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RESEARCH PAPER

Integrative Model Investigation of Occupational Safety and Health for MSMEs Using a Macro-Ergonomics Approach and Human Factors Analysis and Classification

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ABSTRACT
Occupational safety and health (OSH) challenges in the Micro, Small, and Medium Enterprises (MSMEs) sector are serious issues that Warrant significant attention. This study aims at developing an integrative model investigation of Occupational Safety and Health for SMEs that use Job shop production floors with a macro-ergonomics approach and Human Factors Analysis and Classification System (HFACS) to reduce the number of work accidents in this sector. Firstly, the organizational structure and management system of UMKM Job shop are analysed, including work procedures, training, and Occupational Health and Safety (OHS) policies. Then, HFACS is used to identify human factors that contribute to incidents and accidents, including human error, organizational factors, and environmental factors. Finally, the relationship between macro ergonomic variables and HACFS variables is tested using the SEM-PLS (Structural Equation Modelling-Partial Least Squares) method. The results show that the resulting model can improve OHS in the MSME sector including key variables including Physical Environment, Good Supervision, Good Organization, Balanced Division of Tasks, Use of Technology that is in accordance with needs and Human resources will reduce the occurrence of Unsafe Action in MSMEs with the Job shop Layout model.

KEYWORDS: *Occupational safety and health (OSH); Macroergonomics; Human factors analysis and classification system (HFACS); Job shop layout; Micro, Small, Medium enterprises (MSMEs).*

1. Introduction

Indonesia as a developing country continues to carry out intensive infrastructure development [1]. The Ministry of Cooperatives and SMEs reported that in [20], Micro, Small, and Medium Enterprises (MSMEs) were responsible for approximately 61% of Indonesia's GDP, demonstrating substantial sectoral development and providing jobs for around 97% of the national workforce [20]. However, this sector often faces various challenges, especially in terms of occupational safety and health (OSH) [3] and [14]. As the main sector of the Indonesian economy, MSMEs play an important role in creating jobs and driving the local economy [5] and [34]. However, working conditions in many MSMEs, especially those using the job shop production floor model, are still far from ideal standards [35].

The job shop production floor model is a production system that is often found in small industries such as workshops, handicrafts, and small-scale manufacturing. This model has flexible and non-standardised production characteristics [16]. The products produced are often diverse and are produced according to specific customer requests. In this model, each product or order has a unique production process, which is different from large-scale production, which uses standardised production processes [33]. The flexibility of the job shop model, although it provides a competitive advantage, also carries a high risk of work accidents [13, 23, 32]. Workers in these environments often have to handle a variety of machines and equipment without adequate protection and work in less than optimal conditions in terms of safety [19, 31, 37]. Analysis of various studies confirms that work accidents in MSMEs job shops often occur due to a lack of supervision and inadequate implementation of K3 [38] and [6]. Research by [13] revealed that several MSMEs in the metal industry were involved in serious accidents

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due to the improper use of personal protective equipment (PPE). In addition, [24] highlighted that deficits in occupational safety training and education play a significant role in increasing the risk of accidents in MSMEs. Other studies have shown that MSMEs in various regions, such as Nigeria [25] and [28] and Iran [8], also face similar challenges. They tend not to comply with adequate OHS practices, which is often due to a lack of understanding of While occupational safety and health are crucial, there remains a lack of compliance with OHS regulations. Research conducted by [36] and [26] presents an analysis of the opportunities for developing an occupational safety and health protection system in the MSME sector. In the article, they highlight the importance of a comprehensive approach in addressing the challenges of OHS in MSMEs, including those using the Job shop production floor model.

Occupational safety and health (OSH) challenges in the micro, small, and medium enterprises (MSMEs) sector are serious issues that Warrant significant attention. Data from the Indonesian Ministry of Manpower shows cases that illustrate the negative impacts of the lack of adequate OSH implementation. For example, in Jakarta, a worker in a metal workshop suffered a serious injury due to not using adequate personal protective equipment (PPE) while using a cutting machine. Elsewhere, in Yogyakarta, workers in the handicraft industry were exposed to dust and hazardous particles due to the lack of adequate ventilation systems, causing long-term respiratory health problems [21]. These events not only pose risks to the health and safety of employees but also harm the productivity and overall financial well-being of MSMEs. To address this issue, a systematic and comprehensive approach is needed in developing an effective occupational safety and health model for MSMEs, especially those using the job shop production floor model. This approach should include education, training, supervision, and the use of the latest technology to improve working conditions. Study by [17]. Emphasises the importance of implementing an integrated and adaptive safety management system to reduce the risk of accidents and improve worker welfare.

Macroergonomics, as an overarching framework, offers a holistic approach to addressing workplace safety and efficiency by considering organisational, technological, and human factors in tandem. Unlike traditional ergonomics, which primarily focuses on individual worker and task-level interactions, macroergonomics emphasiises systemic integration across all levels of an organization. In the context of industrial processes, macroergonomics has been successfully applied to optimize workflow design, enhance supervisory systems, and align technological applications with human capabilities. For example, in manufacturing environments, macroergonomic interventions have been used to redesign assembly lines, resulting in significant reductions in error rates and physical strain [22]. Similarly, in the service sector, macroergonomic principles have been adopted to improve customer service processes by streamlining task allocations and communication protocols [27].

In comparison to other approaches, such as traditional task-based ergonomics or purely technical safety interventions, macroergonomics provides a broader perspective that incorporates organizational culture, management practices, and worker participation. For instance, while technical methods might focus on enhancing machine safety or implementing protective gear, macroergonomics extends this by addressing supervisory practices and ensuring that safety protocols are embedded within the organizational structure. Additionally, its adaptability makes it particularly suitable for the flexible and non-standardized nature of Job shop production models. By integrating macroergonomics with the Human Factors Analysis and Classification System (HFACS), this study aims to develop a comprehensive OHS model that not only addresses physical safety but also fosters a culture of continuous improvement and systemic resilience.

Despite significant attention to OSH in MSMEs, several critical gaps remain in the existing research. Many studies focus on general OSH practices without delving into the unique challenges posed by the Job shop production model. This model's non-standardized and flexible nature often renders conventional safety frameworks ineffective. Current approaches, as discussed in [36] and [26], tend to adopt a generic, one-size-fits-all methodology that does not align with the specific needs of MSMEs using Job shop systems. Furthermore, while the role of technology in enhancing safety management is acknowledged ([17]), there is limited exploration of affordable and adaptive technologies tailored to the resource constraints of MSMEs. Training and education are also underemphasized; existing programs ([24, 13]) often lack context-specificity, failing to address the diverse skill levels and operational variances within Job shops.

Additionally, there is a noticeable absence of region-specific insights. Studies such as [25] and [28] highlight global OSH challenges but often overlook the socio-economic and cultural factors unique to Indonesian MSMEs. This gap limits the applicability of their findings to local contexts. Addressing these shortcomings requires a nuanced approach that integrates targeted frameworks, cost-effective technological solutions, and culturally sensitive training programs. By developing an OSH model specifically designed for the Job shop production floor, this research aims to bridge these gaps, fostering safer work environments and supporting sustainable economic growth.

By developing an OHS model that is in accordance with the characteristics of UMKM Job shop, it is expected to create a safer and healthier work environment. This will not only increase productivity and operational efficiency, but also support sustainable economic growth. Thus, this study aims at developing an occupational safety and health model that can be implemented effectively in UMKM, with a special focus on the Job shop production floor, in order to reduce the number of work accidents in this sector.

2. Method

2.1. Study design and data collection process

This study introduces a research method that combines macroergonomics and the Human Factors Analysis and Classification System (HFACS) to create a new model specifically designed for Job shops in Micro, Small, and Medium Enterprises (MSMEs). The macroergonomics approach is used to understand the interaction between macro elements of the work environment, such as organizational structure, policies, and corporate culture, with micro factors, such as individual and work group behaviors [27]. Meanwhile, HFACS is used to analyze human factors in work incidents and accidents, focusing on human, organizational, and environmental aspects [30]. First of all, a macroergonomics approach is used to analyze the organizational structure and management system of UMKM Job shop, including work procedures, training, and Occupational Health and Safety (OHS) policies. This analysis helps in understanding the overall work context and identifying potential risks associated with the work system [39] and [19]. Next, HFACS is used to analyze incidents and accidents that occur in UMKM Job shop. Through HFACS, human factors that contribute to incidents and accidents are analyzed, including human error, organizational factors, and environmental factors. By categorizing human errors and related factors at multiple levels, HFACS provides a robust framework for identifying and understanding the underlying causes of incidents. [22] and [4]. The results of this HFACS analysis will provide in-depth insights into the events that occurred and allow the identification of error patterns that may arise in the context of the Job shop MSME.

Data collection was conducted in South Sulawesi Province involving MSMEs in the province in the period between April and May. The sample is a subset of the population that exhibits the characteristics of the larger group. The selection of a large number of samples was done through purposive sampling, where the choice is based on particular considerations and objectives to enhance the accuracy of the results [7]. The sample size in this study was determined based on the following criteria:

1. Inclusion criteria, namely where the researcher makes this subject a sample with the following criteria: Registered as a worker (not a contract) at an MSME; The sample age is 25–55 years; Work experience of workers 5 years or more; Working in UMKM with Job shop Layout type.
2. Exclusion criteria refer to instances where the researcher chooses not to include certain subjects in the sample. Excluded subjects in this study include workers who do not wish to participate as research subjects and do not meet the inclusion criteria. This study employed a cross-sectional sampling technique, which involves collecting data at a single point in time to analyze variables and their relationships. This approach is efficient for understanding the current state of the population and identifying patterns or

associations. A total of 107 individuals who met the inclusion criteria were included as the sample

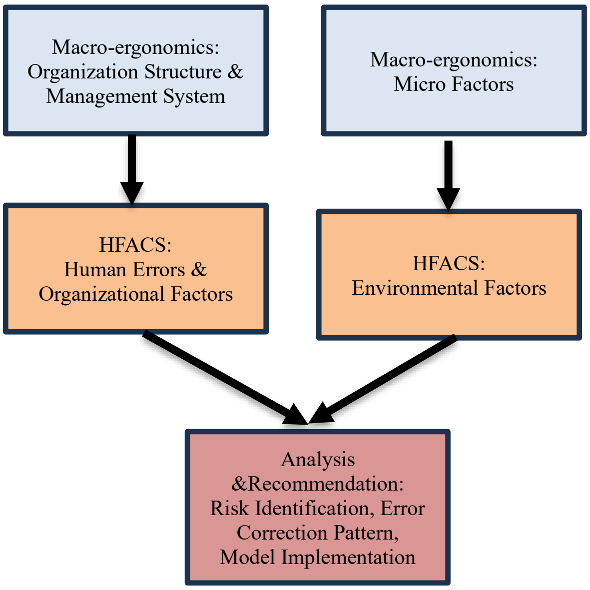

Fig.1. Macro-ergonomics and HFACS Relationship Pattern

To test the relationship between macro-ergonomic variables and HFACS, the SEM-PLS (Structural Equation Modelling-Partial Least Squares) method was used. SEM-PLS was chosen because it can overcome the limitations of regression analysis with the OLS (Ordinary Least Squares) technique in problematic data conditions, such as small sample sizes, missing values, non-normal data distributions, and multicollinearity symptoms. The OLS technique often produces unstable estimates if the sample size is small, there are missing values, or multicollinearity occurs between predictors [29].

To estimate parameters in SEM, it's generally recommended that the sample size be at least five times larger than the number of parameters involved. [2] However, in the context of SEM-PLS, the recommended minimum sample size is 10 times the number of constructs used in the study [12].

2.2. Testing variables against hypothesis

To test the relationship between macro-ergonomic variables and HFACS, the SEM-PLS (Structural Equation Modelling-Partial Least Squares) method was used. SEM-PLS was chosen because it can overcome the limitations of regression analysis with the OLS (Ordinary Least Squares) technique in problematic data conditions, such as small sample sizes, missing values, non-normal data distributions, and multicollinearity symptoms. The OLS technique often produces unstable estimates if the sample size is small, there are missing values, or multicollinearity occurs between predictors [29].

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Tab.1. Initial hypothesis

No.	Hypothesis	Relationship between Safety Culture Variables	Reference
1	H1	Organizational Variables Have a Positive Relationship with Prevention and Protection	Karimi, H., Asilian-Mahabadi, H., Mokarami, H., Taban, A., & Mohammadi, H. (2014)
2	H2	The human resource variable has a positive relationship with Prevention and Protection	Huang, Y., & Guo, Y. (2021)
3	H3	Task variables have a positive relationship with Prevention and Protection	Tucker, S., Turner, N., Barling, J., & Hershcovis, M. (2018)
4	H4	Technology variables have a positive relationship with Prevention and Protection	Dias, D., & Brito, J (2021)
5	H5	Physical Environment Variables Have a Positive Relationship with Prevention and Protection	Zhang, Y., & Chan, A. (2021)
6	H6	The Unsave Action variable has a positive relationship with Prevention and Protection	Smith, J., & Johnson, A. (2022) [32]
7	H7	The Precondition Unsave variable has a positive relationship with Prevention and Protection	Johnson, L., & Smith, K. (2019) [18]
8	H8	The Unsave Supervision variable has a positive relationship with Prevention and Protection	Wang, Q., & Li, M (2016)
9	H9	The Organization Influence variable has a positive relationship with Prevention and Protection	Smith, J., & Johnson, R (2021) [32]

2.3. Step 1

In the first phase of SEM-PLS analysis, the measurement model was applied to assess the association between indicators and their latent constructs. The evaluation of this external model ensures the accuracy and consistency of the overall model. The estimates of the measurement model provide associations between the indicators and the constructs.

These empirical estimates allow one to compare the empirical data, as reported by the sample data, with the predictions of the theoretical and structural models. In this way, we can determine some good theories that are consistent with the facts. [9]. The external measurement model consists of:

1. **Convergent validity**: The validity of the measurement model is assessed by examining the standardized loading factor value, which indicates the strength of the correlation between each measurement item (indicator) and its associated construct. According to Chin (1998), a loading factor greater than 0.7 is considered ideal, meaning the indicator is valid in measuring its construct. However, [10]. suggests that a loading factor as low as 0.5 is acceptable, indicating that if the loading factor exceeds 0.5, convergent validity is achieved.
2. **Internal consistency:** Following the analysis of the standardized loading factor, internal consistency reliability was evaluated using Cronbach's Alpha (CA) and Composite Reliability (CR) values. As stated by [10], variables are considered to have good reliability if both the Cronbach's Alpha and Composite Reliability coefficients exceed 0.7.
3. **Discriminant validity:** To confirm that each concept across the ten variables is distinct from the others, discriminant validity was employed [10]. Discriminant validity for each indicator of the final variable is demonstrated by its cross-loading, which is higher when compared to its cross-loading with the subsequent variable.

2.4. Step 2

To assess the relationship between constructs, structural model testing is performed, reflecting the hypothetical connections that have been formulated [9]. Therefore, after conducting reliability and validity tests, an evaluation was carried out on the main criteria of the PLS-SEM results, namely the coefficient of determination (R2), effect size f2, goodness of fit index (GoF), and the path coefficient of the relationship between Macroergonomics and HACFS variables with the following stages:

1. **Coefficient of determination (R^2):** The R^2 value, or coefficient of determination, reflects the model's effectiveness in forecasting the impact of a set of exogenous variables on endogenous variables, where its values range between 0 and 1. A higher R2 value compared to 1 indicates a higher exogenous model predictive variable. On the other hand, when the R2 value approaches 0, the prediction accuracy approaches 93. R2 values of 0.75, 0.50 and 0.25 indicate substantial, moderate and less.
2. **Effect size f^2:** To evaluate the substantive impact of a variable, Effect Size f^2 is used. f^2 values of 0.02, 0.15, and 0.35 are indicative of small, medium, and large effects that exogenous variables exert on the endogenous variable. In contrast, an f^2 value lower than 0.02 indicates that there is no influence of the exogenous variable on the endogenous variable.
3. **Goodness of fit index (GoF):** To validate the model comprehensively, the Goodness of Fit (GoF) is calculated. The thresholds for GoF are 0.10 for a small fit, 0.25 for a medium fit, and 0.36 for a large fit, as noted by [12] and 10]. The formula applied in this calculation is as follows:
   $\mathrm{GoF}=\sqrt{\mathrm{com}} \times R^2$
4. **Path coefficient:** Path coefficients exhibit standard deviations ranging from -1 to +1. Coefficients approaching +1 signify a strong positive relationship, while values near -1 indicate a strong negative relationship. In the context of Partial Least Squares Structural Equation Modeling (PLS-SEM), the significance of a relationship is assessed using the t-value and p-value derived from bootstrapping procedures. A t-value exceeding the critical threshold allows for the conclusion that the coefficient is statistically significant at the specified level of significance. In general, the critical values for a two-tailed test are 1.65 (significance level= 10%), 1.96 (significance level= 5%), and 2.57 (significance level= 1%). [11].

3. Results and Discussion

3.1. Meamsurement model testing

1. **Convergent validity assessment:** Based on (Appendix 1) The loading factor value was obtained using SmartPLS 3 software, it was found that for each indicator the loading factor value was >0.5. The smallest loading factor value was 0.520 and the largest value was 0.784. It can be concluded that the indicator meets the predetermined criteria so that it is said that convergent validity is met with a high level of validity.
2. **Internal consistency**: According to the findings presented in Table 1, all indicators exhibit Cronbach's alpha and composite reliability values greater than 0.7, confirming that the measured data meet the required standards. The smallest Cronbach alpha value is 0.786 and the largest is 0.883. The smallest composite reliability value is 0.844 and the largest is 0.905. Therefore, based on the Cronbach alpha and composite reliability values obtained, it can be said that all constructs have a high level of reliability.
3. **Discriminant validity:** Based on the data presented in (Appendix 2), the cross-loading values for each indicator of the latent variables exceed the corresponding cross-loading values associated with other latent variables. This finding indicates that each latent variable demonstrates good discriminant validity, confirming that the research variables are highly correlated with their respective constructs rather than with others.

   The conclusion obtained from the results of the measurement model test which includes convergent validity, internal consistency, and discriminant validity tests, namely the theoretical measurements used in this study are very suitable for the data obtained. This is proven by the three measurements of this research model being able to compare theoretical and real measurements that represent sample data.

3.1.1. Structural model testing

1. Coefficient of determination (R2)

To initiate the structural model testing, the coefficient of determination (R^2) is assessed to determine how well the endogenous variables are explained by the exogenous variables. According to the results in Table 3, macroergonomic variables display two distinct levels of determination coefficients: moderate and weak.

Moderate level:

- The determination coefficient test shows that the exogenous variable Physical Environment has an R^2 value of 0.500. This means that the Unsave Action variable explains 50% of the variance of the Physical Environment variable. In other words, Unsave Action has a moderate level of influence in predicting Physical Environment.
- The influence of the exogenous variables Unsave Supervision and Unsave Action on the endogenous variable Tasks/Activities both have an R^2 of 0.530. This shows that these two variables together explain 53% of the variance in Tasks/Activities. Therefore, the influence of Unsave Supervision and Unsave Action in predicting Tasks/Activities is also considered moderate.

Weak level:

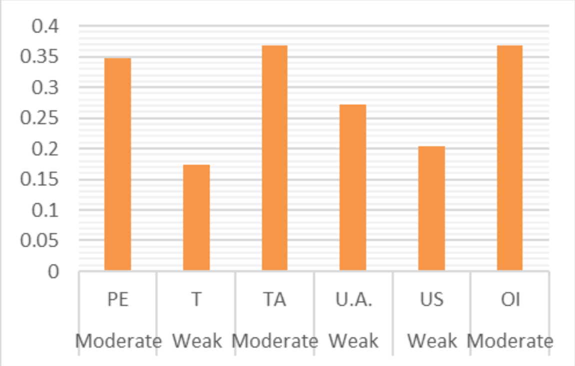
- The influence of the exogenous variable Leadership on the endogenous variable Technology shows an R^2 value of 0.250, which means that only 25% of the variance of Technology can be explained by Leadership. This indicates that Leadership has a weak influence in predicting Technology. Organizational Influence as an exogenous variable explains 39.2% of the variance of the Unsave Action variable ($R^2 = 0.392$), which is also considered a weak influence.

Tab.2. Internal consistency values

Perspective	No	Indicator	Cronbach's Alpha (CA)	Composite Reliability (CR)	Information
Macroergonomics	1	Organization (O)	0.844	0.876	Reliable
	2	Human Resources (HR)	0.810	0.852	Reliable
	3	Tasks/Activities (TA)	0.849	0.882	Reliable
	4	Technology (T)	0.786	0.844	Reliable
	5	Physical Environment (PE)	0.866	0.890	Reliable
Human factors analysis and classification system	6	Unsave Action (UA)	0.867	0.891	Reliable
	7	Unsave Supervision (US)	0.883	0.905	Reliable
	8	Organizational Influences (OI)	0.840	0.875	Reliable

- The influence of Tasks/Activities on Unsave Supervision has an R^2 of 0.293, indicating that only 29.3% of the variance in Unsave Supervision can be explained by Tasks/ Activities, which is also included in the category of weak influence.

  It can be analyzed that exogenous variables such as Human Resources, Organizational Influence, and Task Activities in the context of macroergonomics integration have limited contributions in explaining endogenous variables such as Tasks/Activities, Physical Environment, and Organizational Influences.



Graft.1. Value of determination coefficient (R2)

Tab.3. Effect size f^2 values

No	Variables	Effect size f2	Information
1	O- >TA	0.300	Currently
2	UA- >PE	0.217	Currently
3	T- >TA	0.325	Currently
4	US- >OI	0.751	Big
5	US >PE	0.077	Small
6	HR- >T	0.333	Currently
7	HR- >OI	0.006	There isn't any change
8	OI- >UA	0.646	Big
9	TA- >US	0.415	Big

2. Effect size f^2

The second structural model test using effect size (f^2) aims to assess how much exogenous variables affect changes in the R^2 value. The results of this test indicate that the Unsave Action variable has a very large influence on Organizational Influences with an f^2 value of 0.751. Likewise, Organizational Influences also show a large influence on Unsave Action with an f^2 of 0.646, as well as Activity Tasks on Unsave Supervision with an f^2 value of 0.415. This indicates that these variables are very significant in influencing changes in other related variables.

Furthermore, moderate influences were identified across several variable relationships. For example, Organizational Influences affected Task Activity with an f^2 value of 0.300, and Unsave Action influenced the Physical Environment with an f^2 value of 0.217. Technology also played a role in influencing Task Activity, with an f^2 value of 0.325, while Human Resources had an influence on Technology, reflected by an f^2 value of 0.333. Although these influences were not as robust as the larger effects, they still significantly contributed to the alterations in the impacted variables.

However, there is also a small influence on certain relationships, such as Unsave Supervision on the Physical Environment which has an f^2 value of 0.077. According to Hair (2017) [9], if the f^2 value is less than 0.02, the influence is considered insignificant. For example, Human Resources on Organizational Influences has an f^2 value of 0.006, which means that the influence is very minimal and almost insignificant. Overall, the results of this test indicate that the strength of the influence of exogenous variables on endogenous variables varies, from a very strong influence to an almost imperceptible influence. Variables with larger f^2 values tend to have a more important role in explaining changes in other variables in the structural model being analyzed.

3. Goodness of fit index (GoF)

Based on Equation (1) used is as follows (Henseler, 2013) [15].

$$GoF = \sqrt{Com} \times R2$$

$$GoF = \sqrt{0.42280} \times 0.415833$$

GoF= 0.419

So, the goodness of fit (GoF) value obtained to validate the model as a whole has a value of 0.419 which is included in the criteria for large goodness of fit and indicates that the model is fit.

4. Path coefficient

The running results for path coefficients using bootstrapping on SEM-PLS can be seen in table 4 below:

In accordance with the description of the results of the hypothesis from the assessment of the structural path coefficient between the Macroergonomics and HFACS variables, it is concluded that there are 8 hypotheses that have a strong (significant) relationship, namely H2, H3, H4, H5, H6, H7, H8, and H9. While 1 hypothesis shows that it does not have a strong (not significant) relationship, namely H1.

Tab.4. Structural path coefficients

No	Hypothesis	Variables	β	t value	p value	Information
1	H1	HR- >OI	0.064	0.850	0.396	Not Significant
2	H2	OI- >UA	0.626	9,857	0,000	Significant
3	H3	O- >TA	0.418	6,078	0,000	Significant
4	H4	HR- >T	0.500	7,277	0,000	Significant
5	H5	T- >TA	0.435	6,073	0,000	Significant
6	H6	TA- >US	0.541	6,285	0,000	Significant
7	H7	US- >OI	0.689	11,060	0,000	Significant
8	H8	UA- >PE	0.486	3,515	0,000	Significant
9	H9	US- >PE	0.289	2,056	0.040	Significant

This is because in H1 the hypothesis is said to be insignificant because it has a t-value and is not in accordance with the rules of Hair (2011). So that the structural path coefficient or relationship model between the safety culture variables used in research in steel companies can be described as follows:

Figure 2 illustrates the relationship model of safety culture variables. As shown, the interaction between organizational commitment, employee engagement, and safety communication plays a crucial role in shaping the safety culture in MSMEs. The arrows represent the direction and strength of these relationships, emphasizing the need for a comprehensive safety communication strategy. By integrating macro-ergonomics and the Human Factors Analysis and Classification System (HFACS), the proposed model offers a unique and holistic approach to improving occupational safety and health (OSH) in MSMEs with Job Shop layouts. To highlight its distinct contributions, it is essential to compare this model with established OSH frameworks, such as ISO 45001, ILO-OSH 2001, Behavior-Based Safety (BBS), and ANSI/ASSP Z10. While these frameworks provide robust guidelines for general OSH management, they may fall short in addressing the specific needs of MSMEs operating in Job Shop layouts. Below is a detailed comparison by teble 5.

4. Conclusion and Suggestions

4.1. Conclusion

This study develops an occupational health and safety (OHS) model for MSMEs that use Job shop production floors with a macro-ergonomics approach and Human Factors Analysis and Classification System (HFACS). Based on the analysis and testing carried out, it was found that significant variables affect OHS in the Sector including Key Variables as the basis for the resulting model including Physical Environment, Good Supervision, Good Organization, Balanced Division of Tasks, Use of Technology that is in accordance with needs and Human resources will reduce the occurrence of Unsafe Action in MSMEs with the Job shop Layout model.

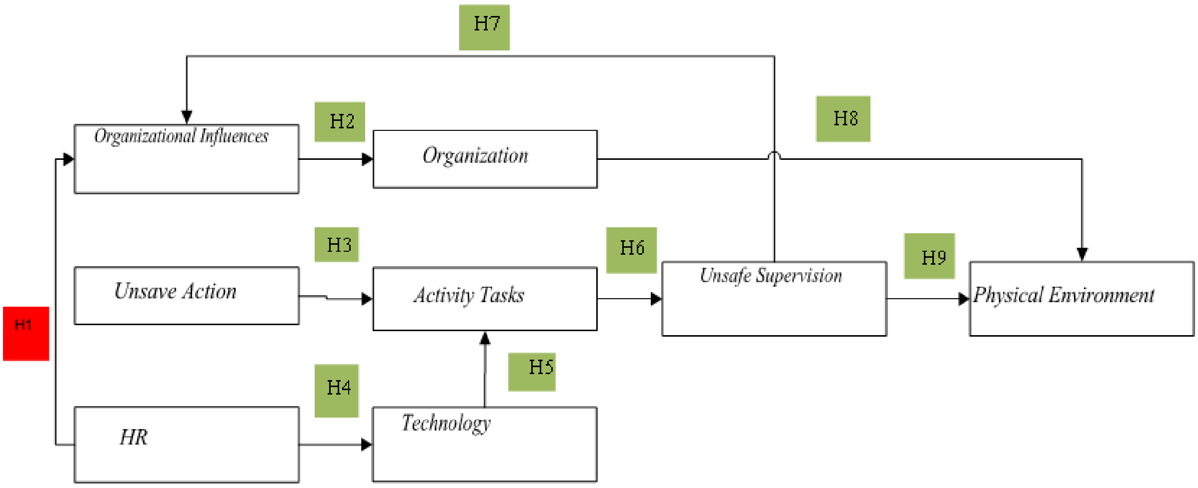


Fig.2. Relationship model of safety culture variables in MSMEs with job shop layout

Tab.5. Comparison of the proposed model with established OSH frameworks

Framework	Key Features	Similarities with Proposed Model	Differences from Proposed Model
ISO 45001	Globally recognized OSH management standard	Emphasis on risk assessment and management	Focuses on policy-level compliance; lacks integration of macro-ergonomics and HFACS for analyzing system-level interactions
	Based on Plan-Do-Check-Act (PDCA) cycle	Encourages management involvement and continuous improvement	Generic framework; not tailored for MSME-specific challenges, especially in Job Shop layouts
ILO-OSH 2001	Broad principles for OSH management, focusing on worker participation and integration into management	Stresses risk-based OSH management and worker involvement	Global applicability with limited sector-specific guidelines; lacks detailed tools for categorizing human and organizational errors
Behavior-Based Safety (BBS)	Focuses on modifying individual behaviors to improve workplace safety	Recognizes the role of human factors in OSH	Primarily focuses on individual behaviors rather than system-level factors; does not address organizational design or Job Shop-specific risks
ANSI/ASSP Z10	U.S.-based OSH management system emphasizing continuous improvement and risk management	-Advocates PDCA cycle and continuous system improvement	Primarily administrative and does not account for macro-level ergonomics or error classification methodologies like HFACS

The primary contribution of this study lies in its development of a novel, integrative OHS model tailored to the specific challenges of MSMEs using Job shop production floors. Unlike existing frameworks, this model uniquely combines macro-ergonomics to address systemic organizational and environmental issues with HFACS to identify and mitigate human error. This dual approach provides a holistic solution, ensuring the model is not only theoretically robust but also practical and scalable for real-world application in MSMEs. Furthermore, the inclusion of region-specific variables and low-cost technological solutions ensures the model's relevance and accessibility for MSMEs in diverse contexts, particularly in Indonesia.

Overall, this study concludes that an integrative approach using macro-ergonomics and HFACS can provide an effective solution in improving occupational health and safety in the MSME sector that uses the Job shop production floor model.

4.2. Suggestions

From the compilation of the recommendations, the main priority that needs to be considered is the recommendation of the Human Resources variable as the primary key in improving safety culture in UMKM job shop Layout Model. Human Resources are made the main priority because they have an important role as a role model to influence the perception, way of thinking, and behavior of workers when doing work.

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Appendix 1:

No	Indikator	Loading Factor	Description	No	Indikator	Loading Factor	Description
1	O1	0,520	Valid	41	LF 5	0,618	Valid
2	O2	0,543	Valid	42	LF 6	0,526	Valid
3	O3	0,784	Valid	43	LF 7	0,700	Valid
4	O4	0,677	Valid	44	LF 8	0,742	Valid
5	O5	0,659	Valid	45	LF 9	0,681	Valid
6	O6	0,640	Valid	46	LF 10	0,701	Valid
7	O7	0,659	Valid	47	LF 11	0,671	Valid
8	O8	0,624	Valid	48	LF 12	0,622	Valid
9	O9	0,650	Valid	49	UA1	0,569	Valid
10	O10	0,667	Valid	50	UA 2	0,652	Valid
11	SDM 1	0,551	Valid	51	UA 3	0,684	valid
12	SDM 2	0,579	Valid	52	UA 4	0,582	valid
13	SDM 3	0,591	Valid	53	UA 5	0,744	valid
14	SDM 4	0,530	Valid	54	UA 6	0,668	valid
15	SDM 5	0,559	Valid	55	UA 7	0,634	valid
16	SDM 6	0,600	Valid	56	UA 8	0,650	valid
17	SDM 7	0,547	Valid	57	UA 9	0,527	valid
18	SDM 8	0,739	Valid	58	UA 10	0,688	valid
19	SDM 9	0,572	Valid	59	UA 11	0,583	valid
20	SDM10	0,756	Valid	60	UA 12	0,636	valid
21	TA 1	0,549	Valid	61	US1	0,749	Valid
22	TA 2	0,718	Valid	62	US 2	0,719	valid
23	TA 3	0,701	Valid	63	US 3	0,781	valid
24	TA 4	0,751	Valid	64	US 4	0,727	valid
25	TA 5	0,719	Valid	65	US 5	0,624	valid
26	TA 6	0,657	Valid	66	US 6	0,776	valid
27	TA 7	0,730	Valid	67	US 7	0,633	valid
28	TA 8	0,626	Valid	68	US 8	0,615	valid
29	TA 9	0,594	Valid	69	US 9	0,653	valid
30	T1	0,532	Valid	70	US 10	0,694	valid
31	T2	0,707	Valid	71	OI1	0,524	valid
32	T3	0,768	Valid	72	OI2	0,674	valid
33	T4	0,776	Valid	73	OI3	0,655	valid
34	T5	0,643	Valid	74	OI4	0,655	valid
35	T6	0,591	Valid	75	OI5	0,723	valid
36	T7	0,584	Valid	76	OI6	0,711	valid
37	LF1	0,606	Valid	77	OI7	0,732	valid
38	LF 2	0,572	Valid	78	OI8	0,581	valid
39	LF 3	0,625	Valid	79	OI9	0,620	valid
40	LF 4	0,546	Valid	80	O10	0,520	valid

Appendix 2:

	O	SDM	TA	T	LF	UA	US	OI
O1	0,520	0,362	0,309	0,339	0,225	0,246	0,327	0,205
O2	0,543	0,220	0,136	0,204	0,253	0,185	0,220	0,183
O3	0,784	0,163	0,365	0,418	0,547	0,338	0,444	0,305
O4	0,677	0,263	0,231	0,382	0,449	0,294	0,449	0,272
O5	0,659	0,094	0,191	0,215	0,326	0,173	0,297	0,065
O6	0,640	0,280	0,375	0,416	0,526	0,321	0,444	0,378
O7	0,659	0,132	0,173	0,238	0,437	0,146	0,290	0,095
O8	0,624	0,033	0,033	0,170	0,336	0,102	0,291	0,112
O9	0,650	0,120	0,239	0,258	0,377	0,254	0,442	0,286
O10	0,667	0,282	0,237	0,424	0,551	0,241	0,403	0,250
SDM 1	0,082	0,569	0,441	0,365	0,151	0,353	0,205	0,544
SDM 2	0,101	0,652	0,443	0,416	0,176	0,322	0,295	0,507
SDM 3	0,234	0,684	0,401	0,537	0,302	0,424	0,301	0,527
SDM 4	0,091	0,582	0,358	0,275	0,025	0,229	0,295	0,422
SDM 5	0,176	0,744	0,480	0,535	0,259	0,447	0,377	0,448
SDM 6	0,270	0,668	0,551	0,615	0,341	0,549	0,371	0,555
SDM 7	0,254	0,634	0,445	0,445	0,253	0,403	0,218	0,427
SDM 8	0,303	0,650	0,357	0,486	0,166	0,247	0,296	0,349
SDM 9	0,148	0,527	0,366	0,434	0,096	0,414	0,282	0,292
SDM10	0,380	0,688	0,528	0,620	0,467	0,571	0,415	0.458
SDM 1	0,101	0,583	0,347	0,271	0,035	0,206	0,310	0,402
SDM 2	0,138	0,636	0,307	0,622	0,184	0,438	0,289	0,337
TA 1	0,099	0,309	0,532	0,221	0,178	0,238	0,265	0,237
TA 2	0,340	0,567	0,707	0,513	0,307	0,477	0,444	0,516
TA 3	0,169	0,544	0,768	0,480	0,300	0,477	0,447	0,677
TA 4	0,304	0,461	0,776	0,397	0,407	0,449	0,477	0,588
TA 5	0,313	0,457	0,643	0,466	0,470	0,420	0,432	0,648
TA 6	0,192	0,410	0,591	0,427	0,275	0,414	0,279	0,567
TA 7	0,246	0,314	0,584	0,280	0,292	0,241	0,321	0,357
TA 8	0,277	0,658	0,488	0,749	0,289	0,556	0,427	0,490
TA 9	0,431	0,556	0,479	0,719	0,432	0,531	0,368	0,443
T1	0,404	0,539	0,415	0,781	0,461	0,587	0,415	0,519
T2	0,328	0,625	0,485	0,727	0,412	0,543	0,414	0,439
T3	0,364	0,522	0,431	0,624	0,274	0,304	0,377	0,433
T4	0,398	0,555	0,496	0,776	0,403	0,494	0,414	0,477
T5	0,275	0,418	0,377	0,633	0,308	0,390	0,406	0,429
T6	0,384	0,448	0,440	0,615	0,365	0,495	0,291	0,390
T7	0,268	0,441	0,337	0,653	0,206	0,513	0,267	0,489
LF1	0,346	0,486	0,350	0,694	0,288	0,575	0,397	0,461
LF 2	0,667	0,282	0,237	0,424	0,551	0,241	0,403	0,250
LF 3	0,385	0,046	0,149	0,102	0,579	0,137	0,272	0,187
LF 4	0,417	0,243	0,242	0,353	0,591	0,337	0,444	0,185
LF 5	0,445	0,183	0,196	0,315	0,530	0,087	0,337	0,116
LF 6	0,379	0,180	0,393	0,351	0,559	0,299	0,381	0,267
LF 7	0,286	0,158	0,170	0,229	0,600	0,163	0,220	0,104
LF 8	0,286	0,195	0,294	0,304	0,547	0,219	0,296	0,251
LF 9	0,371	0,208	0,329	0,257	0,739	0,243	0,373	0,406
LF 10	0,351	0,278	0,430	0,289	0,572	0,284	0,358	0,430
LF 11	0,371	0,230	0,348	0,277	0,756	0,259	0,389	0,424
LF 12	0,196	0,337	0,337	0,510	0,290	0,524	0,317	0,332
UA1	0,424	0,473	0,456	0,511	0,355	0,674	0,366	0,432
UA 2	0,218	0,356	0,443	0,441	0,302	0,655	0,301	0,430

UA 3	0,226	0,323	0,376	0,491	0,303	0,655	0,337	0,441
UA 4	0,202	0,497	0,421	0,445	0,283	0,723	0,295	0,442
UA 5	0,251	0,365	0,410	0,505	0,286	0,711	0,316	0,460
UA 6	0,269	0,384	0,402	0,531	0,349	0,732	0,254	0,375
UA 7	0,124	0,371	0,285	0,349	0,144	0,581	0,138	0,257
UA 8	0,230	0,552	0,396	0,479	0,093	0,620	0,300	0,465
UA 9	0,223	0,304	0,282	0,314	0,167	0,520	0,189	0,375
UA 10	0,328	0,191	0,274	0,245	0,332	0,205	0,549	0,205
UA 11	0,405	0,347	0,363	0,394	0,366	0,341	0,718	0,426
UA 12	0,321	0,298	0,312	0,339	0,268	0,252	0,701	0,393
US1	0,537	0,227	0,307	0,285	0,352	0,257	0,751	0,338
US 2	0,445	0,304	0,388	0,357	0,487	0,258	0,719	0,414
US 3	0,307	0,339	0,389	0,352	0,377	0,335	0,657	0,448
US 4	0,421	0,354	0,444	0,406	0,429	0,277	0,730	0,324
US 5	0,320	0,495	0,554	0,525	0,495	0,422	0,626	0,467
US 6	0,423	0,283	0,464	0,300	0,402	0,302	0,594	0,384
US 7	0,185	0,399	0,570	0,393	0,299	0,435	0,466	0,606
US 8	0,098	0,365	0,391	0,344	0,150	0,254	0,319	0,572
US 9	0,324	0,464	0,525	0,418	0,489	0,326	0,538	0,625
US 10	0,291	0,519	0,546	0,396	0,381	0,392	0,482	0,632
OI1	0,044	0,281	0,413	0,336	0,083	0,332	0,189	0,618
OI2	0,078	0,545	0,407	0,333	0,136	0,324	0,207	0,526
OI3	0,240	0,363	0,585	0,393	0,267	0,438	0,283	0,700
OI4	0,316	0,479	0,691	0,489	0,484	0,536	0,406	0,742
OI5	0,296	0,505	0,398	0,504	0,373	0,403	0,382	0,681
OI6	0,385	0,579	0,515	0,519	0,347	0,521	0,395	0,701
OI7	0,156	0,321	0,434	0,412	0,174	0,375	0,225	0,671
OI8	0,147	0,363	0,488	0,365	0,271	0,373	0,350	0,622
Description:								
▨	The cross loading value of each latent variable has a greater value compared to the cross loading value with other latent variables							

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