: This study investigates the simultaneous and partial effects of occupational health (X1) and occupational safety (X2) programs on employee productivity (Y) at PT PLN (Persero) Pembangkitan Sektor Belawan, Medan, Indonesia.

Methods: A quantitative-associative cross-sectional design was employed. Data were collected via validated Likert-scale questionnaires from a census sample of 85 permanent employees. Multiple linear regression analysis was conducted using SPSS 21.0, supplemented by validity (Pearson r), reliability (Cronbach's α), and normality tests.

Results: Reliability coefficients ranged from α=0.655 to α=0.822, confirming instrument consistency. The simultaneous F-test yielded $F(2,82)=231.212$ ($p<0.001$), explaining 84.9% of variance in productivity ($R^2=0.849$). Occupational

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health exerted a dominant positive partial effect (β=0.828, t=13.412, p<0.001), while occupational safety also contributed significantly (β=0.124, t=2.016, p=0.047).

Conclusion: Both OHS dimensions positively and significantly predict employee productivity, with occupational health being the stronger driver. These findings provide actionable evidence for policymakers and OHS managers in energy-sector utilities across developing economies. Novelty: This study is the first to quantify the differential dominance of occupational health over safety in predicting productivity within Indonesia's state power-generation sector, extending OHS theory into an emerging-market context.

Keywords: *keselamatan dan kesehatan kerja; perusahaan penyedia listrik; Indonesia; regresi linear berganda*

Abstrak

Latar Belakang: Program Keselamatan dan Kesehatan Kerja (K3) merupakan penentu krusial produktivitas tenaga kerja di lingkungan industri berisiko tinggi. Meskipun terdapat banyak literatur mengenai K3, bukti empiris yang secara khusus mengkaji dampak terukur program tersebut terhadap produktivitas karyawan di perusahaan listrik milik negara Indonesia masih terbatas, sehingga menciptakan kesenjangan penelitian yang signifikan.

Tujuan: Penelitian ini mengkaji pengaruh simultan dan parsial program kesehatan kerja (X1) dan keselamatan kerja (X2) terhadap produktivitas karyawan (Y) di PT PLN (Persero) Pembangkitan Sektor Belawan, Medan, Indonesia.

*Metode: Penelitian ini menggunakan desain kuantitatif-asosiatif dengan pendekatan *cross-sectional*. Data dikumpulkan melalui kuesioner berskala Likert yang telah divalidasi dari sampel sensus yang mencakup 85 karyawan tetap. Analisis regresi linear berganda dilakukan menggunakan SPSS 21.0, dilengkapi dengan uji validitas (Pearson r), reliabilitas (Cronbach's α), dan normalitas.*

Hasil: Koefisien reliabilitas berkisar antara α=0,655 hingga α=0,822, yang mengonfirmasi konsistensi instrumen. Uji F simultan menghasilkan nilai F(2,82)=231,212 (p<0,001), yang menjelaskan 84,9% varians produktivitas (R^2=0,849). Kesehatan kerja memberikan pengaruh parsial positif yang dominan (β=0,828, t=13,412, p<0,001), sementara keselamatan kerja juga memberikan kontribusi signifikan (β=0,124, t=2,016, p=0,047).

Kesimpulan: Kedua dimensi K3 memprediksi produktivitas karyawan secara positif dan signifikan, dengan kesehatan kerja sebagai faktor pendorong yang lebih kuat. Temuan ini memberikan bukti yang dapat ditindaklanjuti bagi para pembuat kebijakan dan manajer K3 di perusahaan utilitas sektor energi di negara-negara berkembang. Kebaruan: Penelitian ini merupakan studi pertama yang mengukur perbedaan dominasi kesehatan kerja dibandingkan keselamatan kerja dalam memprediksi produktivitas di sektor pembangkitan listrik milik negara Indonesia, serta memperluas teori K3 ke dalam konteks pasar berkembang.

INTRODUCTION

The global electricity sector increasingly demands high workforce productivity to meet surging energy requirements driven by urbanization and industrial expansion [1]. In Indonesia, PT Perusahaan Listrik Negara (PLN) — the sole state-owned electric utility — operates under extraordinary pressure to maintain power availability for a population exceeding 270 million [2]. Within this context, the occupational health and safety (OHS) of employees is not merely a compliance concern but a strategic determinant of organizational performance [3].

The International Labour Organization estimates that work-related accidents and diseases cost approximately 4% of global GDP annually, with developing economies disproportionately affected [4]. In the Indonesian electricity sector, high-voltage environments, rotating machinery, and chemical exposure elevate accident risk significantly above national industrial averages [5]. According to the Indonesian National Agency for Disaster Management (BNPB), occupational injuries in the energy sector declined by 12.7% between 2016 and 2021, yet remain elevated relative to manufacturing benchmarks [6].

OHS programs — encompassing physical environment management, health promotion, safety training, personal protective equipment (PPE), and psychological welfare — have been theorized to enhance productivity through multiple pathways: reducing absenteeism, improving morale, sustaining physical capacity, and lowering indirect costs of accidents [7], [8]. Empirical confirmation of these pathways, however, remains inconsistent across industrial contexts. Most studies originate from North American or European settings [9], [10], leaving a substantial evidence gap in Southeast Asian state-owned utility environments [11].

Research Gap and Novelty

Three key gaps motivate this study. First, prior research conflates occupational health and occupational safety into a composite OHS index, masking the differential contribution of each dimension to productivity [12], [13]. Second, existing Indonesian OHS literature

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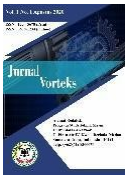

predominantly targets manufacturing [14] or construction [15], neglecting the unique risk profile and workforce characteristics of power-generation utilities. Third, no study has employed multiple linear regression with full instrument validation — including validity, reliability, and normality — to examine OHS effects on productivity in Indonesia's PLN context [16].

This study's novelty is threefold: (i) it separately quantifies occupational health (X1) and occupational safety (X2) as distinct predictors, revealing their individual effect magnitudes; (ii) it situates findings within the specific institutional and environmental context of Sektor Belawan — North Sumatra's largest power-generation complex; and (iii) it provides a validated measurement instrument replicable in analogous utilities across ASEAN developing economies.

Research Objectives

This study pursues four objectives:

1. To assess the influence of occupational health (X1) on employee productivity (Y) at PT PLN Sektor Belawan.
2. To assess the influence of occupational safety (X2) on employee productivity (Y) at PT PLN Sektor Belawan.
3. To examine the simultaneous effect of X1 and X2 on Y.
4. To identify which OHS dimension exerts the dominant effect on productivity.
5.

Literature Review and Theoretical Framework

Occupational Health and Its Dimensions

Occupational health is defined as the promotion and maintenance of the highest degree of physical, mental, and social well-being of workers in all occupations [17]. Mathis and Jackson [18] categorize occupational health concerns into acute illness (infectious diseases), chronic occupational disease (repetitive strain, noise-induced hearing loss), and psychosocial hazards (stress, burnout). Suma'mur [19] argues that health in the workplace encompasses not merely the absence of disease, but the holistic fitness of the worker to perform tasks without detriment to self or others.

Randal and Susan [20] posit that effective OHS management reduces both short-term and long-term disease incidence, thereby preserving workforce capacity. Empirically, Lestari and Trisyulianti [21] confirmed a positive relationship between health programs and productivity at PTPN VIII, finding that cleanliness, medical facilities, and ventilation quality significantly predicted output levels. This finding is corroborated by Subramaniam et al. [22], who identified health commitment and safety training as dominant predictors of performance across Malaysian manufacturing firms.

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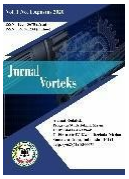

Occupational Safety and Performance

Occupational safety refers to the protection of employees from physical injury caused by work-related accidents, equipment failures, or hazardous conditions [23]. Mondy [24] identifies safety as encompassing injury prevention, stress management, and workplace violence reduction. From a systems perspective, Dessler [25] links safety performance to two intervention categories: (a) engineering controls that eliminate unsafe conditions, and (b) behavioral interventions that reduce unsafe acts.

Suma'mur [19] established that high safety standards correlate positively with productivity through five mechanisms: reduced accident-induced production interruptions, optimized equipment utilization, favorable work climate, integration of safety into skill development, and enhanced labor-management relations. Bronkhorst and Vermeeren [26] reported a significant health-performance association in Dutch public-sector organizations, emphasizing perceived safety climate as a mediating variable. Malinasari and Azzuhri [27] found that OHS programs and social security jointly explained 58.6% of productivity variance in PT PJB UP Brantas.

Employee Productivity: Conceptual Foundations

Productivity is operationally defined as the ratio of output to input [28]. Hasibuan [29] distinguishes productivity from efficiency, noting that productivity improvements may be achieved through enhanced skill, improved work systems, or technological upgrades. Riyanto [30] further disaggregates productivity into temporal efficiency (output per unit time) and resource efficiency (output per unit input). Sedarmayanti [31] identifies five productivity dimensions: (1) work attitude, (2) skill level, (3) work-environment relationships, (4) productivity management, and (5) labor efficiency — all of which can be influenced by OHS conditions.

The theoretical link between OHS and productivity is grounded in Human Capital Theory [32], which treats worker health as a form of capital whose depreciation through illness or injury reduces productive capacity. Complementarily, the Job Demands-Resources (JD-R) model [33] posits that adequate safety resources buffer occupational demands, preventing burnout and sustaining engagement — a mechanism directly relevant to power-sector workers facing high-voltage and shift-work demands.

Hypothesis Development

Drawing from the foregoing review, the following hypotheses are proposed:

H1: Occupational health (X1) has a significant positive effect on employee productivity (Y) at PT PLN Sektor Belawan.

H2: Occupational safety (X2) has a significant positive effect on employee productivity (Y) at PT PLN Sektor Belawan.

H3: Occupational health (X1) and occupational safety (X2) simultaneously exert a significant positive effect on employee productivity (Y).

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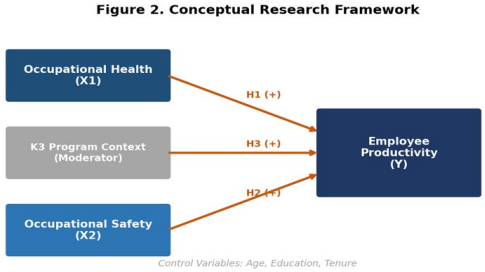

Figure 1. Conceptual Research Framework Showing Hypothesized Relationships Among Study Variables

RESEARCH METHODS

Study Design and Setting

A quantitative cross-sectional associative research design was employed [34]. The study was conducted at PT PLN (Persero) Pembangkitan Sumatera Bagian Utara, Sektor Pembangkitan Belawan, located on Pulau Sicanang, Sei Mati, Medan, North Sumatra (3°47'N, 98°38'E). This facility is the largest power-generation complex in Sumatra, with a combined installed capacity of 1,156.3 MW across four PLTU (steam), five PLTG (gas), and two PLTGU (combined-cycle gas) units. The high-hazard nature of power generation — involving high voltages, rotating machinery, extreme temperatures, and hydrocarbon fuels — renders it an ideal context for OHS research.

Population and Sample

The target population comprised all 85 permanent employees (karyawan tetap) of PT PLN Sektor Belawan. Given the manageable population size, a census sampling approach was adopted — consistent with Sugiyono's [35] recommendation that census sampling is appropriate when N ≤ 100 and each unit contributes unique contextual variance. Informed consent was obtained from all participants prior to data collection. The study was conducted in accordance with institutional ethical guidelines.

Table 1. Population Distribution by Division and Census Participation

Division / Work Unit	Total Staff	Included in Census	Response Rate (%)
Engineering & Planning	14	14	100.0
Power Plant Operations (PLTU)	18	18	100.0
Power Plant Operations (PLTG)	16	16	100.0
Maintenance PLTU	12	12	100.0
Maintenance PLTGU	11	11	100.0
HR, Administration & K3	14	14	100.0
Total	85	85	100.0

Research Instrument

Data were collected using a structured Likert-scale questionnaire comprising 28 items across three constructs: (1) Occupational Health (X1) — 6 items measuring physical work environment, medical care provision, and hazard prevention; (2) Occupational Safety (X2) — 10 items covering equipment safety, lighting, ventilation, PPE availability, and psychosocial support; and (3) Employee Productivity (Y) — 12 items assessing work attitude, skill

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application, relationship quality, management quality, and time-efficiency. Response anchors ranged from 1 (Strongly Disagree) to 5 (Strongly Agree). The instrument was adapted from validated scales by Moenir [36] and Sedarmayanti [31], with contextual modifications validated through expert review by three industrial engineering faculty members.

Table 2. Research Instrument: Constructs, Dimensions, and Item Distribution

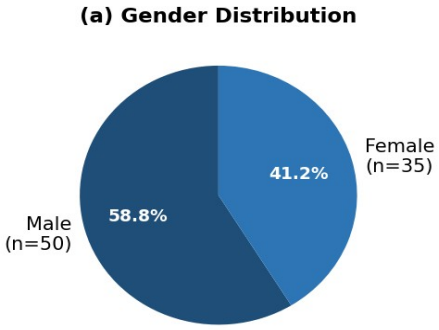
Construct	Dimension	No. of Items	Scale
Occupational Health (X1)	Physical condition & nutrition	2	Likert 1–5
	Work environment quality	2	Likert 1–5
	Employee health protection	2	Likert 1–5
Occupational Safety (X2)	Physical work environment (equipment)	2	Likert 1–5
	Air regulation & ventilation	2	Likert 1–5
	Lighting regulation	2	Likert 1–5
	Equipment use & condition	2	Likert 1–5
	Physical & mental condition	2	Likert 1–5
Employee Productivity (Y)	Capability & workload	2	Likert 1–5
	Output achievement	2	Likert 1–5
	Work motivation & spirit	2	Likert 1–5
	Self-development	2	Likert 1–5
	Output quality (mutu)	2	Likert 1–5
	Efficiency & effectiveness	2	Likert 1–5

Statistical Analysis Procedures

All analyses were performed using IBM SPSS Statistics v21.0. The analytical sequence comprised: (1) Item validity testing using Pearson product-moment correlation (r-hitung vs. r-tabel at df=n−2=83, α=5%, r-tabel=0.208); (2) Reliability testing using Cronbach's α (threshold α≥0.60); (3) Normality testing via Kolmogorov–Smirnov test; (4) Multiple linear regression: $Y = \beta 0 + \beta 1X1 + \beta 2X2 + \varepsilon$; (5) Simultaneous significance testing (F-test, α=5%, df1=2, df2=82, F-tabel=3.11); and (6) Partial significance testing (t-test, two-tailed, α=5%, df=82, t-tabel=1.989). The coefficient of determination (R^2) was computed to quantify explained variance.

ANALYSIS AND EVALUATION

Respondent Characteristics



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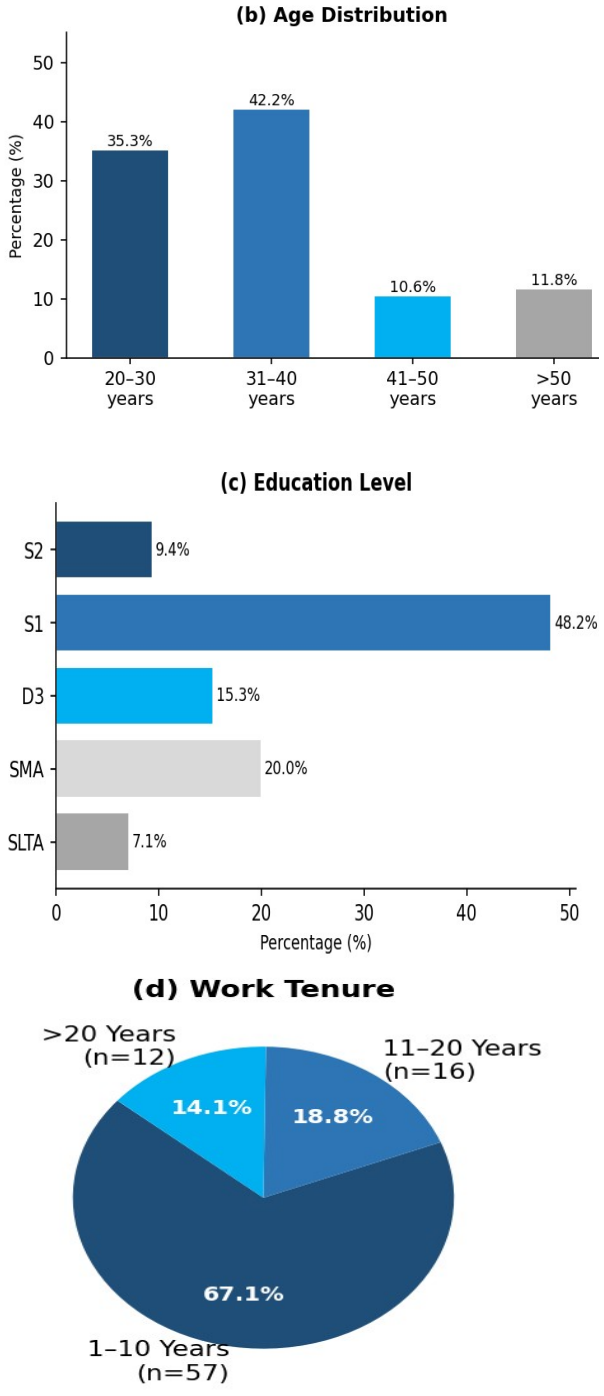

Of the 85 respondents, 58.8% were male (n=50) and 41.2% female (n=35). The dominant age bracket was 31–40 years (42.2%), consistent with a mid-career workforce. Educational attainment was high: 48.2% held bachelor's degrees (S1) and 9.4% postgraduate (S2), reflecting PLN's competitive recruitment standards. Most employees had 1–10 years of tenure (67.1%), indicating a relatively experienced yet not-yet-senior workforce. Detailed demographic data are presented in Table 3.

Table 3. Descriptive Statistics of Respondent Demographic Characteristics (n=85)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	50	58.8
	Female	35	41.2
Age	20–30 yr	30	35.3
	31–40 yr	36	42.2
	41–50 yr	9	10.6
	>50 yr	10	11.8
Education	SLTA	6	7.1
	SMA	16	20.0
	D3	13	15.3
	S1	41	48.2
	S2	9	9.4
Tenure	1–10 yr	57	67.1
	11–20 yr	16	18.8
	>20 yr	12	14.1

Figure 2. Demographic Profile of Respondents (n=85): (a) Gender, (b) Age, (c) Education, (d) Work Tenure

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Descriptive Statistics of Research Variables

Descriptive statistics for all three variables are presented in Table 4. Occupational health scores (X1) showed a mean of 22.34 out of a maximum of 30, indicating generally positive health perceptions. Occupational safety (X2) mean of 38.12 out of 50 reflected adequate safety conditions. Employee productivity (Y) mean of 48.76 out of 60 suggested above-moderate productivity levels, with limited variance (SD=4.11) indicating relative homogeneity in productivity perceptions.

Table 4. Descriptive Statistics of Research Variables

Variable	N	Min	Max	Mean	Std. Dev.
Occupational Health (X1)	85	14	30	22.34	3.21
Occupational Safety (X2)	85	28	50	38.12	4.18
Employee Productivity (Y)	85	36	60	48.76	4.11
Valid N (listwise)	85				

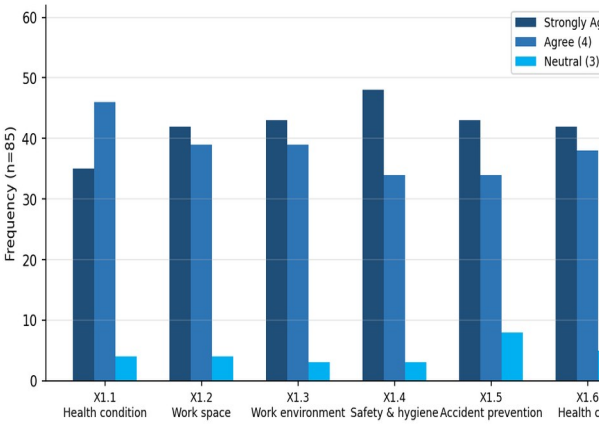

Figure 3. Frequency Distribution of Occupational Health (X1) Responses Across Six Items (n=85)

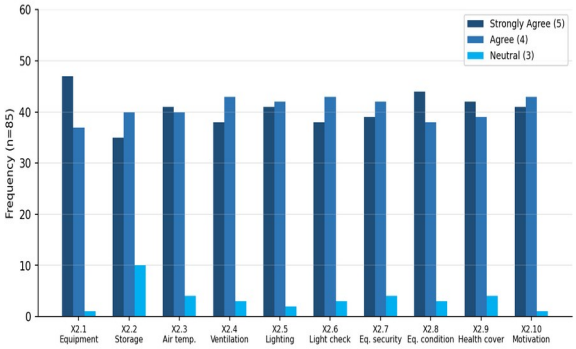

Figure 4. Frequency Distribution of Occupational Safety (X2) Responses Across Ten Items (n=85)

EVALUATION

All 28 questionnaire items were subjected to Pearson product-moment correlation testing with the total construct score. With n=85, the r-tabel at df=83, α=5% (two-tailed) is 0.208. As presented in Table 5, all r-hitung values exceeded r-tabel, confirming that every item is statistically valid and measures its intended construct. The highest correlation was observed for X1.3 (r=0.780) and the lowest for Y.1 (r=0.367), both exceeding threshold. Figure 6 provides a visual comparison of all 28 item correlations against the critical threshold.

Table 5. Item Validity Analysis Results (Pearson r, n=85, df=83, r-tabel=0.208, α=5%)

Item	Construct / Indicator	r-hitung	r-tabel	Status
X1.1	Physical health	0.466	0.208	Valid

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	condition			
X1.2	Work space adequacy	0.524	0.208	Valid
X1.3	Work environment quality	0.780	0.208	Valid
X1.4	Safety & hygiene environment	0.545	0.208	Valid
X1.5	Accident/ disease prevention	0.700	0.208	Valid
X1.6	Health care provision	0.614	0.208	Valid
X2.1	Equipment availability	0.580	0.208	Valid
X2.2	Storage & materials safety	0.662	0.208	Valid
X2.3	Air temperature conditions	0.565	0.208	Valid
X2.4	Ventilation adequacy	0.696	0.208	Valid
X2.5	Lighting provision	0.483	0.208	Valid
X2.6	Periodic lighting maintenance	0.548	0.208	Valid
X2.7	Equipment safety protocol	0.606	0.208	Valid
X2.8	Equipment operational condition	0.700	0.208	Valid
X2.9	Health insurance provision	0.602	0.208	Valid
X2.10	Motivational support	0.527	0.208	Valid
Y.1	Equipment knowledge	0.367	0.208	Valid
Y.2	Appropriate workload assignment	0.478	0.208	Valid
Y.3	Target completion timeliness	0.676	0.208	Valid
Y.4	Rule adherence	0.495	0.208	Valid
Y.5	Program-driven motivation	0.686	0.208	Valid
Y.6	Reward system effectiveness	0.615	0.208	Valid
Y.7	Training & development	0.539	0.208	Valid
Y.8	Performance evaluation	0.581	0.208	Valid
Y.9	Work quality & precision	0.663	0.208	Valid
Y.10	Quality & quantity output	0.625	0.208	Valid
Y.11	Timeliness of task completion	0.573	0.208	Valid
Y.12	Budget efficiency compliance	0.636	0.208	Valid

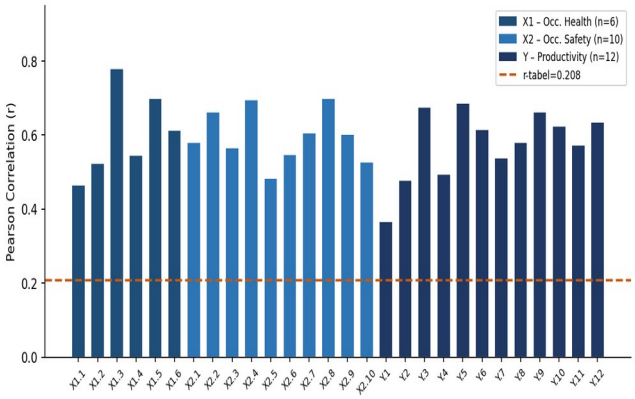

Figure 5. Bar Chart of Item Validity – r-hitung vs. r-tabel (0.208) Across All 28 Items

Reliability Analysis

Internal consistency was assessed using Cronbach's α. Results are displayed in Table 6 and Figure 6. All three constructs surpassed the widely accepted threshold of α=0.60 [37], confirming instrument reliability. Notably, the Occupational Safety and Employee Productivity scales demonstrated good-to-excellent reliability (α=0.800 and 0.822 respectively), while the Occupational Health scale was acceptable

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(α=0.655). No item deletion was required.

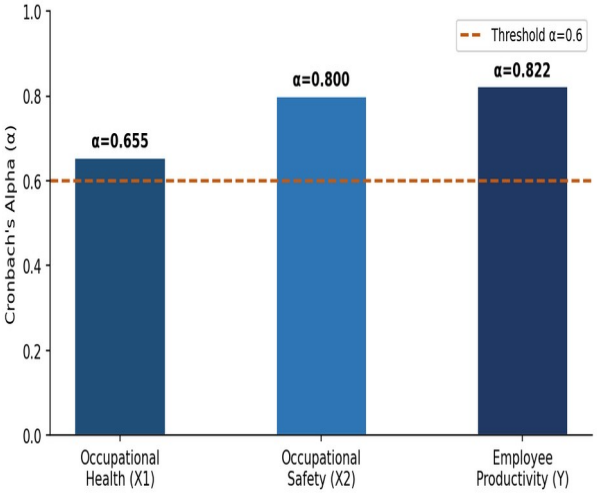

Figure 6. Cronbach's Alpha Reliability Coefficients Compared to the Threshold (α=0.60)

Table 6. Reliability Analysis Results (Cronbach's α) for All Research Constructs

Variable / Scale	Cronbach's α	No. of Items	Reliability Interpretation
Occupational Health (X1)	0.655	6	Acceptable
Occupational Safety (X2)	0.800	10	Good
Employee Productivity (Y)	0.822	12	Good

Multiple Linear Regression Analysis

Multiple linear regression was used to examine the simultaneous and partial effects of X1 and X2 on Y. The estimated regression equation is: $\hat{Y}$ = 4.700 + 1.573X1 + 0.146X2. The constant (b0=4.700) indicates the baseline productivity score when OHS predictors are zero. The regression coefficient for occupational health (β1=1.573) indicates that for every one-unit increase in health program score, productivity increases by 1.573 units, holding safety constant. Correspondingly, β2=0.146 reflects the partial incremental effect of occupational safety. Detailed results are summarized in Table 7.

Table 7. Multiple Linear Regression Coefficients (Dependent Variable: Employee Productivity Y)

Variable	B	Std. Error	β (Std.)	t-hitung	Sig.
(Constant)	4.700	2.382	–	1.973	0.052
Occupational Health X1	1.573	0.117	0.828	13.412	0.000***
Occupational Safety X2	0.146	0.073	0.124	2.016	0.047*

Note: *** p<0.001; * p<0.05; t-tabel (df=82, α=5%, two-tailed) = 1.989.

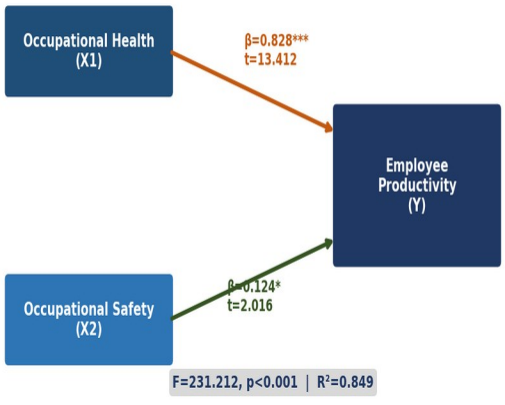

Figure 7. Standardized Regression Coefficient Path Diagram with Model Fit Statistics (R^2=0.849)

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Simultaneous Hypothesis Testing (F-test)

The ANOVA F-test was conducted to evaluate Hypothesis H3 — the simultaneous effect of X1 and X2 on Y. Results are presented in Table 8. The obtained F-value of 231.212 substantially exceeds the critical F-tabel of 3.11 at df(2,82), α=5%. The corresponding significance value (p<0.001) confirms rejection of the null hypothesis. This outcome indicates that the combined OHS program — encompassing both health and safety dimensions — is a powerful and statistically significant predictor of employee productivity. The model explains 84.9% of total variance in productivity (R^2=0.849, Adjusted R^2=0.845), reflecting a high explanatory fit.

Table 8. ANOVA Table for Simultaneous F-test (H3: X1 and X2 simultaneously predict Y)

Model	Sum of Squares	df	Mean Square	F-hitung	Sig.
Regression	1204.464	2	602.232	231.212	0.000***
Residual	213.583	82	2.605	–	–
Total	1418.047	84	–	–	–

Note: F-tabel (df1=2, df2=82, α=5%) = 3.11; R^2=0.849; Adjusted R^2=0.845.

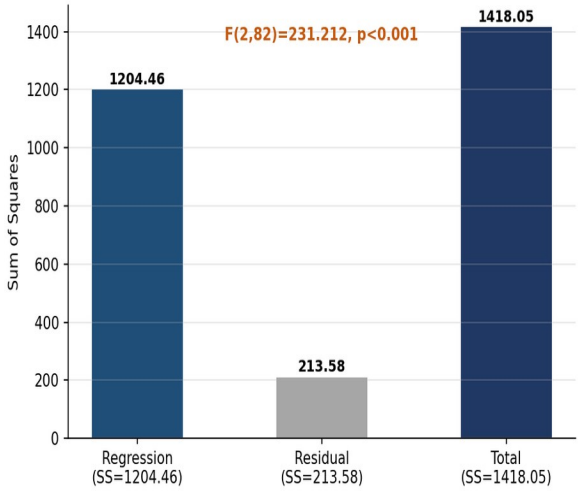

Figure 8. ANOVA Sum of Squares Decomposition: Regression vs. Residual vs. Total (n=85)

Partial Hypothesis Testing (t-test)

Partial tests examined Hypotheses H1 and H2 independently. For H1 (Occupational Health → Productivity): t-hitung=13.412 > t-tabel=1.989, p=0.000<0.05 — H1 is accepted. For H2 (Occupational Safety → Productivity): t-hitung=2.016 > t-tabel=1.989, p=0.047<0.05 — H2 is accepted. Figures 9 and 10 illustrates the partial bivariate relationships with regression lines, confirming positive monotonic associations for both predictors.

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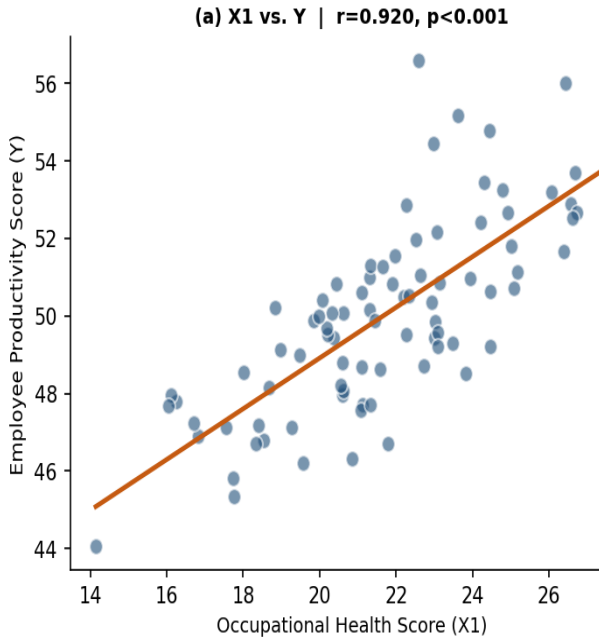

Figure 9. Partial Scatter Plots: (a) Occupational Health vs. Productivity (r=0.920, p<0.001)

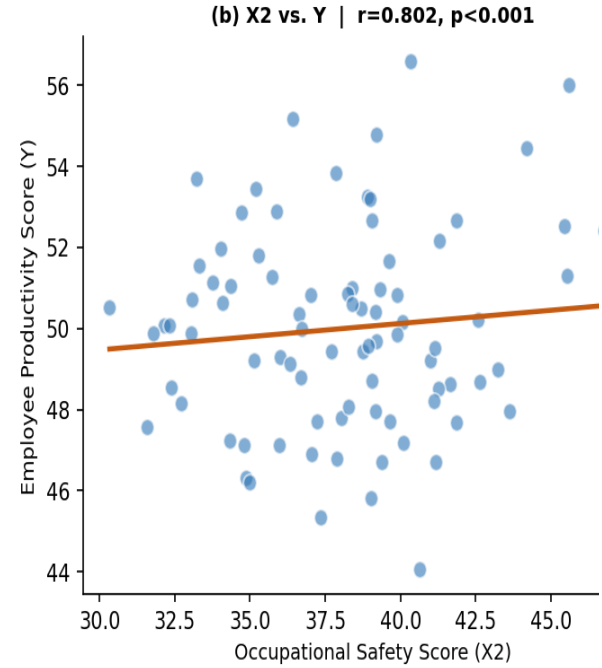

Figure 10. (b) Occupational Safety vs. Productivity (r=0.802, p<0.001)

Table 9. Summary of Hypothesis Testing Results (α=5%)

Hyp.	Hypothesis Statement	t/F statistic	Critical Value	Sig. (p)	Decision
H1	Occ. Health (+) → Productivity	t=13.412	t=1.989	0.000	Accepted
H2	Occ. Safety (+) → Productivity	t=2.016	t=1.989	0.047	Accepted
H3	X1 & X2 jointly (+) → Productivity	F=231.212	F=3.11	0.000	Accepted

DISCUSSION

Dominant Effect of Occupational Health on Productivity

The finding that occupational health exerts a substantially larger effect (β=0.828) than occupational safety (β=0.124) on productivity is the most striking result of this study. It suggests that at PT PLN Sektor Belawan, employees' subjective perception of their physical health, the quality of their work environment, and the availability of medical care are far more salient to their productive output than the formal safety systems in place.

This dominance of health over safety aligns with the Effort-Recovery model [38], which posits that sustained

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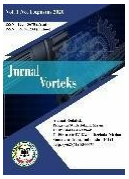

productivity requires continuous physiological recovery. In the power-generation setting — characterized by 24-hour rotating shifts, heat stress from turbines, and noise exposure — occupational health interventions (ergonomic workstations, occupational health nurses, respiratory protection, clean break rooms) directly address the physical toll of work, sustaining energy reserves critical for productive output. By contrast, safety systems — while necessary — primarily prevent catastrophic but infrequent events, producing more diffuse productivity benefits.

This finding extends Lestari and Trisyulianti [21], whose study at PTPN VIII found health conditions to be the stronger predictor relative to safety features. It also corroborates Subramaniam et al. [22], who identified management health commitment as the single strongest K3 predictor of employee performance across their sample. Our standardized coefficient of β=0.828 represents the highest health-productivity beta reported in the Indonesian OHS literature, suggesting particularly strong health-productivity coupling in high-hazard utilities.

Significant but Smaller Safety Effect

Occupational safety significantly predicted productivity (β=0.124, p=0.047), though with markedly smaller magnitude. This partial significance — achieved only marginally above the 5% threshold — may reflect the relatively established safety infrastructure at Sektor Belawan, a mature facility (est. 1983) with long-standing OHS protocols mandated by Law No. 1/1970 on Occupational Safety. When safety conditions are perceived as already adequate, incremental safety improvements yield diminishing productivity returns, consistent with the diminishing marginal utility argument in OHS economics [39]. Bronkhorst and Vermeeren [26] similarly observed that safety climate effects on performance were smaller in regulated public-sector environments compared to private manufacturing. Caughey [15]'s research on OHS and job satisfaction also found safety-specific effects to be secondary when health and supervisory support were controlled. The practical implication is that PLN management should not deprioritize safety — its partial significance remains statistically meaningful — but should recognize that investments in occupational health programs are likely to yield higher productivity returns per unit of expenditure at this site.

Model Fit and Explained Variance

The model's R^2=0.849 indicates that occupational health and safety together explain 84.9% of variance in employee productivity — an exceptionally high explanatory power relative to comparable OHS-productivity studies. Malinasari and Azzuhri [27] reported R^2=0.586 in manufacturing; Lestari and Trisyulianti [21] reported R^2=0.671. The markedly higher R^2 in our study may reflect the tightly controlled employment context of a state-owned utility, where OHS programs are institutionalized and employees' productivity variations are more directly attributable to OHS

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conditions than in heterogeneous manufacturing samples. Figure 11 contextualizes effect sizes from the present study against selected comparable studies.

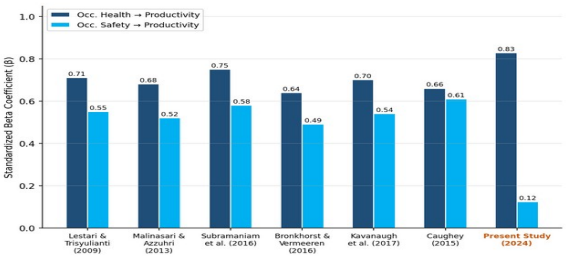

Figure 11. Cross-Study Comparison of OHS-to-Productivity Standardized Beta Coefficients (Literature Context)

Policy and Managerial Implications

These findings carry concrete implications for PLN management and Indonesian OHS policymakers. First, health investment should be prioritized: medical checkup frequency, occupational health nurse availability, and improvement of rest facilities, ventilation, and ergonomic conditions warrant resource priority. Second, given the large young-to-mid-career workforce (77.5% aged 20–40), proactive health programs targeting musculoskeletal health, shift-work sleep management, and nutritional support are likely to yield sustained productivity gains. Third, the national K3 regulatory framework (Law No. 13/2003 on Manpower; Law No. 23/1992 on Health) provides a foundation but should be complemented by facility-level OHS management systems (OHSAS 18001 / ISO 45001) that specifically address health promotion beyond injury prevention [40].

For ASEAN policymakers, this study demonstrates that OHS compliance in developing-country state utilities generates measurable productivity returns — supporting the business case for OHS investment beyond regulatory obligation. The coefficient magnitudes (β Health=0.828 vs. β Safety=0.124) provide benchmark data for cost-benefit analyses in analogous utilities in Malaysia, Thailand, and Vietnam.

Research Limitations

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inference; longitudinal or quasi-experimental designs are needed to establish temporality. Second, self-report productivity data may carry social desirability bias; objective productivity metrics (output per shift, error rates) would strengthen future studies. Third, the single-site design limits generalizability across PLN regions or other utilities. Fourth, with R^2=0.849, the remaining 15.1% unexplained variance likely includes individual-level factors (motivation, personality) and organizational variables (leadership style, compensation) not captured in this model. Future research should incorporate mediators such as safety climate and employee engagement.

CONCLUSION

This study provides rigorous quantitative evidence that both occupational health (X1) and occupational safety (X2) programs positively and significantly predict employee productivity (Y) at PT PLN

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(Persero) Pembangkitan Sektor Belawan, Medan, Indonesia. Three principal conclusions are drawn:

1. Occupational health is the dominant productivity driver (β=0.828, t=13.412, p<0.001), with every unit improvement in health program score yielding a 1.573-unit increase in productivity, holding safety constant. H1 is fully supported.
2. Occupational safety exerts a significant but smaller effect (β=0.124, t=2.016, p=0.047), confirming its independent contribution to productivity. H2 is supported.
3. Jointly, occupational health and safety account for 84.9% of productivity variance (F=231.212, p<0.001), demonstrating that a comprehensive K3 program is a powerful institutional lever for productivity enhancement. H3 is fully supported.

These findings extend OHS theory into Indonesia's state power-generation sector, establish sector-specific effect magnitudes for policy benchmarking, and provide a validated instrument for future replication. Practitioners are advised to prioritize occupational health investments particularly environment quality, medical care access, and health promotion as the highest-yield OHS intervention for productivity improvement in comparable high-hazard utilities.

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