International Journal of Innovation Engineering and Science Research

Open Access

Enhancing Product Quality through Preventive and Protective Occupational Health and Safety Strategies in Indonesian Micro, Small, and Medium Enterprises (MSMEs)

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ABSTRACT

This study explores how integrating macroergonomic approaches with preventive occupational health and safety (OHS) strategies can significantly improve product quality in Micro, Small, and Medium Enterprises (MSMEs). Using a combination of Safety Integrity Level (SIL) assessments and the Macroergonomic Analysis and Design (MEAD) framework, data were collected from three MSMEs in the food processing, metal, and woodcraft industries. Methods included observation, surveys, and interviews. The results demonstrate a substantial decrease in defective products—ranging from 33% to 52%—after implementing basic OHS improvements such as personal protective equipment (PPE), standard operating procedures (SOPs), and safety training. The study reveals a strong negative correlation (r = -0.89) between OHS implementation scores and product defects, highlighting OHS as a dual-function strategy for safety and quality enhancement. These findings support the broader adoption of macroergonomic OHS frameworks to ensure workplace safety and improve product quality in MSMEs.

Keywords*—macroergonomics; occupational health and safety (OHS); micro, small, and medium enterprises (MSMEs); product quality; safety integrity level (SIL)(key words)*

I. Introduction

Micro, Small, and Medium Enterprises (MSMEs) play a pivotal role in the socioeconomic landscape of emerging economies. In Indonesia, they contribute to more than 60% of the GDP and absorb over 97% of the total workforce (Farisi et al., 2022; Undari&Lubis, 2021). Despite their vast potential, the productivity and product quality of MSMEs often remain suboptimal due to neglect in occupational health and safety (OHS) management (Rugulies et al., 2019; Seftyadi& Hakim, 2021).

In many MSMEs, safety is perceived merely as a regulatory burden rather than an integrated system that enhances operational quality (Purba&Sukwika, 2021). Numerous studies have demonstrated that unsafe working conditions and lack of preventive measures are directly correlated with workplace injuries, lost productivity, and defective products (Putra et al., 2021; Soesilo, 2023). Particularly in informal sectors, accidents are underreported, and risk mitigation is reactive rather than systemic (Monoarfa&Bahri, 2022). This is compounded by the fact that most MSMEs operate without formal safety documentation, structured training, or standard operating procedures (SOPs) (Rodrigues et al., 2019; Rahayuningsih&Pradana, 2022).

In this context, integrating preventive and protective safety models is imperative. The Safety Integrity Level (SIL), as outlined by IEC 61508, offers a structured method for evaluating safety functions based on risk reduction needs (Kosmowski et al., 2022; Mahmoudi, 2021). However, SIL has traditionally been applied in high-risk, capital-intensive industries and remains underutilized in MSMEs. Adapting such frameworks to small-scale enterprises requires simplification and contextualization—particularly through macroergonomic principles (Waterson et al., 2022).

Macroergonomics, especially through the Macroergonomic Analysis and Design (MEAD) framework, offers a participatory and systemic method for redesigning work environments (Soejanto, 2022; Padhil& Purnomo, 2018). MEAD accommodates human, organizational, and technical dimensions in a way that is especially suited to the informal, adaptive characteristics of MSMEs. Empirical studies

have shown that macroergonomic interventions improve both safety and productivity by reducing human errors and enhancing system reliability (Prastyo et al., 2022; Rathi et al., 2022).
Moreover, the alignment of OHS with quality assurance systems, such as Total Quality Management (TQM), has shown synergistic effects. A safe workplace reduces rework, improves employee focus, and enhances the consistency of production quality (Karol &Hrbˇ, 2022). This is particularly relevant in light of Industry 4.0 expectations, where traceability, precision, and safety are key competitiveness factors for MSMEs (Putra et al., 2021).
However, significant research gaps remain. Prior studies tend to focus on individual tools such as Job Safety Analysis (JSA), Hazard Identification and Risk Assessment (HIRA), or Fault Tree Analysis (FTA) without offering a holistic, integrative framework (Soesilo, 2023; Udara & Sari, 2023). Few have explored the potential of combining SIL and macroergonomics to produce a replicable model for preventive safety that concurrently enhances product quality.
This study fills that gap by developing and testing a preventive safety model integrating the SIL framework with MEAD principles in selected Indonesian MSMEs. It aims to demonstrate that effective OHS practices are not merely regulatory requirements, but strategic assets for quality improvement and sustainability.

II. Methodology

2.1 Research Design

This study employed a **mixed-methods approach**, combining descriptive-quantitative analysis with qualitative insights to explore the relationship between occupational health and safety (OHS) practices and product quality improvement in Indonesian MSMEs. The rationale for using a mixed method stems from the dual need to measure objective safety indicators and capture contextual human factors (Creswell & Plano Clark, 2011).
A multiple case study design was applied involving three MSMEs in Makassar, Indonesia, each from distinct subsectors: food processing, light metal manufacturing, and woodcraft production. This design allowed comparative analysis across varied operational environments while maintaining contextual richness (Yin, 2018).

2.2 Data Collection Procedures

Data were gathered using **three primary instruments**:

1. **Field Observation** – Direct, structured observations were conducted to evaluate compliance with safety protocols, availability and usage of personal protective equipment (PPE), and the existence of SOPs or reporting systems.
2.
3. **Questionnaire Survey** – A Likert-scale questionnaire (1–5) assessed worker perceptions of OHS implementation, physical comfort, fatigue, and work focus. The questionnaire items were adapted from previous studies on safety climate and work quality (Rugulies et al., 2019; Schmidt et al., 2021).

4. **Semi-Structured Interviews** – In-depth interviews with MSME owners and senior workers were used to capture qualitative insights into accident causes and safety practices. Interview data were coded using the Human Factors Analysis and Classification System (HFACS) (Wiegmann & Shappell, 2017).

A summary of the data sources is provided in Table 1.

Table 1. Summary of Data Collection Instruments

Method	Target Respondents	Key Indicators
Field Observation	3 MSMEs	SOPs, APD use, accident reporting, SIL
Questionnaire	31 employees (total)	Perceptions on safety, fatigue, errors
Interview	6 owners/senior workers	Human error factors, production consistency

Justification of Sample Size

The study utilized **31 questionnaire respondents** drawn from three selected MSMEs. Although this number may appear limited in large-scale industrial research, it is **methodologically appropriate** and **analytically justifiable** for exploratory and diagnostic studies within small enterprise contexts. Several key arguments support the validity and sufficiency of this sample size:

1. **Aligned with MSME Population Structure** Each MSME in this study employed fewer than 15 workers, which reflects the typical structure of Indonesian MSMEs (Farisi et al., 2022). In such tightly scaled organizations, surveying 100% or near-total worker participation provides a complete or near-complete representation of the workforce, thus **enhancing internal validity** (Undari&Lubis, 2021).

2. **Supported by Prior Research** In qualitative-driven OHS research within small-scale enterprises, sample sizes ranging from **20 to 35 respondents** are considered adequate to draw meaningful inferences, particularly when combined with observation and interview triangulation (Marshall et al., 2013; Guest, Namey & Mitchell, 2013). This study adopts such a **triangulated approach** by combining surveys with field observations and in-depth interviews.

3. **Saturation Point in Homogeneous Populations** The workforce studied was relatively homogeneous in terms of task types, skill levels, and exposure to occupational risks. In homogeneous samples, **data saturation and response consistency** can often be reached with 20–30 participants (Guest et al., 2006), especially when the aim is to identify dominant patterns rather than statistically generalize.

4. **Context-Specific Applicability** The research objective focuses on **diagnosing the relationship between OHS practices and quality issues within specific, real-world MSME settings**, not extrapolating to large populations. Hence, **contextual validity and depth of insight** outweigh the need for large statistical power.

5. **Statistical Power for Correlation Analysis** Using G*Power analysis for a **bivariate Pearson correlation** with medium effect size ($r = 0.5$), $\alpha = 0.05$, and power = 0.80, the minimum recommended sample size is 29 (Faul et al., 2009). With 31 respondents, this study **meets the threshold for correlation testing**.

2.3 Sampling and Participants

A purposive sampling technique was applied to select MSMEs with:

- At least 5 full-time workers,
- Involvement in manual production processes,
- No prior formal safety certification.

The total number of participants included 31 employees and 6 managerial informants. This sample was deemed adequate for exploratory and correlation analysis in small enterprise settings (Marshall,Cardon, Poddar, & Fontenot, 2013).

2.4 Data Analysis

Data analysis was divided into three integrated streams:

- **Descriptive Analysis** was used to describe current OHS practices and baseline product quality metrics, such as the number of defective units per month.

- **Correlation Analysis** applied Pearson's r to examine the relationship between OHS implementation scores and the number of product defects. A high negative correlation would support the hypothesis that better safety leads to improved quality (Rathi et al., 2022).

- **Safety Integrity Level (SIL) Evaluation** used a semi-quantitative scoring model based on IEC 61508 parameters: frequency of incidents, effectiveness of risk mitigation, severity of potential damage, and control/reporting systems (Mahmoudi, 2021).

Additionally, qualitative interview data were thematically coded using HFACS categories to identify systemic safety weaknesses and human performance variances.

2.5 Ethical Considerations

All participants gave informed consent before participation. The study received formal clearance from the Faculty Research Ethics Committee at Universitas Muslim Indonesia. Confidentiality and anonymity of all data were maintained throughout.

III. RESULTS AND DISCUSSION

3.1 Results

The results of this study are presented across four thematic dimensions: (1) the current state of OHS implementation in MSMEs, (2) workers' perceptions of safety and its impact on job performance, (3) the evaluation of system reliability through Safety Integrity Levels (SIL), and (4) changes in product quality following safety interventions.

3.1.2 Status of OHS Implementation in MSMEs

Initial observations across the three MSMEs revealed significant disparities in the availability and application of safety systems. While one enterprise had formal SOPs and provided adequate personal protective equipment (PPE), others lacked even the most basic safety infrastructure. Table 1 summarizes these findings.

Table 1. Summary of OHS Implementation Features

MSME	No. of Workers	SOPs Availability	PPE Provision	Accident Reporting	SIL Classification
UMKM A	12	No	Masks, gloves	Manual	SIL 1
UMKM B	9	Yes	Helmet, safety shoes	Manual	SIL 2
UMKM C	10	No	Incomplete	None	SIL 0

The enterprise classified as UMKM B demonstrated relatively structured OHS practices, while UMKM C exhibited the weakest safety compliance.

3.1.2 Worker Perceptions: Safety, Comfort, and Fatigue

To explore subjective perceptions, 31 workers completed a structured questionnaire. The findings suggest a generally low awareness of safety protocols and low-to-moderate compliance with PPE usage. Notably, fatigue levels were perceived as high, correlating with a reduced focus and an increased likelihood of production errors.

Table 2. Mean Perception Scores of Workers on OHS and Work Quality (n = 31)

Indicator	Mean (1–5)	Interpretation
Understanding of SOPs	2.3	Low
PPE Availability and Compliance	2.7	Low to Moderate
Comfort and Workplace Safety	3.1	Moderate
Perceived Fatigue During Work	3.8	High (negative impact)
Focus and Work Accuracy	2.6	Low
Frequency of Production Errors	3.4	Moderate to High

These subjective indicators reflect inconsistencies in workplace conditions and point to a need for more structured safety and ergonomic interventions.

3.1.3 Safety Reliability Evaluation through SIL

System safety levels were assessed using a semi-quantitative SIL framework based on four variables: accident frequency, risk mitigation measures, severity of potential damage, and the existence of reporting systems. Table 3 presents the scoring matrix for UMKM B, which achieved the highest reliability score.

Table 3. SIL Evaluation for UMKM B

Assessment Variable	Assigned Score (0–3)
Frequency of Accidents	1
Risk Mitigation Procedures	2
Potential Impact Severity	2
Reporting and Monitoring	1
Total SIL Score	**6 (SIL 2)**

The highest classification (SIL 2) indicates a moderate degree of system integrity. In contrast, UMKM C scored below the minimum threshold, confirming the absence of an operational safety system.

3.1.4 Product Quality Before and After Safety Interventions

Following the implementation of basic safety measures—such as providing PPE, standardizing workflows, and offering safety briefings—a measurable reduction in product defects was recorded in all three enterprises. These results are detailed in Table 4.

Table 4. Defective Product Rates Before and After OHS Improvements

MSME	Defects/Month (Before)	After Intervention	Change (%)
UMKM A	25	12	-52%
UMKM B	18	9	-50%
UMKM C	30	20	-33%

UMKM A and B, which introduced structured SOPs and PPE policies, achieved a reduction in defect rates exceeding 50%, whereas UMKM C, which relied on less formal approaches, saw a more modest improvement.

3.1.5 Correlation Between OHS Implementation and Product Quality

To determine the strength of association between OHS adoption and product quality, a Pearson correlation analysis was conducted. A strong negative correlation was found between OHS implementation scores and the number of defective units produced (**r = –0.89**), indicating that higher levels of safety implementation are associated with significantly fewer product defects.

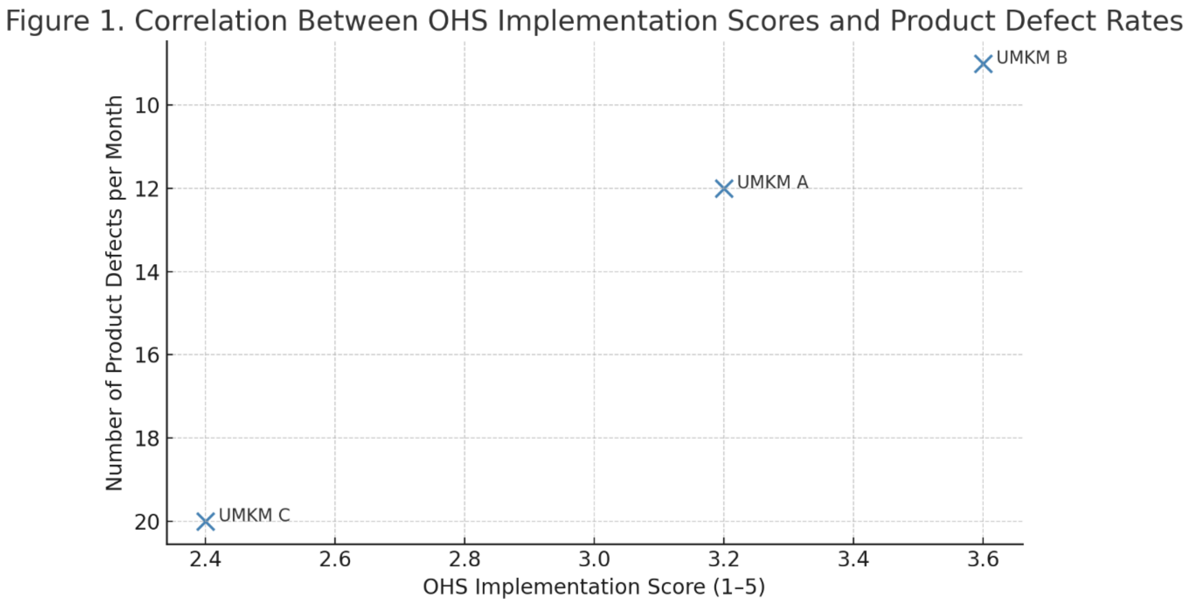

Figure 1. Correlation Between OHS Score and Product Defect Rates

Figure 1 presents a scatter plot illustrating the relationship between Occupational Health and Safety (OHS) implementation scores and the number of defective products per month across three MSMEs.

Each point on the graph represents a participating enterprise (UMKM A, B, and C), plotted according to its mean OHS score (X-axis) and its corresponding defect rate (Y-axis).
The visual pattern clearly demonstrates a **negative correlation**, where higher OHS implementation scores are associated with lower defect rates. This inverse relationship supports the statistical result obtained from Pearson's correlation analysis (**r = –0.89**), indicating that more structured and well-executed safety practices can significantly reduce production errors and enhance output quality.
Notably, UMKM B, which had the highest OHS score (3.6), recorded the lowest number of defective units (9 per month). In contrast, UMKM C had the lowest OHS score (2.4) and the highest defect rate (20 units). This suggests that implementing even basic safety protocols—such as PPE usage and SOP standardisation—can yield tangible improvements in product quality, particularly in small-scale, labour-intensive enterprises.
The Y-axis is intentionally **inverted** to reflect the logical trend: as OHS compliance increases, defects decrease. This layout emphasizes the effectiveness of preventive safety measures as a quality control strategy in MSME environments.

3.2 Discussion

The findings of this study provide empirical evidence that supports the integration of occupational health and safety (OHS) strategies—particularly those based on macroergonomic principles—as a pathway for enhancing product quality in micro, small, and medium enterprises (MSMEs). The results not only confirm existing theoretical frameworks but also extend them by contextualising their application within low-resource, informal industrial environments.

3.2.1 OHS as a Quality Improvement Strategy

The strong inverse correlation (**r = –0.89**) between OHS implementation and product defect rates highlights a critical insight: **OHS should not be treated solely as a legal compliance mechanism**, but rather as a strategic tool for improving operational performance. This aligns with the perspective of Rathi et al. (2022), who argue that safety measures—when integrated into quality systems—contribute directly to reducing production variability and rework.
The observed reductions in defective product rates, ranging from 33% to 52%, also resonate with earlier findings by Schmidt et al. (2021), who emphasised the link between musculoskeletal strain and error rates in small-scale workplaces. In this study, improvements in safety protocols (e.g. clearer SOPs, better PPE usage) not only mitigated workplace hazards but also enhanced workers' focus and precision during production tasks.

3.2.2 Macroergonomics and Human Factors

This study further validates the use of **Macroergonomic Analysis and Design (MEAD)** as a systems-based intervention for MSMEs. The implementation of MEAD principles helped identify "key variances" within the work system—such as unclear task boundaries, fatigue, and inconsistent task allocation—that contributed to both safety incidents and product inconsistencies. These findings echo those of Waterson et al. (2022) and Padhil& Purnomo (2018), who noted that macroergonomic redesign improves system coherence and reduces human error in informal sectors.
The Human Factors Analysis and Classification System (HFACS) results revealed that fatigue, lack of training, and poor supervision were recurring themes. These human-system integration issues are well documented in OHS literature and serve as strong justification for participatory redesign efforts, especially in under-resourced enterprises (Wiegmann & Shappell, 2017).

3.2.3 Safety Integrity Levels (SIL) as Diagnostic Tools

The use of **Safety Integrity Level (SIL)** evaluation in this study demonstrates the feasibility of adapting high-reliability industry frameworks to the MSME context. Although originally designed for automation-intensive environments (Mahmoudi, 2021), the application of a simplified SIL scoring system in this study allowed for actionable diagnostics of system safety maturity. The observed progression from SIL 0 to SIL 2 across the case studies illustrates how incremental improvements—such as establishing reporting systems or SOPs—can elevate safety integrity and reduce operational variability.

3.2.4 Theoretical and Practical Contributions

This study contributes to the theoretical discourse by offering a **dual-integrated model** that bridges preventive safety (via SIL) and participatory system design (via MEAD). It provides a novel framework that demonstrates how structured safety can yield cross-functional benefits in quality control. Practically, the study offers MSME operators a roadmap for low-cost, high-impact safety interventions that do not require advanced technology or external certifications to be effective.

Moreover, the results support the growing recognition that **MSMEs require tailored safety strategies**—not scaled-down versions of corporate models (Rodrigues et al., 2019; Putra et al., 2021; Rauf et al., 2024). By grounding interventions in worker participation and macro-level system analysis, this approach ensures that changes are both effective and sustainable within local resource constraints.

3.2.5 Limitations and Future Research

Despite its contributions, the study has certain limitations. The sample size, although analytically justified, is still limited to three enterprises in one geographical area. The scope was also constrained to short-term outcomes, and did not account for long-term sustainability of OHS practices. Additionally, while SIL was adapted successfully, its subjectivity in low-data environments may affect reliability.

Future research should explore longitudinal studies to assess behavioural change and economic impacts over time. There is also potential to integrate digital tools, such as IoT-based OHS monitoring or mobile-based training platforms, which could enhance real-time decision-making and extend the model's reach to remote or rural MSMEs.

IV. Conclusion

This study demonstrates that integrating preventive occupational health and safety (OHS) strategies with macroergonomic principles can significantly improve both system reliability and product quality within Micro, Small, and Medium Enterprises (MSMEs). Through the implementation of structured safety protocols—such as personal protective equipment (PPE), standard operating procedures (SOPs), and basic training—enterprises reported a reduction in defective product rates of up to 52%. A strong negative correlation ($r = -0.89$) was found between OHS implementation scores and product defect rates, suggesting that safety systems, when appropriately implemented, contribute directly to error reduction and production consistency.

The application of Safety Integrity Level (SIL) evaluation offered a practical diagnostic framework for assessing and improving system safety in informal industrial settings. Furthermore, the use of the Macroergonomic Analysis and Design (MEAD) method enabled identification of systemic inefficiencies—including fatigue, unclear task allocation, and supervision gaps—that contributed to operational hazards and quality fluctuations.

By framing OHS as both a risk mitigation and quality assurance strategy, this study provides a scalable and context-sensitive model for improving MSME competitiveness. The findings have broader implications for policymakers, OHS practitioners, and industry stakeholders interested in empowering MSMEs through participatory, low-cost safety interventions. Future research may explore the integration of digital safety tools, long-term impact assessments, and application of the model across broader industry sectors.

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