



Occupational Safety Management Barriers on the Usilimo–Karubaga Road Preservation Project in Highland Papua

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Abstract

Background: Remote road preservation work combines construction hazards with difficult terrain and limited access, complicating consistent occupational safety management.

Objective: To assess reported and observed *Sistem Manajemen Keselamatan dan Kesehatan Kerja* (SMK3; Occupational Safety and Health Management System) practices against the 166-criterion framework, rank perceived barriers, and formulate project-specific improvements for the Usilimo–Karubaga corridor in Highland Papua.

Methods: A descriptive mixed-methods case study combined observation, document review, an 18-item, five-point Likert-scale questionnaire involving 34 personnel, and structured interviews with 30 informants. Item-total correlations, Cronbach's alpha, descriptive rankings, and an exploratory one-sample *t*-test were integrated with qualitative evidence.

Results: The overall perceived-barrier mean was 2.97, within the moderate interval of 2.61–3.40; it was not a regulatory compliance score. Item-total correlations exceeded 0.339, and Cronbach's alpha was 0.829. The leading barriers were PPE awareness and formal training (both 3.18), PPE availability (3.15), and vigilance and supervision (both 3.12). The reported *t*-test did not distinguish the mean from the neutral value of 3.00. Interview accounts linked these obstacles to transportation difficulties, weather, terrain, and uneven supervisory reach. A complete criterion-level audit score was not reported.

Conclusion: The evidence supports coordinated PPE reserves, structured training, risk-based supervision, emergency preparedness, and locally adapted safety communication. These case-specific proposals require prospective evaluation; their effectiveness and wider applicability have not been established.

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INTRODUCTION

Construction work exposes personnel to changing weather conditions, temporary work fronts, heavy equipment, and physically demanding tasks (Baek & Choi, 2026; Karthick et al., 2021; Nilsson et al., 2026). The International Labour Organization (2023) identifies construction as one of the sectors with substantial exposure to fatal occupational injuries. Road preservation activities introduce additional hazards, including moving traffic, earthworks, unstable ground, and dispersed work locations. These interacting hazards make consistent field-level control essential (Umeokafor et al., 2023; Yap et al., 2022). Along the Usilimo–Karubaga corridor, rainfall, steep slopes, and difficult access further complicate the delivery of personal protective equipment

(PPE), supervision, and emergency support. The practical challenge, therefore, is to understand how an established safety management system operates across remote work fronts.

In Indonesia, *Sistem Manajemen Keselamatan dan Kesehatan Kerja* (SMK3), or the Occupational Safety and Health Management System, is positioned as an integrated management mechanism for controlling work-related risks and creating safe, efficient, and productive workplaces ([Peraturan Pemerintah Republik Indonesia Nomor 50 Tahun 2012](#); [Undang-Undang Republik Indonesia Nomor 13 Tahun 2003](#)). Government Regulation No. 50 of 2012 provides the national framework for SMK3 implementation and establishes three assessment levels comprising 64 initial criteria, 122 transitional criteria, and 166 advanced criteria. The source study adopted the advanced assessment level because the project was classified as a large, high-risk construction activity. Despite this comprehensive regulatory framework, evidence from construction projects across Indonesia indicates that formal SMK3 compliance does not always align with actual field practices, particularly on projects located far from urban administrative centers ([Kadir et al., 2022](#)).

SMK3 can be understood as a management system that integrates safety policy, planning, responsibilities, procedures, implementation, monitoring, evaluation, and continual improvement into routine organizational activities ([J. EL- Matury et al., 2025](#)). Its practical objective extends beyond PPE use to establishing a systematic process for identifying hazards, controlling risks, monitoring performance, learning from incidents, and improving working conditions ([Kunodzia et al., 2024](#)).

The source study identifies unsafe acts and unsafe conditions as important immediate contributors to workplace accidents and applies the logic of management control to explain the need for preventive systems. In construction, examples include inadequate PPE use, fatigue, insufficient concentration, poor housekeeping, slippery work areas, unsuitable equipment, inadequate warning systems, and insufficient supervision. These factors have been associated with unsafe worker behavior in recent structural equation modeling research involving frontline construction workers ([Li et al., 2024](#)).

The 166-criterion advanced SMK3 framework applied to this project covers management commitment and policy, documentation, contract review, document control, improvement, safe work practices, monitoring standards, reporting and corrective action, the management of materials and services, SMK3 auditing, and competency development. Even when such a comprehensive framework is in place, regulatory and institutional weaknesses can constrain its practical implementation, particularly in developing-country contexts where technological, organizational, and governance barriers interact ([Yap et al., 2022](#)). Similar constraints on occupational health and safety management system (OHSMS) implementation have also been documented on other Indonesian infrastructure projects located outside major urban centers ([Ahadian et al., 2021](#)).

The study groups potential barriers into four dimensions: human, management, technical, and environmental. Human factors include PPE awareness, safety knowledge, vigilance, concentration, and training attendance. Management factors include budgeting, training provision, supervision, enforcement, incident reporting, and health, safety, and environment (HSE) staffing. Technical and environmental factors concern PPE availability, equipment and material arrangement, and worksite conditions. These dimensions organize the 18 questionnaire items; they are analytical categories rather than independently validated latent constructs. Indonesian safety-climate research likewise highlights the interaction of training, communication, working conditions, and organizational priorities ([Lestari et al., 2020](#)). Comparable groupings of safety-management barriers are discussed by ([Abu Aisheh et al., 2021](#); [Vigneshkumar & Saravanamuthu, 2021](#)).

The Usilimo–Karubaga corridor presents a distinctive safety management context characterized by heavy rainfall, muddy terrain, steep slopes, unstable ground, difficult land transportation, and dispersed work fronts. Research on infrastructure in Papua describes geographical and accessibility constraints Fauzi et al. (2019), while research in Ternate identifies constraints on OHSMS implementation in another Indonesian setting ([Ahadian et al., 2021](#)). These sources provide contextual comparisons rather than direct measurements of conditions on the

present project. In this case, wet terrain can accelerate PPE deterioration, while transportation disruptions can delay the delivery of replacement equipment. Geographical distance can also limit supervisory coverage and access to emergency services. Consequently, PPE awareness and supervision cannot be interpreted independently of the availability and accessibility of safety controls.

Previous studies of SMK3 and construction safety have examined toll-road projects Marthinus (2019), railway construction Hapsari & Wiriyanto (2022), hotel construction Imani et al. (2021), and river-mouth protection works (Yunanto, 2021). Comparative evidence from Sumatra further broadens the range of project settings examined (J. EL- Matury et al., 2025). However, findings from these settings do not establish how the same barriers operate along the Usilimo–Karubaga highland corridor. Safety-climate research has already combined quantitative and qualitative evidence (Lestari et al., 2020); therefore, the use of mixed methods alone is not claimed as a novel contribution. The more specific research gap concerns the project-level explanation of how perceived barriers intersect with terrain, transportation, and supervision constraints in road preservation activities in Highland Papua.

This study contributes a context-specific account of SMK3 barriers on the Usilimo–Karubaga Road Preservation Project by interpreting responses to an 18-item questionnaire alongside field observations, document reviews, and interviews with HSE officers, site managers and project implementers, foremen, and workers. The 166 advanced criteria provide the regulatory assessment framework. The study's contribution lies in connecting perceived human and organizational barriers with the practical delivery of safety controls under highland conditions, rather than introducing a new compliance standard or establishing a causal model.

Accordingly, the study examines how SMK3 practices operate on this project, which perceived barriers receive the highest ratings, and which improvement measures can be derived from the combined evidence. The resulting recommendations are specific to this case and may inform comparisons with other remote projects; however, their effectiveness requires subsequent evaluation.

The objectives are to assess reported and observed SMK3 practices with reference to the 166 advanced criteria; rank perceived barriers using the 18-item questionnaire; and formulate context-sensitive improvement strategies through questionnaire–interview triangulation. Because criterion-level audit totals are not reported, the study does not calculate a regulatory compliance percentage or assign a formal audit achievement category.

The study illustrates how worker behavior, organizational provision, and access conditions can jointly constrain safety controls on a remote road preservation project. For project management, the findings identify priorities for PPE reserves, formal training, and supervisory coverage. For regulators and researchers, the study provides a bounded case for examining the implementation of SMK3 requirements under difficult geographical conditions. Applying the findings to other projects requires comparisons of workforce characteristics, logistical arrangements, and risk exposure.

METHOD

The study employed a descriptive mixed-methods case study design focusing on the Usilimo–Karubaga Road Preservation Project in Tolikara Regency, Highland Papua. Questionnaires were used to quantify perceived barriers, while field observations, document reviews, and structured interviews were conducted to explain how these barriers arose in practice. This combination was appropriate because barrier scores alone cannot distinguish between worker behavior, resource unavailability, and restricted site access. Integration occurred at the interpretation stage, where highly ranked questionnaire items were compared with interview accounts and observation notes, including areas of agreement and divergence, to develop recommendations. The design does not establish causal effects.

The questionnaire was administered to 34 project personnel and comprised 18 statements rated on a five-point Likert scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*), with higher scores indicating stronger perceived barriers. The original sample-size calculation used Slovin's formula with a 15% margin of error. This represents a coarse planning

assumption rather than evidence of statistical representativeness, as the population size, sampling frame, and selection probabilities were not reported. Accordingly, the sample is treated as project-specific and exploratory. Interviews involved 30 informants: two health, safety, and environment (HSE) officers, three site managers or project implementers, five foremen, and 20 field workers. The extent of overlap between questionnaire respondents and interview participants was not specified. The questionnaire items operationalized the human, management, technical, and environmental dimensions through the barriers listed in Table 3. The available documentation does not establish whether the items were derived systematically, reviewed by experts, or pilot-tested; therefore, these development procedures are not claimed. The reported correlation and reliability tests assess item associations and internal consistency within the sample.

Field observations and document reviews were used to compare site practices with the 166 criteria of the advanced Occupational Safety and Health Management System (*Sistem Manajemen Keselamatan dan Kesehatan Kerja*, SMK3). The checklist included the assessment criteria, supporting documents, scores, and compliance notes. However, the manuscript does not report criterion-level compliance counts or a complete audit score. Consequently, the regulatory framework supports a qualitative appraisal of implementation, whereas the questionnaire measures perceived barriers; these two measures are not interchangeable.

Item means and the overall questionnaire mean were used to rank perceived barriers. Scores were classified as follows: 1.00–1.80, very low; 1.81–2.60, low; 2.61–3.40, moderate; 3.41–4.20, high; and 4.21–5.00, very high. Pearson item–total correlations were used to assess item associations, while Cronbach’s alpha was used to assess internal consistency. Neither measure, by itself, establishes regulatory compliance or construct validity. An exploratory one-sample *t*-test compared the respondent-level overall mean with the neutral Likert-scale value of 3.00, which served as a reference point rather than a regulatory threshold for satisfactory performance. The test assumes independent respondent-level scores and an approximately normal sampling distribution of the mean; however, diagnostic results are unavailable. Interview evidence was condensed and organized by barrier dimension and stakeholder account, then compared with the quantitative rankings through data presentation and conclusion verification. Convergent and divergent accounts informed the identification of improvement priorities.

RESULTS AND DISCUSSION

Results

Respondent Profile

Table 1

Sociodemographic Distribution of Respondents (n = 34)

Characteristic	Category	n	%
Gender	Male	24	70.6
	Female	10	29.4
Age	<30 years	6	17.6
	30–39 years	14	41.2
	40–49 years	10	29.4
	≥50 years	4	11.8
Position	Field worker	18	52.9
	Heavy-equipment operator	5	14.7
	Foreman	4	11.8
	Site manager/project implementer	3	8.8
	Project administrator	2	5.9
	HSE officer	2	5.9

Table 1 presents the sex, age group, and position of the 34 questionnaire respondents, providing demographic context for interpreting the barrier rankings reported in the following

subsections.

The questionnaire sample was dominated by field workers, reflecting the labor structure of road construction. The age distribution was concentrated in the 30–39-year age group. These characteristics provide a practical perspective on day-to-day safety implementation rather than focusing solely on managerial compliance.

Instrument Validity and Reliability

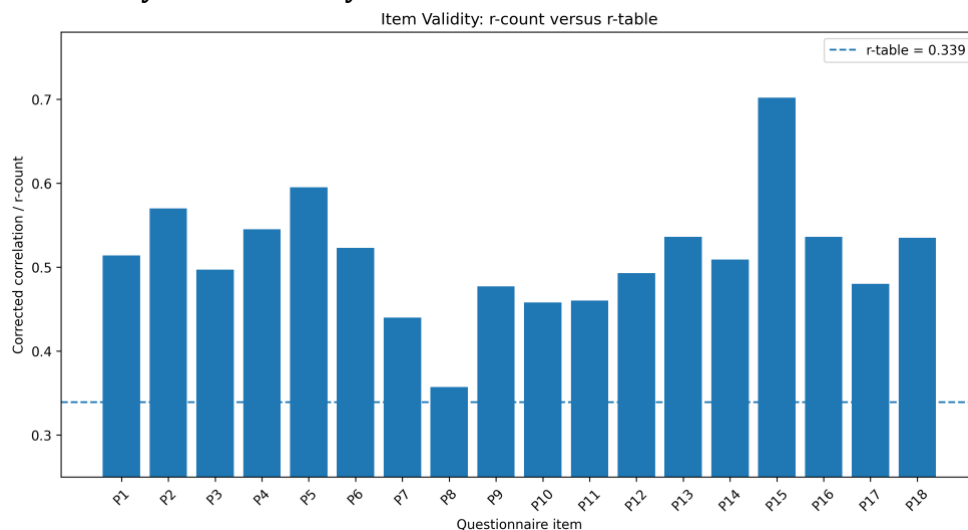


Figure 1. Item validity results (r-count) for the 18 barrier statements compared with the r-table criterion of 0.339.

Figure 1 plots the item–total correlation coefficient for each of the 18 barrier statements against the reported critical r-value of 0.339. All items exceeded this threshold. The item–total correlation results show that all 18 items exceeded the reported critical r-value of 0.339. The lowest coefficient was recorded for P8 (0.357), whereas the highest was recorded for P15 (0.702). Cronbach’s alpha was 0.829, indicating good internal consistency among the 18 items. These results support the use of the questionnaire for descriptive barrier ranking within this project-specific sample. However, item–total correlations and internal consistency alone do not establish broader construct validity.

Table 2

Summary of Item Validity and Reliability Test Results

Statistic	Result	Interpretation
Number of questionnaire items	18	All items tested
Sample size	34	Complete cases
r-table	0.339	5% significance level
r-count range	0.357–0.702	All items > r-table
Cronbach’s alpha	0.829	Very high reliability

Table 2 summarizes the key psychometric indicators of the 18-item barrier questionnaire, including the number of items tested, sample size, critical r-value, observed item–total correlation range, and overall Cronbach’s alpha coefficient.

All 18 questionnaire statements met the reported item–total correlation criterion. Item–total correlations ranged from 0.357 to 0.702, with each coefficient exceeding the critical r-value of 0.339. Cronbach’s alpha was 0.829, indicating good internal consistency among the items.

Main Barriers to SMK3 Implementation

The ranking of the 18 items shows a concentrated pattern involving worker awareness, training, PPE provision, vigilance, and supervision. The highest mean scores were recorded for insufficient worker awareness of PPE use (P1 = 3.18) and insufficient company-provided safety

training (P7 = 3.18), which were tied for first place. These were followed by insufficient PPE availability (P16 = 3.15), insufficient worker vigilance (P3 = 3.12), and insufficient OSH supervision (P8 = 3.12). All five items fell within the moderate-barrier category and had mean scores above the overall mean of 2.97. This pattern indicates that the most prominent perceived weaknesses were not confined to a single dimension of SMK3 but spanned worker behavior, organizational training, resources, and field-level controls.

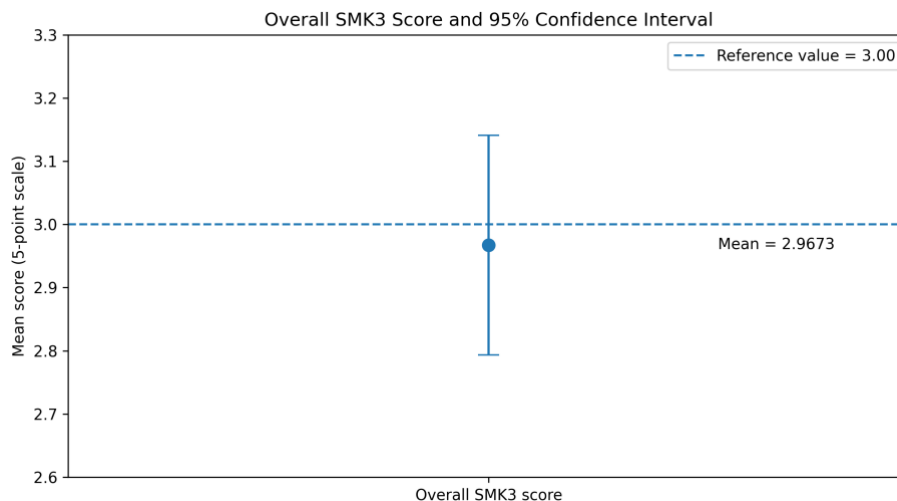


Figure 2. Overall perceived-barrier mean and the reported 95% confidence interval relative to the neutral reference value of 3.00

Figure 2 presents the overall questionnaire mean and its 95% confidence interval, illustrating that the interval includes the reference value of 3.00 used in the one-sample test.

The overall perceived-barrier mean was 2.9673 (SD = 0.4982; n = 34), placing it within the moderate-barrier interval of 2.61–3.40. The reported one-sample test yielded $t(33) = -0.382$, with a two-tailed p-value of approximately .705 and a right-tailed p-value of approximately .648. The null hypothesis was not rejected. Thus, the evidence does not demonstrate a statistically significant departure from the reference value of 3.00; however, it does not establish statistical equivalence, satisfactory SMK3 performance, or a regulatory compliance rating. Because higher questionnaire scores represent stronger perceived barriers, the mean cannot be interpreted as a measure of implementation achievement.

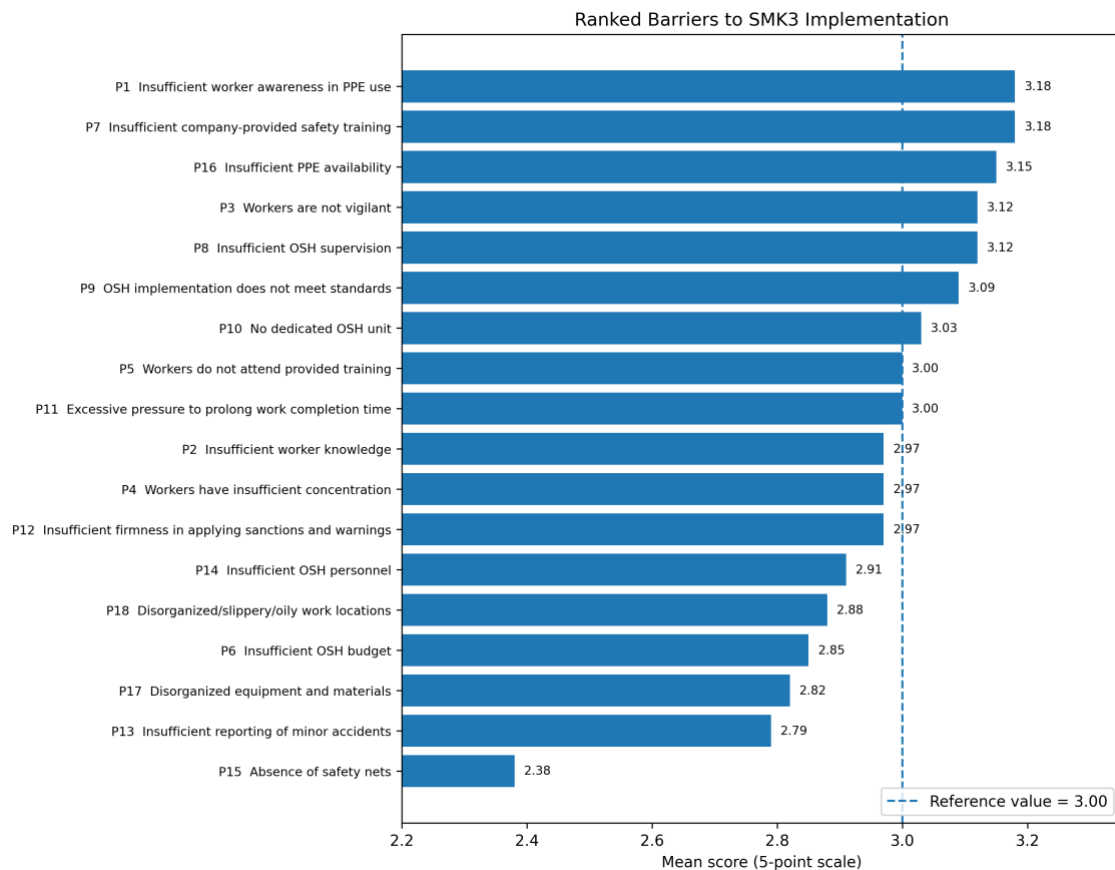


Figure 3. Ranked mean scores of all 18 questionnaire barriers; the dashed line marks the study reference value of 3.00

Figure 3 orders the 18 barrier items from the highest to the lowest mean score, visually highlighting the five items with the highest mean scores relative to the reference value of 3.00.

Table 3

Ranking of SMK3 Implementation Barriers Based on Mean Scores (n = 34)

Rank	Code	Barrier	Mean	Category
1	P1	Insufficient worker awareness in PPE use	3.18	Moderate
2	P7	Insufficient company-provided safety training	3.18	Moderate
3	P16	Insufficient PPE availability	3.15	Moderate
4	P3	Insufficient worker vigilance	3.12	Moderate
5	P8	Insufficient K3/OSH supervision	3.12	Moderate
6	P9	K3 implementation not fully aligned with standards	3.09	Moderate
7	P10	No dedicated K3 unit	3.03	Moderate
8	P5	Workers do not attend available training	3.00	Moderate
9	P11	Excessive time pressure to complete work	3.00	Moderate
10	P2	Insufficient worker knowledge	2.97	Moderate
11	P4	Insufficient worker concentration	2.97	Moderate
12	P12	Weak enforcement of sanctions/warnings	2.97	Moderate
13	P14	Insufficient K3 personnel	2.91	Moderate
14	P18	Disorganized/slippery/oily work locations	2.88	Moderate
15	P6	Insufficient K3 budget	2.85	Moderate
16	P17	Disorganized equipment/materials	2.82	Moderate
17	P13	Insufficient minor-accident reporting	2.79	Moderate
18	P15	Absence of safety nets	2.38	Low

Table 3 lists all 18 questionnaire items in descending order of mean score, together with their corresponding barrier categories. The five highest-ranked items—worker awareness of PPE use, company-provided safety training, PPE availability, worker vigilance, and OSH supervision—represent the most prominent perceived barriers to SMK3 implementation in this project. In contrast, the absence of safety nets was the lowest-ranked item and the only barrier classified in the low category.

Exploratory One-Sample Test

The exploratory right-tailed test evaluated $H_0: \mu \leq 3.00$ against $H_1: \mu > 3.00$, where μ denotes the population mean perceived-barrier score. With $n = 34$, a sample mean of 2.9673, an SD of 0.4982, and 33 degrees of freedom, the reported t-value was -0.382 , below the one-tailed critical value of 1.692 at $\alpha = .05$. The right-tailed p-value was approximately .648, so the null hypothesis was not rejected. This test examines perceived barrier intensity relative to the neutral reference value; it does not assess whether implementation satisfies all 166 regulatory criteria. Given the small, project-specific sample and the absence of reported diagnostic checks for the test assumptions, descriptive rankings and triangulation provide the primary basis for interpretation.

Qualitative Findings and Triangulation

Interview findings indicate that the project has a formal, multilayered safety management structure. HSE officers described management responsibilities, Stop Work Authority, pre-work hazard analysis, induction, incident response, daily and weekly inspections, and monthly internal audits. Site managers and foremen described direct field supervision and daily toolbox meetings. The qualitative evidence therefore indicates that formal safety mechanisms are in place, although their reach and intensity vary across the long and challenging work corridor.

The strongest contextual explanation concerns PPE. Informants consistently described delays in transporting PPE along the Jayapura–Wamena–Tolikara route and the rapid deterioration of boots and gloves under muddy, wet, and rocky conditions. Accordingly, the quantitative finding of inadequate PPE availability should not be interpreted solely as worker noncompliance; it also reflects structural supply-chain constraints.

Triangulation also revealed partial divergence between the quantitative and qualitative findings concerning training and supervision. Daily safety talks, toolbox meetings, induction, and multilayered inspections were reported as routine practices. However, respondents appeared to associate “training” primarily with formal, scheduled programs rather than daily briefings. Supervision was also perceived as insufficient at remote work locations because of the project’s extensive geographic coverage and difficult terrain.

Discussion

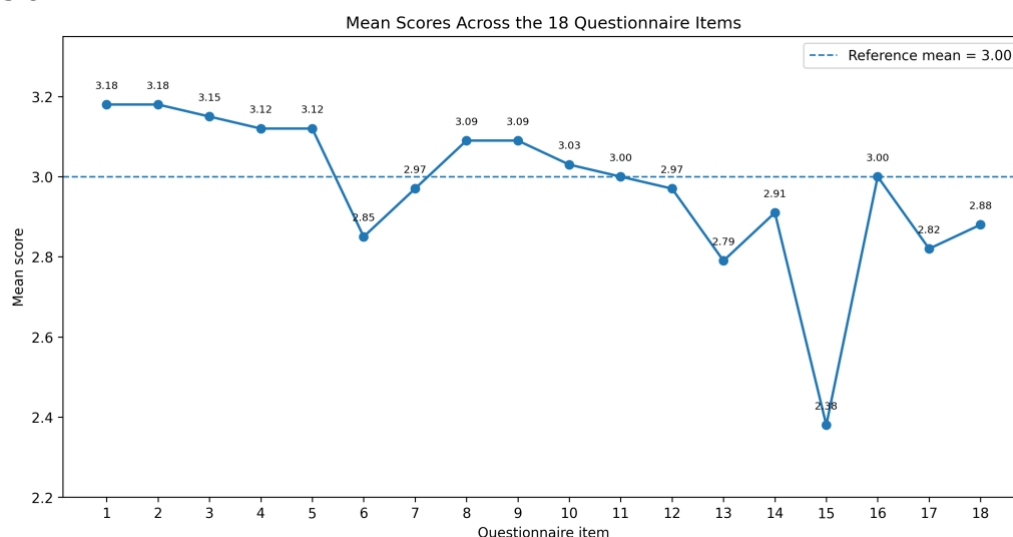


Figure 4. Mean scores of the 18 SMK3 barrier items shown in questionnaire order (P1-P18), with the reference line at 3.00.

Figure 4 complements Figure 3 by presenting the same 18 barrier items in their original questionnaire sequence rather than in ranked order. This presentation allows each barrier code discussed in the following subsections to be traced directly to its position in the questionnaire.

Implementation Is Present but Not Yet Optimal

The quantitative and qualitative evidence addresses different aspects of safety management. A mean score of 2.97 indicates a moderate level of perceived barriers, whereas interview accounts describe induction, toolbox meetings, inspections, internal audits, hazard analysis, and Stop Work Authority. The coexistence of these arrangements and perceived obstacles suggests uneven implementation of controls rather than a demonstrated failure to meet a predefined performance threshold. Indonesian safety-climate research also identifies tensions among formal commitment, resource availability, and field practices ([Kadir et al., 2022](#)). In this case, limitations in training and supervision may reduce hazard recognition, while terrain and supply interruptions may prevent workers from acting safely even when they recognize a hazard. These are plausible interacting mechanisms supported by triangulation, not statistically tested causal pathways.

This distinction is important for remote construction projects. A safety management system may be formally established while its practical effectiveness remains constrained by logistics, weather, distance, terrain, and worker adaptation. The interviews support this interpretation: management commitment and social cooperation were identified as strengths, whereas extreme weather, steep terrain, unstable soil, and transport interruptions were repeatedly identified as constraints.

PPE as a Socio-Technical Issue

PPE availability and PPE use require separate but coordinated responses. Internally, management controls procurement planning, reserve stocks, replacement procedures, training, and enforcement. Externally, difficult transport conditions and wet, muddy, and rocky terrain can delay resupply and shorten the service life of equipment. The questionnaire identifies perceived deficiencies in worker awareness of PPE use (P1 = 3.18) and PPE availability (P16 = 3.15) as priorities, but it does not quantify the contribution of either mechanism. Interview reports of transport delays and equipment deterioration provide contextual explanations. Research on PPE noncompliance identifies supervision, training, risk perception, and management support as relevant factors ([Ammad et al., 2021](#); [Jalil Al-Bayati et al., 2023](#)). Accordingly, instructions to wear PPE should be accompanied by the provision of suitable equipment and timely replacement rather than treating shortages as worker misconduct.

Training and Supervision Need Greater Formalization and Reach

Training (P7 = 3.18) and supervision (P8 = 3.12) warrant coordinated improvement. Daily briefings provide frequent contact with workers but may not offer the practical exercises and assessment associated with formal training. Rantsatsi ([2025](#)) emphasizes the design of induction programs, while Rantsatsi ([2025](#)) connect training with learning and instructional principles. Sankar et al. ([2024](#)) relate safety leadership to dimensions of safety climate. For dispersed work fronts, brief task-based demonstrations, refresher sessions, and risk-based inspection zones are feasible proposals because they connect learning with actual hazards and allocate oversight according to exposure. Their benefits depend on accessibility, HSE staffing availability, and follow-through on corrective actions. Effectiveness was not tested in this study and should be assessed through training completion, observed task performance, inspection coverage, and corrective-action closure rather than inferred from attendance alone.

Local Context Should Be Incorporated into Safety Education

The remote and environmentally demanding setting means that safety communication cannot be separated from local working conditions. The project's steep terrain, unstable ground, rainfall, long transport routes, and dispersed work locations can affect how safety controls are

understood and applied. Research on frontline construction workers also indicates that objective working conditions and safety management jointly shape unsafe behavior, reinforcing the importance of considering environmental and organizational conditions together (Li et al., 2024). Local adaptation should therefore involve practical demonstrations, visual materials, language that workers understand, scenario-based instruction, and supervisors who can translate formal SMK3 requirements into task-specific actions. The objective is not to lower the SMK3 standard but to improve its usability and consistent application under the project's actual environmental and social conditions.

Recommended Improvement Framework

Table 4

Recommended Improvement Framework for SMK3 Implementation

Priority	Problem	Recommended action	Expected result
1	PPE awareness and availability	Maintain weather-resistant reserve PPE; conduct routine PPE checks; reinforce compliance through HSE supervision.	Higher PPE availability and compliance.
2	Formal training	Implement scheduled monthly training and refresher sessions in addition to daily briefings.	More consistent worker competence and safety awareness.
3	Supervision reach	Divide the corridor into risk-based supervision zones and increase inspection frequency at high-risk points.	Broader and more consistent field oversight.
4	Worker vigilance	Strengthen daily toolbox meetings using practical hazard examples and locally adapted communication.	Improved hazard recognition and attention.
5	Emergency preparedness	Improve emergency facilities, slope protection, shelter, and disaster-response training.	Faster response to incidents and environmental hazards.

Table 4 translates the leading perceived barriers and contextual interview findings into proposed actions and expected outcomes. These outcomes are prospective; the study did not implement or evaluate the proposed interventions.

Reserve PPE logistics, scheduled training, risk-based supervision, locally adapted communication, and emergency preparedness address interconnected weaknesses identified through triangulation. Management should review stock levels and access constraints together, link training to observed tasks, and use inspection records to follow up on unresolved hazards. A proposed monthly training schedule is a planning option rather than a frequency demonstrated to be effective by this study.

Table 5

Evidence-Based Monitoring Framework Linking Barriers to Recommended Actions and Indicators

Priority	Evidence from study	Recommended action	Monitoring indicator
1. PPE	P1 = 3.18; P16 = 3.15	Reserve stock, weather-resistant PPE, scheduled replacement	Proposed: serviceable PPE units available / units required; compliant PPE observations / total observations;

2. Training	P7 = 3.18; P5 = 3.00	Formal induction/refresher calendar and task-based modules	record stockouts and replacement delays. Proposed: personnel completing scheduled modules / personnel due; personnel passing task demonstrations / personnel assessed.
3. Supervision	P8 = 3.12; P9 = 3.09	Risk-zone supervision and escalation rules	Proposed: inspections completed / inspections planned by risk zone; corrective actions closed by due date / actions due.
4. Worker vigilance	P3 = 3.12	Pre-task hazard checks and behavior reinforcement	Proposed: safe task observations / total task observations; record repeat unsafe practices by work front.
5. Environment	P17 = 2.82; P18 = 2.88	Housekeeping, drainage, slope and access controls	Proposed: environmental hazards closed by due date / hazards due; record access interruptions and overdue hazards.

Table 5 presents proposed monitoring measures rather than additional research findings. Each indicator requires a defined numerator, denominator or time basis, responsible recorder, and consistent review period. Project management should establish baselines and risk-based targets before using these indicators. No target attainment or improvement effect is claimed.

Limitations and future research

This single-project assessment relies on a small questionnaire sample and interview accounts. Information on sampling probabilities, respondent overlap, instrument-development records, and complete criterion-level audit totals was unavailable. The cross-sectional evidence cannot establish causation or intervention effects. Comparative studies across highland and lowland projects, together with longitudinal monitoring of PPE supply, task competence, supervisory coverage, and hazard closure, should test the transferability of the proposed actions.

CONCLUSIONS

This case study identifies a gap between reported formal SMK3 arrangements and consistent field-level implementation on the Usilimo–Karubaga Road Preservation Project. The mean score of 2.97 represents a moderate level of perceived barriers, not an audit-based achievement score. Worker awareness of PPE use, company-provided training, PPE availability, worker vigilance, and supervision received the highest ratings. The evidence supports prioritizing

these issues but does not establish a regulatory compliance category or causal relationships.

The study's contribution is a contextual explanation of how human and organizational barriers coincide with logistical difficulties, rainfall, and unstable terrain in a remote road-preservation setting. PPE reserves, structured training, risk-based supervision, and locally adapted communication should be considered together. These recommendations are grounded in the reported project evidence, but their effectiveness remains untested.

The conclusions are limited to one project, 34 questionnaire respondents, and 30 interview informants. Future studies should compare infrastructure projects with different geographical and access conditions, report complete criterion-level audit results, and evaluate proposed actions over time using observed safety practices and incident or near-miss records. Such designs can test the transferability of the recommendations and their intervention effects beyond this descriptive case study.

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AUTHOR CONTRIBUTION STATEMENT

James Thoengsal contributed to conceptualization, methodology design, data analysis, and drafting of the original manuscript. Yudith Helene Mustakim contributed to data curation, field observation, and review and editing of the manuscript. Duberto Sarina contributed to supervision, validation of the analytical approach, and final approval of the manuscript for submission. All authors have read and approved the final version of the manuscript and take public responsibility for its content.

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