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Quantitative Analysis of The Effect of SMK3 Implementation on Worker Productivity in Bridge Construction Projects in North Maluku, Indonesia

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ABSTRACT
Project construction bridge own risk safety and health high work safety (K3). However, the empirical relationship between the implementation of the Occupational Health and Safety Management System (OHSMS) and workers' productivity in Indonesia, especially in remote infrastructure project areas, has not yet Been Widely researched. This research analyzes the impact of implementing SMK3 on workers' productivity during bridge construction in North Maluku Province. Approach quantitative, with an explanatory design survey used. Data collected from 40 respondents using a 5-point Likert-scale questionnaire were analyzed using multiple linear regression. Five independent variables examined: K3 regulations and procedures (X1), communication workers (X2), competent workers (X3), environmental work (X4), and workers' involvement in K3 (X5). The results of the F test show that the fifth variables are, in a way, simultaneously influential on productivity among workers ($F = 16.443$; $p < 0.05$). The coefficient of determination ($R^2 = 0.574$) indicates that the model explains 57.4% of the variation in productivity. Competence worker become the most dominant factor ($\beta = 0.307$; $t = 3.744$; $p = 0.001$), followed by involvement worker in K3 ($\beta = 0.267$) and the environment work ($\beta = 0.222$).

Keywords: *System K3 Management; Productivity Workers; Project Construction Bridge; Competence Workers; Involvement of Workers.*

1. Introduction

The construction industry is a sector with the highest level of work-related accidents in the world. International Labour Organization data shows that this sector accounts for around 30-40% of fatal work accidents, though it employs only 10% of the global workforce [1]. In Indonesia, data from the Organizing Agency Guarantee Social Employment show that accidents in the construction sector account for the largest share, averaging 32% of total cases per year [2]. The project construction bridge faces greater specific risks, including work at height, use of heavy tools, and work on water bodies. Conditions: This confirms the implementation of urgency, System Management, and Effective Occupational Safety and Health (SMK3).

Accident Work not only causes casualties but also directly impacts the project's productivity. Accident cause loss in the form of cost compensation, damages equipment, delays schedules, and a decline in worker morale [3]. Several studies show that projects with a safety level of Good tend to have higher productivity, higher height, and completion within an appropriate time [4,5]. This shows that investment in K3 is not just an obligation under regulations, but rather a business strategy that provides profit.

A previous study has examined aspects of K3 specifics and their impact on performance construction. Adekunle et al. [6] found a positive correlation between safety commitment and

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productivity in a project. Zara et al. [7] showed that effective communication increases compliance with K3 procedures. Navarro Claro et al. [8] identified that system-structured K3 management increases an organization's overall performance. However, some large studies conducted in developed countries have institutional contexts and power structures different from those in Indonesia. Research that comprehensively tests several factors, implementation of SMK3 in general, simultaneously, and identifies the dominant factor in the context of the project. Indonesian infrastructure, especially in the archipelago region with limited power sources, is still very limited.

The gap study the base studies this. This research aims to analyze the influence of the simultaneous and partial implementation of SMK3 on workers' productivity on a bridge construction project in North Maluku. Contribution: theoretical study. This is a testing of the empirical SMK3 model based on OHSAS 18001 in the context of project infrastructure in remote areas of Eastern Indonesia, which have been overlooked in research. Contribution practically is a priority managerial intervention for contractors operating in the area with limitations; source: Power man trained.

2. Materials and Methods

2.1. Location and Time of Research

Study implemented in the Bridge Construction project Akelamo in West Halmahera Regency, North Maluku Province, which the national contractor carried out during March-October 2023. This project is a bridge steel frame with a 60-meter span and a value of Rp 12.4 billion. The selection location based on three considerations. First, the project has implemented SMK3 formally in accordance with Regulation of the Minister of PUPR Number 10 of 2021. Second, the project has a high technical complexity, including work on foundation poles above the river, installation of a steel frame up to 8 meters high, and the use of heavy ground-contoured equipment. Third, the project aims to condition the project infrastructure in the Eastern Indonesian archipelago, which faces power supply limitations.

2.2. Research Design

This study uses a quantitative approach with an explanatory survey design. This design was chosen because the study aims to test the causal relationship between independent variables (factors) and the implementation of SMK3, and between independent variables and dependent variables (worker productivity), using cross-sectional data. The analysis statistics used are multiple linear regression. Research adopts the framework from OHSAS 18001:2007, which defines SMK3 as a management system for developing K3 policies and managing K3 risks [9].

2.3. Variables Study

Variables independent in the study. This consists of five factors for SMK3 implementation. Table 1 presents the definition of operational and the indicators for every variable.

Table 1. Variables Research and Indicators

Variables	Definition Operational	Key Indicators	Reference
X_1: K3 Regulations & Procedures	Clarity, completeness, and convenience of implementation of the regulation, as well as K3 procedures	Availability of SOP; socialization procedures; convenience understood; suitability condition field; sanctions violation; update periodically	[10]
X_2: Communication Worker	Effectiveness delivery of K3 information between management and workers	Toolbox meeting frequency; clarity instructions; bait come back workers; system reporting danger; communication emergency	[11]

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Variables	Definition Operational	Key Indicators	Reference
X_3: Competence Worker	Knowledge, skills, and attitudes related to K3	Understanding danger ; use of PPE; action emergency ; K3 experience ; certification ; attitude proactive	[12]
X_4: Environment Work	Condition physique place Work, including layout and facilities safety	Cleanliness of work area; lighting; ventilation; availability of PPE; access to emergency; material management	[13]
X_5: Engagement Worker	An active worker in the planning, implementation, and evaluation of K3	Participation in safety meetings; near-miss reporting; hazard identification; suggestions for OHS improvements; safety audits	[14]
Y: Productivity Worker	The output produced workers per unit of time, accounting for quality and efficiency.	Settlement task appropriate time; quality work; efficiency material usage; minimizing rework; working hours productive	[15]

2.4. Population and Sample

The population study of all workers on the Bridge Akelamo project, numbering 67, consists of 18 technical workers (site engineer, supervisor), 12 foremen, and 37 workers. Sampling technique sample using purposive sampling with the following criteria : (1) has work at least 3 months, (2) is directly involved in activity construction, and (3) is willing to become respondents. Based on these criteria, 40 respondents fulfil the participation criteria, comprising 12 technical workers, 8 supervisors, and 20 field workers.

A sample of 40 respondents for 5 variables independent fulfils the minimum ratio of 5:1 suggested by Hair et al. [16] for analysis regression (ratio actual 8:1). For strengthen justification, post-hoc power analysis was performed using G*Power with parameters: $f^2 = 0.30$ (medium-large effect), $\alpha = 0.05$, number of predictors = 5. The results show a statistical power of 0.82, exceeding the minimum threshold of 0.80 [17]. Although the limitations of generalizing from these findings to other projects remain, they need to be acknowledged.

2.5. Instrument Study

Data collected using a structured questionnaire based on study literature and adapted to the context of project construction in Indonesia. The questionnaire uses a 5-point Likert scale (1 = very much agree; 5 = strongly agree) to measure respondents' perceptions of each variable. The number of items per variable ranges from 5 to 6, as shown in Table 1.

2.6. Validity and Reliability

Validity test done using Pearson Product-Moment correlation. Items are declared valid if r- count value > r- table (r- table = 0.312 for $n = 40$, $\alpha = 0.05$) [18]. Reliability testing using Cronbach's Alpha with a criterion instrument is considered reliable if the α value ≥ 0.60 [19]. α value ≥ 0.70 is considered satisfactory for a survey study [16].

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2.7. Data Analysis Methods

2.7.1. Assumption Test Classic

Before the analysis regression, four classic assumption tests were carried out : (1) normality test using Kolmogorov-Smirnov; (2) multicollinearity test using Variance Inflation Factor (VIF) with VIF limits < 10 and Tolerance > 0.1 [20]; (3) heteroscedasticity test using the Glejser test; (4) linearity test using the F test.

2.7.2. Analysis Multiple Linear Regression

A multiple linear regression model is used to analyze the influence of independent variables on the dependent variable:

$$Y = \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \varepsilon$$

where Y = productivity workers ; α = constant ; β_1-β_5 = coefficient regression ; X_1-X_5 = variable independent ; ε = error term.

2.8. Hypothesis Testing

The F test is used to test the influence of an independent variable. The t-test is used to test the influence of every variable. The coefficient of determination (R^2) measures the proportion of the dependent variable's variation explained by the model. All testing uses a level of significance α = 0.05.

3. Results And Discussions

3.1. Characteristics of Respondents

Table 2 presents the complete profile study of 40 respondents.

Table 2. Profile Respondents (n = 40)

Characteristics	Category	Amount	Percentage (%)
Age	20-25 years	12	30.0
	26-30 years old	16	40.0
	31-35 years old	12	30.0
Education	High School/Vocational School	11	27.5
	D3	1	2.5
	S1	28	70.0
Years of service	< 5 years	28	70.0
	5-10 years	8	20.0
	> 10 years	4	10.0
Gender	Man	28	70.0
	Woman	12	30.0
Position	Technical Staff	12	30.0
	Foreman	8	20.0
	Worker Field	20	50.0

The majority of respondents aged 26-30 years (40%) have a bachelor's degree (70%), which reflects the composition of projects that prioritize power technical education. However, 70% of respondents have less than 5 years of work experience. A combination of a good formal education

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and limited field experience. This is relevant to findings research, where K3 competency becomes a dominant factor. The limitations of experience make structured K3 training crucial.

3.2. Validity and Reliability Test Results

Tables 3 and 4 present the validity and reliability test results of the instrument.

Table 3. Validity Test Results Instrument

Variables	Number of Items	Range of r- count	Sig. Value	Information
X_1	6	0.445-0.723	< 0.05	Valid
X_2	5	0.512-0.789	< 0.05	Valid
X_3	5	0.478-0.701	< 0.05	Valid
X_4	5	0.456-0.734	< 0.05	Valid
X_5	5	0.489-0.768	< 0.05	Valid
Y	5	0.412-0.756	< 0.05	Valid

Table 4. Reliability Test Results Instrument

Variables	Cronbach's Alpha	Information
X_1	0.724	Reliable
X_2	0.626	Reliable (sufficient)
X_3	0.678	Reliable (sufficient)
X_4	0.745	Reliable
X_5	0.778	Reliable
Y	0.794	Reliable

All items are valid. The calculated r-value is above the r-table (0.312). The Cronbach's Alpha value ranges from 0.626 to 0.794. The variables X_2 and X_3 have Alpha values below 0.70, indicating that reliability is sufficient, though still above the minimum threshold of 0.60 [19]. This need considered in the interpretation results; testing on larger samples is recommended for the upcoming study.

3.3. Assumption Test Results Classic

Table 5 summarizes the results of the fourth classic assumption test.

Table 5. Summary of Assumption Test Results Classic

Test	Methods/ Statistics	Results	Conclusion
Normality	Kolmogorov-Smirnov	Sig. = 0.124 (> 0.05)	Normal residual
Multicollinearity	VIF (see Table 6)	VIF 1.476-2.427; Tolerance 0.412-0.678	n't any multicollinearity

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Test	Methods/ Statistics	Results	Conclusion
Heteroscedasticity	Glacier Test	Sig. all variable > 0.05	n't any heteroscedasticity
Linearity	F test	F- count > F- table; Sig. < 0.05	Linear relationship

Table 6. Multicollinearity Test Results

Variables	Tolerance	VIF	Information
X_1	0.589	1,698	n't any multicollinearity
X_2	0.412	2,427	n't any multicollinearity
X_3	0.634	1,577	n't any multicollinearity
X_4	0.678	1,476	n't any multicollinearity
X_5	0.523	1,912	n't any multicollinearity

3.4. Analysis Multiple Linear Regression

The multiple linear regression obtained is :

$$\mathbf{Y = -22.941 + 0.181X_1 + 0.180X_2 + 0.307X_3 + 0.222X_4 + 0.267X_5}$$

A constant negative value (-22.941) has no practical meaning because, in real conditions, the value variables are not simultaneously zero. All regression coefficients are positive, indicating that implementing SMK3 improves productivity across all aspects. Competence workers (X_3) have the highest coefficient ($\beta = 0.307$), indicating the biggest impact on productivity.

3.5. Hypothesis Test Results

Table 7. F Test Results (ANOVA)

Model	Sum of Squares	df	Mean Square	F- count	Sig.
Regression	388,967	5	77,793	16,443	0,000
Residual	160,829	34	4,730		
Total	549,796	39			

The F-value is 16.443, with a significance of 0.000 (< 0.05), indicating that the fifth variable is, in a sense, simultaneously influential on productivity. H_1 accepted.

Table 8. Results of the t-Test (Partial)

Variables	Coefficient (β)	Std. Error	t- count	Sig.	Information
Constant	-22,941	5,244	-4,375	0,000	-
X_1: K3 Regulations & Procedures	0.181	0.083	2,177	0.037	Significant
X_2: Communication Worker	0.180	0.084	2,143	0.039	Significant
X_3: Competence Worker	0.307	0.082	3,744	0.001	Significant *

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Variables	Coefficient (β)	Std. Error	t- count	Sig.	Information
X_4: Environment Work	0.222	0.088	2,523	0.017	Significant
X_5: Engagement Worker	0.267	0.086	3,105	0.004	Significant

Note: dominant factor (β coefficient and t- count) highest

The coefficient of determination (R^2) = 0.574 indicates that 57.4% of the variation in workers' productivity is explained by the five variables: implementation of SMK3. The remaining 42.6% is explained by factors outside the model, such as motivation, intrinsic factors, compensatory factors, and other managerial factors.

3.7. Discussion

Findings of the main study. This is competence workers (X_3) as the most dominant factor ($\beta = 0.307$; $t = 3.744$; $p = 0.001$), not communication, as often assumed in construction K3 research. This is a substantive contribution.

Domination competence worker, consistent with human capital theory, states that investment in training increases productivity [21]. In the context project bridge in North Maluku, where 70% of workers own experience Work not enough from 5 years, K3 competency becomes critical. Competent workers can identify danger more quickly, take preventive action, and work more safely and efficiently. These results support the findings of Yu et al. [22], which showed that correlated K3 competencies are strongly associated with performance safety in the project infrastructure.

Involvement workers occupy the second ($\beta = 0.267$). This confirms that participative management theory states that involving workers in decision-making increases commitment and performance [23]. Participation in safety meetings, hazard identification, and near-miss reporting creates a culture of safety that drives every individual toward safety together. Hu et al.'s research [24] on the project construction scale, big support connection.

Environment work (X_4) is in position third ($\beta = 0.222$). Condition physique place fulfilling work K3 standards, such as good housekeeping, adequate lighting, and clear access to emergency exits, creating optimal conditions for workers to concentrate and work efficiently. On the project bridge with work at height and over bodies of water, site layout that takes into account safety, direct impact on efficiency, worker mobilization, and materials [25].

Communication workers (X_2) and regulations, as well as the K3 procedure (X_1), show significant influence ; however, the coefficients are lower ($\beta = 0.180$ and 0.181). This does not mean communication is not important. Communication plays an enabling role for other factors; without effective communication, competence, and engagement , workers cannot develop. However, here communication is not a stand-alone driving force but a main productivity factor, unlike the assumptions common in many studies. Zhao and Li's [26] research also found that effective communication on productivity is mediated by competence.

Findings study. This differs from several previous studies that placed communication or procedure as a dominant factor [7,8]. The difference can be explained by the context-specific nature of this project in a remote area, with relatively young and less experienced workers who need more improvement in competence than in formal repair system communication. Interpretation: This need was tested more with multiple case studies.

4. Conclusions

This study provides empirical evidence that SMK3 implementation significantly increases workers' productivity during bridge construction. The fifth SMK3 factor, studied simultaneously, explain 57.4% of the variation in productivity ($R^2 = 0.574$; $F = 16.443$; $p < 0.05$). In general, partial competence workers become the most dominant factor ($\beta = 0.307$), followed by involvement workers ($\beta = 0.267$), environment workers ($\beta = 0.222$), K3 regulations and procedures ($\beta = 0.181$), and communication workers ($\beta = 0.180$). Findings: This challenge assumptions general that

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communication is a major factor in system K3 management. In the context of project infrastructure in remote areas of Eastern Indonesia, with young, less experienced workers, competence becomes key.

Management project construction needs to prioritize three things: (1) investment in training and certification programs for sustainable worker K3 competency ; (2) building a mechanism for participation of real workers through the safety committee and system near-miss reporting; and (3) ensuring a standard environment Work physique fulfilled through routine inspection. Research the upcoming need, use a longitudinal design with measurement of greater productivity objectives based on actual output data, and expand the sample to various project infrastructures to increase the generalizability of findings.

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