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Enhancing Sustainable Safety Performance in the Construction Industry: A Total Safety Management Approach

Rita Ambarwati[1]*; Handaru A. Putra[2]; Dedy[3]; Wiwik Sulistiyowati[4]; Boy Isma Putra[5]

[1]Master of Management Department, Faculty of Business Law and Social Science,
Universitas Muhammadiyah Sidoarjo
Sidoarjo, Indonesia 61215
[2]Directorate General of Small and Medium Industries, Ministry of Industry Republic of Indonesia
Jakarta, Indonesia 12950
[3]Department of Health Safety Environment, PT PLN Nusantara Power
Surabaya, Indonesia 60231
[4,5]Department of Industrial Engineering, Faculty of Science and Technology, Universitas Muhammadiyah Sidoarjo
Sidoarjo, Indonesia 61215
[1]ritaambarwati@umsida.ac.id; [2]handaru.alfian@gmail.com;
[3]dedyohs@gmail.com; [4]wiwik@umsida.ac.id; [5]boy@umsida.ac.id

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ABSTRACT

Indonesia's construction industry is known for high accident rates, underscoring the urgency and practical impact of the research. The research explored the causal relationship between Total Safety Management (TSM), safety culture, safety behavior, and safety performance within Indonesia's construction sector, aiming to reduce high workplace accident rates. The research uniquely integrated these variables into a unified model tailored specifically to the Indonesian construction context, clearly distinguishing itself from previous research by addressing existing gaps in the literature. Data were collected from 173 staff and managers at contractor companies involved in various construction projects, each respondent having at least one year of relevant industry experience. A structured questionnaire assessed the implementation of safety programs and practices in respondents' workplaces over a three-month period (March to May 2023). Structural Equation Modeling–Partial Least Squares (SEM-PLS) was employed for rigorous data analysis. Findings indicate that TSM significantly influences both safety culture and safety behavior, with each positively impacting overall safety performance. Specifically, a robust safety culture fosters proactive safety behaviors among workers, significantly reducing accidents and enhancing safety outcomes. Implementing TSM as a continuous improvement approach effectively creates an environment emphasizing worker safety, well-being, and operational effectiveness. The research empirically validates a comprehensive and integrated safety management model using SEM-PLS, providing practical recommendations specifically designed to enhance construction safety performance in developing countries. These insights assist industry practitioners in achieving sustainable safety management, reducing workplace incidents, and striving toward zero fatalities.

Keywords: safety behavior, safety culture, safety performance, sustainable safety management, Total Safety Management (TSM)

*Corresponding Author

INTRODUCTION

An industrial company performs economic activities to produce goods or services in a specific setting. Effective management is essential to improving quality and staying competitive. Continuous improvement of employees' skills, processes, and working conditions is best achieved through Total Quality Management (TQM), which involves organizational change in structure, roles, and goals. TQM has been shown to positively influence work characteristics (Al Tamimi et al., 2017). Safety culture is built on the principles of Total Safety Management (TSM), which is derived from TQM. TSM encourages all members of an organization to participate in creating and maintaining a safe workplace, ultimately enhancing both productivity and quality. By implementing TSM, companies can gain a competitive advantage through improved safety and continuous performance growth (Talapatra et al., 2019).

The primary objective of TSM is to safeguard workers' well-being while simultaneously enhancing operational efficiency through meticulous quality management practices. Key components of a robust quality management system include comprehensive risk assessment, clearly defined and reliable safety procedures, and thorough employee training. Organizations prioritizing worker safety can significantly enhance their reputation among both employees and the broader community, thereby attracting and retaining high-caliber talent (Leva et al., 2014).

Moreover, by implementing TSM, companies can ensure compliance with all relevant regulations and industry standards, effectively mitigating risks of regulatory penalties and damage to their brand. Both individual employees and organizational leadership play pivotal roles in the effective implementation of Occupational Health and Safety (OHS) quality management (Leva et al., 2014). Quality management is a structured approach designed to ensure workplace activities consistently adhere to established quality standards. Within OHS, it involves systematically identifying, evaluating, and mitigating risks associated with accidents, injuries, or illnesses that may occur at work, creating a safe environment for both employees and visitors. Employees must possess a clear understanding of OHS policies and diligently adhere to these practices. Management, meanwhile, must actively allocate sufficient resources, foster meaningful employee engagement in safety-related decisions, and cultivate a positive safety-focused organizational culture (Yiu et al., 2019).

Despite extensive research on safety management, very few studies have empirically validated the integration of TSM with safety culture and safety behavior, specifically within the Indonesian construction sector, highlighting a critical research gap. The construction industry is one of the riskiest sectors due to its complex nature and frequent safety challenges (Durdyev et al., 2017). The rapid infrastructure development during the 2017–2022 period has resulted in numerous work-related accidents in construction projects. Several unique factors distinguish the construction industry from others, including complex project processes, temporary organizational structures, ever-changing work environments (Winge et al., 2019), and inconsistent worker behavior compared to the manufacturing industry (Ghahramani & Salminen, 2019), making it harder to control and standardize operations. Due to the decentralized nature of construction projects, workers often operate in different locations and must solve problems on their own. Consequently, the construction sector needs a real-time safety monitoring system to manage risks and hazards effectively (Gu & Guo, 2022; Jung et al., 2020; Newaz et al., 2021). Therefore, empirical research integrating TSM principles within this challenging context is urgently required to enhance safety culture, behavior, and performance comprehensively.

The continuous expansion of the construction sector workforce has been accompanied by a significant rise in work-related accidents. According to the Ministry of Manpower and Transmigration, the ongoing nature of construction projects often leads to worker fatigue, which is a major contributing factor to accidents in the field (Narada Katiga Nusantara, 2022). As a result, the construction sector consistently ranks among the highest for national work accident rates. Based on data from the Social Security Administrator for Employment (Badan Penyelenggara Jaminan Sosial (BPJS) Ketenagakerjaan), reported work accidents in the construction industry increased from 123,041 cases in 2017 to 173,105 in 2018 (Adiratna et al., 2022), with Employment Injury Security (Jaminan Kecelakaan Kerja (JKK)) claims reaching IDR 1.2 trillion in 2019. The number of incidents rose further by 55.2% to 177,000 cases in 2020 (BPJS Ketenagakerjaan, 2023). Between January and September 2021, 82,000 work accidents and 179 occupational diseases were reported, with 65% attributed to COVID-19-related issues. This alarming increase highlights the urgency for immediate research-driven interventions, such as integrating TSM to mitigate occupational risks and sustainably enhance worker safety.

Collaboration among owners, contractors, subcontractors, and designers has driven recent improvements in safety management systems. Active involvement from all organizational elements has been shown to positively influence project safety performance by setting safety goals, selecting competent contractors, and participating in safety management throughout the construction process (Ghahramani & Salminen, 2019; Nkrumah et al., 2021; Su, 2021). Ultimately, safety implementation is the responsibility of contractors on-site. They must adopt adequate safety systems to manage both the work environment and human behavior effectively (Xian-Zhong, 2017). Building a strong safety culture within the contractor's organization is essential, emphasizing a top-down management approach to safety (Cooper et al., 2019; Turner, 2000). However, existing research has not sufficiently explored how these collaborations and systematic approaches specifically affect safety culture and safety behavior within the unique context of Indonesian construction projects.

The concept of safety culture is deeply rooted in the philosophy of TSM, which builds on the principles of TQM. While TSM is relatively new in the construction industry, it has gained traction due to its holistic approach to addressing perceptual, psychological, behavioral, and managerial factors (Ladewski & Al-Bayati, 2019). TSM encourages full participation from all organization members in creating and maintaining a safe and productive work environment. Its primary goal is to achieve safety excellence through continuous improvement in both processes and products, with total involvement and dedication from all stakeholders (Dennis et al., 2015). As a structured approach, TSM is guided by two key principles: customer satisfaction and continuous improvement. These principles align closely with the standards set in TQM (Álvarez-Santos et al., 2018). The research addresses the existing gap by empirically validating how the integration of TSM principles specifically shapes safety culture and behavior within construction firms in Indonesia. Hence, these hypotheses are formulated:

H1: TSM has a significant and positive influence on safety culture,

H2: TSM has a significant and positive influence on safety behavior.

The research focuses on the sustainability aspect of safety management, emphasizing sustainable safety practices in construction projects. The implementation of TSM, which adapts principles from TQM to a safety context, can provide organizations with a sustainable competitive advantage (Ghahramani & Salminen, 2019). Integrating a comprehensive safety management system, combined with a strong safety culture, can significantly improve safety behavior at project sites. Worker behavior and the safety management system are two critical factors influencing the development of a safety culture (Ramos et al., 2020; Skład, 2019; Burlov et al., 2019; Su, 2021).

In the context of developing a safe project environment, the workgroup environment plays a key role in ensuring safety during construction projects. Effective safety system management that addresses all safety-related issues contributes to creating and maintaining a safe project environment (Burlov et al., 2019; Su, 2021). The research's unique contribution is the explicit exploration and validation of how TSM-based interventions directly foster sustainable safety culture and behaviors within the highly dynamic Indonesian construction sector.

To achieve long-term improvements in safety performance, companies must develop a strong safety culture and safety climate. It ensures that safety practices are sustained beyond individual projects and incorporated into subsequent ones (Hu et al., 2021). Developing a safety culture begins with fostering a safe work environment through an effective safety management system and promoting positive safety behavior via TSM. Previous studies suggest that total safety culture is established by integrating three key elements: safety behavior, safety climate, and a safe work environment (Jiang et al., 2019; Quenon et al., 2020). Behavior-Based Safety (BBS) is an effective tool for improving workers' safety behavior by minimizing unsafe actions and increasing safe practices. The BBS framework uses a four-step approach known as Define, Observe, Intervene, and Test (DO IT). Simultaneously, improving the safe work environment through TSM involves continuous improvement, teamwork, management commitment, customer focus, and adherence to safe work procedures (Jung et al., 2020; Lee, 2022). Hence, the third hypothesis is as follows:

H3: Safety culture has a significant positive influence on safety behavior.

Efforts to enhance safety performance are crucial to achieving zero accidents in construction projects. Traditionally, project success has been assessed using the triple constraints of cost, time, and quality. However, it is equally important to evaluate success based on worker safety performance. Implementing TSM and fostering a strong safety culture, supported by organizational commitment, can reduce accidents and improve overall project outcomes (Su, 2021). Without adequate attention to safety performance, project performance cannot be considered optimal or successful. Thus, integrating TSM with safety culture and behavior is essential for addressing persistent safety issues and achieving long-term improvements in the Indonesian construction industry.

The construction industry differs significantly from other industries due to its unique challenges and characteristics. Unlike manufacturing, construction projects have complex processes, temporary organizational structures, dynamic work environments, and highly variable worker behaviors (Akinlolu et al., 2022; Wang & Cheng, 2022; Winge et al., 2019; Yiu et al., 2019). These factors make it difficult to standardize safety practices and require a tailored approach to developing a safety culture. Previous research on safety climate and safety culture in construction projects has yielded inconsistent results, reflecting the complexity and variability of this sector (Yiu et al., 2019). Therefore, it is essential to address the unique characteristics of construction projects and develop more reliable models for evaluating and fostering a better safety culture in this context. Further research and practical frameworks are needed to standardize these evaluation methods. The research addresses this critical need by developing and validating an integrated TSM-based framework explicitly tailored to the Indonesian construction context. The following hypotheses are formulated:

H4: Safety culture has a significant positive influence on safety performance,

H5: Safety behavior has a significant positive influence on safety performance.

A critical analysis of existing studies reveals several gaps in the context of safety management within the construction industry, particularly in Indonesia. While TSM has been widely acknowledged as an effective approach to enhancing safety performance, its application and comprehensive evaluation in the Indonesian construction sector remains limited. Most previous research has focused on individual aspects, such as safety culture or safety behavior in isolation, without integrating these elements into a unified framework that examines their collective impact on safety performance.

From a conceptual perspective, there is a lack of studies that establish the causal relationships between TSM, safety culture, safety behavior, and safety performance. While international research has highlighted these connections, similar empirical evidence is scarce in Indonesia's context. It leaves a significant gap in understanding how TSM principles can be adapted and effectively implemented in local construction environments, characterized by unique challenges such as varying organizational structures, decentralized project management, and diverse worker behavior. Methodologically, many existing studies rely on qualitative analysis or descriptive statistics, which provide limited insights into the causal mechanisms linking safety culture, safety behavior, and performance. The research addresses this gap by employing Structural Equation Modeling-Partial Least Squares (SEM-PLS) to test these relationships and provide a robust quantitative assessment rigorously.

Empirically, the research extends the body of knowledge by focusing on both government and private construction projects in four diverse regions of East Java: Surabaya, Sidoarjo, Nganjuk, and Malang. This geographic diversity ensures a more comprehensive understanding of how TSM implementation varies across different project types and organizational settings. The research findings are expected to provide actionable insights for improving safety performance, contributing to the development of sustainable safety management practices in Indonesia's construction industry. The novelty and unique contribution lie in integrating TSM principles explicitly into a cohesive model that simultaneously evaluates safety culture, safety behavior, and safety performance using a robust quantitative method, SEM-PLS. By addressing these conceptual, methodological, and empirical gaps, the researchers offer a significant contribution to the field of occupational health and safety, specifically in the context of developing countries like Indonesia. The integration of safety culture, safety behavior, and safety performance through the lens of TSM presents a novel approach that has practical implications for both academic research and industry practices.

METHODS

The quantitative research aims to examine the relationship between TSM, safety culture, safety behavior, and safety performance. The primary objective is to explore how these variables influence each other, both directly and indirectly. The research adopts a hypothesis-testing approach, with a clear focus on demonstrating causality among the identified variables. A detailed process is followed, which includes problem formulation, a literature review, questionnaire development, and rigorous data analysis to ensure the robustness of the research.

The research design follows a structured approach, beginning with a comprehensive review of previous studies to identify research gaps and formulate hypotheses. Data collection is conducted over a three-month period (March to May 2023). A pilot test is conducted before distributing the final questionnaire to ensure the reliability and validity of the measurement instruments. The pilot test involves 30 respondents from similar construction companies to assess the clarity and consistency of their responses. Feedback from the pilot test is used to refine the questionnaire.

The questionnaire is designed using a 5-point Likert scale, where respondents indicate their level of agreement with each statement (1= Strongly Disagree, 5= Strongly Agree). The questionnaire items are developed to measure four primary constructs: TSM, safety culture, safety behavior, and safety performance. Each construct is operationalized using reflective indicators based on validated scales from previous research (see Table 1).

The research population consists of staff and managers with at least one year of experience in large-scale construction companies in East Java, Indonesia. These companies include both state-owned and private enterprises involved in building construction projects. The sampling frame is based on employees' records from participating companies. The research is conducted in four cities: Surabaya and Sidoarjo (metropolitan areas), Nganjuk (a transit city), and Malang (a tourist city).

The total population size is approximately 1,200 employees across these companies. The minimum sample size is determined using the rule of thumb for Structural Equation Modeling (SEM), where the required sample size is five to ten times the number of indicators. Given the 32 indicators used, the sample size needed is between 160 and 320. A final sample size of 173 respondents is achieved through simple random sampling, ensuring equal representation without bias. Stratified sampling is considered but ultimately not used due to the relatively homogeneous characteristics of the target population, consisting mainly of construction professionals with similar job

Table 1 Reflective Indicators Used to Measure Studied Constructs with Supporting References

Construct	Indicator	Reference
Total Safety Management (TSM)	Visionary Leadership, Safety Training,	Ghahramani and Salminen (2019)
	Safe Work Procedures, and Safety Evaluation	Talapatra et al. (2019)
Safety Culture	Safety Awareness and Employee Involvement	Cooper et al. (2019)
Safety Behavior	Use of Personal Protective Equipment	Jung et al. (2020)
	Safe Operational Tools and Safety Obedience	Lee (2022)
Safety Performance	First Aid for Injury and Lost Workdays	Su (2021)

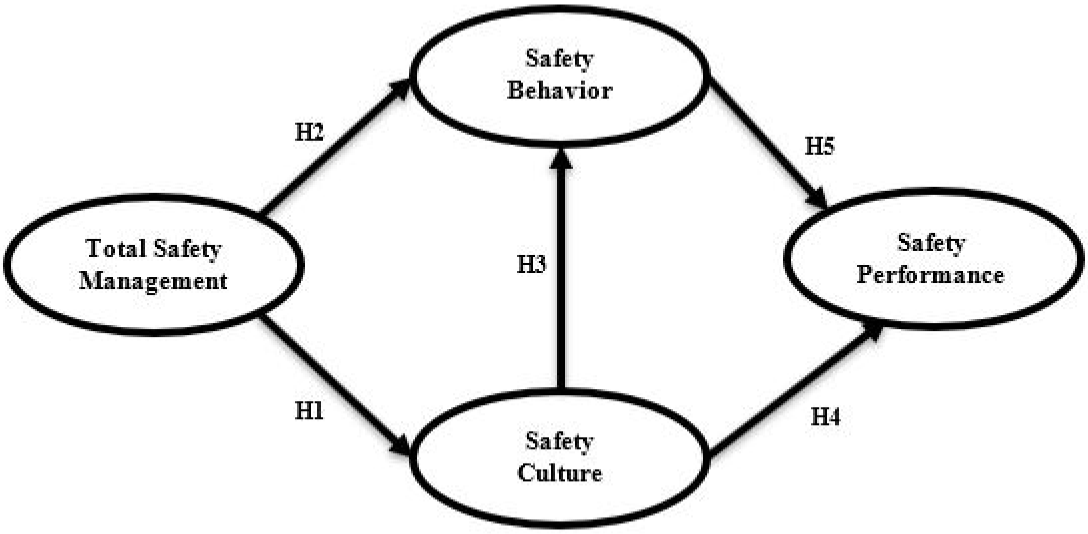

Figure 1 Conceptual Framework

roles and safety-related experiences.

Primary data are collected using the refined questionnaire. Respondents are asked to provide information about their perceptions of safety practices and behaviors at their respective worksites. Secondary data, such as historical safety records and organizational safety policies, are used to supplement the primary data and provide additional context.

The data analysis is conducted using SEM-PLS with SmartPLS software, chosen for its ability to handle complex models with multiple constructs and indicators. The analysis follows a structured process to ensure the validity and reliability of the findings. The evaluation of the outer model focuses on assessing the reliability and validity of the measurement model. Convergent validity is determined through outer loading values and the Average Variance Extracted (AVE). Indicators with outer loading values greater than 0.60 are retained for further analysis. Then, the cross-loading method and the Fornell-Larcker criterion are applied to ensure discriminant validity. Internal consistency is verified using composite reliability and Cronbach's alpha. All constructs achieve composite reliability values above 0.70 and Cronbach's alpha values above 0.60, indicating strong internal consistency (Sarstedt et al., 2014).

The inner model evaluation is conducted using R-squared (R^2) values to assess the explanatory power of the independent variables on the dependent variable. Path coefficients and effect sizes (f-squared) are calculated to determine the strength and significance of the relationships between constructs. Bootstrapping with 5,000 resamples is used to test the significance of the path coefficients at a 95% confidence interval ($p < 0.05$), ensuring robust statistical inference (Sarstedt et al., 2019).

The pilot study helps refine several questionnaire items, particularly those related to safety behavior and performance. For example, the wording of the indicators for the use of personal protective equipment and safe operational tools is adjusted to improve clarity. After the pilot test, the full-scale data collection proceeds smoothly, with a high response rate from the target population. The research offers reliable insights into the relationship between TSM, safety culture, safety behavior, and safety performance by combining both primary and secondary data and using a robust statistical analysis approach. The findings provide a foundation for improving safety practices in the Indonesian construction industry.

The conceptual model illustrated in Figure 1 presents the relationships between TSM, safety culture, safety behavior, and safety performance. The model is based on a theoretical framework that hypothesizes causal relationships among these variables. Specifically, TSM serves as the foundational element that influences safety culture and safety behavior, which, in turn, affect safety performance. The model reflects both direct and indirect relationships to demonstrate how the integration of safety management practices contributes to improved safety outcomes in construction projects.

RESULTS AND DISCUSSION

Table 2 illustrates the demographics of 173 research participants. The questions are answered by 116 males (67.05%) and 57 women (32.95%). The most prevalent age group is 21–30, with 129 (74.57%). There are 34 people between 31 and 40 (19.65%), 7 between 41 and 50 (4.05%), and 3 over 50 (1.73%). Around 101 respondents (58.38%) have bachelor's degrees. Then, the result is followed by a diploma (39, 22.54%), a master's degree (12.14%), and high school (12, 6.94%). Next, 73 respondents (42.20%) indicate that they work in engineering. There are 25 people (14.45%) in Quality Health Safety Environment (QHSE), 14 people (8.09%) as supervisor, 17 people (9.83%) as manager, 11 people (6.36%) in Quality Assurance (QA)/Quality Control (QC), 6 people (3.47%) in logistics, 9 people (5.20%) as surveyor, and 18 people (10.40%) as other positions. Of the 125 respondents, 72.25% have worked on projects for 1–5 years. The other results are 33 people (19.08%) for 6–10 years, 13 (7.51%) for 11–15 years, and 2 (1.16%) for more than 15 years. Finally, 52.60% have only worked on one or two projects. The result is followed by 43 (24.86%) on 3–4 projects, 12 (6.94%) on 5–6 projects, 7 (4.04%) on 7–8 projects, and 20 (11.56%) on more than 8 projects. These characteristics indicate that respondents are primarily young professionals, highly educated, and have diverse career experiences and project involvement, with a focus on engineering.

Outer model evaluation aims to assess research instruments through validity and reliability tests, utilizing convergent validity, discriminant validity, Cronbach's alpha, and composite reliability by constructing a measurement model. Convergent validity is assessed using outer loading and AVE. According to Sarstedt (2019), indicators with outer loading above 0.5 are valid. Initially, all indicators show outer loadings above 0.5. However, the AVE for the safety behavior dimension is below 0.5 (0.448), indicating inadequate validity. Consequently, three indicators in bold in Table 3 (SB1, SB7, and SB9) are removed due to their low outer loadings, and the test is rerun. After removal, the AVE improves to above 0.5, confirming the validity of the safety behavior construct. All constructs show acceptable AVE values: TSM (0.524), safety culture (0.517), safety behavior (0.502), and safety performance (0.625). Thus, the measurement model is deemed valid, allowing for progression to assessments of discriminant validity and reliability.

Table 2 Respondents' Demographic Characteristics

Characteristics	Frequency	%
Gender:		
Male	116	67.05%
Female	57	32.95%
Age:		
21−30	129	74.57%
31−40	34	19.65%
41−50	7	4.05%
> 50	3	1.73%
Education:		
High School	12	6.94%
Diploma	39	22.54%
Bachelor's Degree	101	58.38%
Master's Degree	21	12.14%
Position in the Project:		
Manager	17	9.83%
Engineering	73	42.20%
Supervisor	14	8.09%
Quality Health Safety Environment (QHSE)	25	14.45%
Quality Assurance (QA)/ Quality Control (QC)	11	6.36%
Logistics	6	3.47%
Surveyor	9	5.20%
Others	18	10.40%
Years of Working on the Project:		
1−5	125	72.25%
6−10	33	19.08%
11−15	13	7.51%
> 15	2	1.16%
Number of Projects Worked on:		
1−2	91	52.60%
3−4	43	24.86%
5−6	12	6.94%
7−8	7	4.04%
> 8	20	11.56%

Discriminant validity assesses the uniqueness of each construct relative to the others in the model. It is assessed using cross-loading values, which should be greater than the loadings on other latent variables (Sarstedt et al., 2019). Table 4 shows that all constructs have greater cross-loading values than the loadings on other constructs, confirming acceptable discriminant validity. All constructs, namely safety behavior, safety culture, safety performance, and TSM, demonstrate the highest loading values on their constructs compared to the loadings on other constructs. For example, safety behavior shows a loading value of 0.708 on itself, which is higher than its loadings on other constructs. Similarly, safety culture (0.789), safety performance (0.791), and TSM (0.724) exhibit

Table 3 Outer Loading of Constructs and Indicators

Variables and Indicators	TSM	SC	SB	SP
Total Safety Management (TSM)				
Visionary Leadership (TSM1)	0.768			
Feedback and Recognition (TSM2)	0.786			
Empowerment (TSM3)	0.603			
Maintenance (TSM4)	0.728			
Safety Process Management (TSM5)	0.833			
Safe Work Procedure (TSM6)	0.719			
Updating Procedure (TSM7)	0.817			
Safety Training (TSM8)	0.776			
Safety Evaluation (TSM9)	0.754			
Goals Oriented (TSM10)	0.585			
Target Oriented (TSM11)	0.518			
Safety Culture (SC)				
Informing Culture (SC1)		0.643		
Investigation (SC2)		0.692		
Unsafe Condition (SC3)		0.772		
Nearmiss (SC4)		0.648		
Sharing Knowledge (SC5)		0.677		
Safe Work Environment (SC6)		0.689		
Safety Awareness (SC7)		0.825		
Employee Involvement (SC8)		0.783		
Safety Behavior (SB)				
Personal Protective Equipment (SB1)			**0.000**	
Safe Operational Tool (SB2)			0.797	
Attitude Towards Damaged Equipment (SB3)			0.710	
Safety Obedience (SB4)			0.626	
Safety Supervision (SB5)			0.716	
Safety Equipment (SB6)			0.721	
Safety Ensurement (SB7)			**0.000**	
Equipment Examination (SB8)			0.669	
Hygiene (SB9)			**0.000**	
Waste Removal (SB10)			0.705	
Safety Performance (SP)				
First Aid Injuries (SP1)				0.664
Recordable Injuries (SP2)				0.790
Safety Violation (SP3)				0.780
Severity (SP4)				0.796
Eligibility (SP5)				0.851
Lost Workdays (SP6)				0.849

(Source: Output of SmartPLS 4.0)

the highest loadings on their respective constructs. These findings indicate that each construct in the model demonstrates adequate discriminant validity, as the indicators clearly differentiate their respective constructs. Therefore, the model meets the criteria for discriminant validity based on the cross-loading analysis (Sarstedt et al., 2019).

Table 4 Discriminant Validity Based on Cross-Loadings

	SB	SC	SP	TSM
SB	**0.708**			
SC	0.772	**0.789**		
SP	0.720	0.733	**0.791**	
TSM	0.710	0.624	0.632	**0.724**

Note: Total Safety Management (TSM), Safety Culture (SC), Safety Behavior (SB), and Safety Performance (SP).

(Source: Output of SmartPLS 4.0)

Additionally, discriminant validity is further confirmed using the Heterotrait-Monotrait ratio (HTMT). The results in Table 5 indicate acceptable validity. All HTMT values are below 0.9, confirming the discriminant validity of constructs in the model (Sarstedt et al., 2019).

Table 5 Heterotrait-Monotrait Ratio (HTMT) for Discriminant Validity Assessment

	SB	SC	SF	TSM
SB				
SC	0.865			
SF	0.780	0.819		
TSM	0.794	0.833	0.705	

Note: Total Safety Management (TSM), Safety Culture (SC), Safety Behavior (SB), and Safety Performance (SP).

Testing the reliability of the instrument using the SEM-PLS method involves assessing composite reliability and Cronbach's Alpha. The recommended threshold values are greater than 0.7 for composite eliability and greater than 0.6 for Cronbach's alpha (Hair et al., 2019). Cronbach's alpha values obtained in Table 6 are all above 0.6. Then, the composite reliability values are all above 0.7. Thus, the results confirm the reliability of all constructs.

Inner model evaluation examines the model's goodness-of-fit and the significance of path coefficients. The coefficient of determination/R-squared (R^2) measures the extent to which exogenous variables explain endogenous variables, categorized as strong (≥ 0.67), moderate (≥ 0.33), and weak (≥ 0.19) (Sarstedt et al., 2019). The R^2 values for each endogenous variable are shown in Table 7.

Table 7 indicates an R^2 value of 0.612 for safety behavior, representing a moderate effect. It implies that safety behavior is explained by safety culture and TSM by 61.2%. The remaining influences stem from variables outside this model. The R^2 for safety culture is 0.68, indicating a strong explanatory power, suggesting that total safety management substantially influences safety culture by 68%. The R^2 value for safety performance is 0.596. It reflects a moderate explanatory power, where safety performance is influenced by safety behavior and safety culture variables by 59.6%.

Table 6 The Results of Reliability and Validity of Measurement Constructs

	Cronbach's Alpha	rho_A	Composite Reliability	AVE
SB	0.837	0.847	0.875	0.502
SC	0.865	0.874	0.895	0.517
SP	0.879	0.883	0.909	0.625
TSM	0.906	0.912	0.922	0.524

Note: Total Safety Management (TSM), Safety Culture (SC), Safety Behavior (SB), Safety Performance (SP), and Average Variance Extracted (AVE).

(Source: Output of SmartPLS 4.0)

Table 7 The Results of R-Squared (Coefficient of Determination) for Endogenous Variables

	R^2	R^2 Adjusted
SB	0.612	0.608
SC	0.680	0.678
SF	0.596	0.591

Note: Safety Culture (SC), Safety Behavior (SB), and Safety Performance (SP).

(Source: Output of SmartPLS 4.0)

The magnitude of relationships between exogenous and endogenous variables is assessed using the effect size (f^2) value. According to Chin (2010), f^2 values of 0.02, 0.15, and 0.35 indicate small, medium, and large effects, respectively. Meanwhile, values below 0.02 imply negligible effects. The relationship between TSM and safety culture has an f^2 of 2.122, indicating a large effect. The relationship between TSM and safety behavior denotes a small effect, with an f^2 of 0.044. Then, the relationship between safety culture and behavior consists of f^2 of 0.28, indicating a medium effect. The relationship between safety culture and safety performance has an f^2 of 0.192 (medium effect). Meanwhile, the relationship between safety behavior and performance shows an f^2 of 0.146 (medium effect) (see Table 8).

Table 8 Effect Size (F²) of Structural Model Relationships

	SB	SC	SF
SB			0.146
SC	**0.280**		**0.192**
SF			
TSM	0.044	**2.122**	

Note: Safety Culture (SC), Safety Behavior (SB), and Safety Performance (SP).

(Source: Output of SmartPLS 4.0)

Table 9 Results of Path Coefficients and Significance of Structural Model

	Original Sample	Sample Mean (M)	Standard Deviation	T-Statistics	P-Values
SB → SP	0.382	0.404	0.073	5.233	0.000
SC → SB	0.582	0.593	0.068	8.611	0.000
SC → SF	0.438	0.420	0.082	5.322	0.000
TSM → SB	0.230	0.226	0.087	2.643	0.009
TSM → SC	0.824	0.830	0.021	39.950	0.000

Note: Total Safety Management (TSM), Safety Culture (SC), Safety Behavior (SB), and Safety Performance (SP).

(Source: Output of SmartPLS 4.0)

The significance of relationships (path coefficients) is assessed using SEM-PLS through t-statistics (> 1.96) and p-values (< 0.05). Results are presented in Table 9. It clearly indicates significant relationships across all tested paths.

The results of H1 based on significance and path coefficients demonstrate that TSM positively and significantly affects safety culture. This finding confirms that TSM significantly shapes safety culture within building construction projects. This result aligns with previous studies, which have shown that TSM effectively establishes a safety culture in the mining industry (Ismail et al., 2021; Quenon et al., 2020). Additionally, a robust safety culture emerges from implementing comprehensive TSM systems, particularly in construction and manufacturing companies, driven by strong organizational commitment to safety (Al-Bayati, 2021).

The TSM variable in the research is assessed through eleven indicators: visionary leadership, feedback and recognition, empowerment, teamwork, safety process management, maintenance, updating procedures, safety training, safety evaluation, goal-oriented, and target-oriented. Analysis reveals that indicators related to safety process management and updating procedures demonstrate the highest loading factor, while indicators concerning goal-oriented and target-oriented display the lowest loading. In terms of safety process management, it is crucial for project organizations to design standardized and safe working procedures during construction activities to protect worker safety. Preventive maintenance programs are required before field operations to identify potential hazards and ensure worker safety proactively. Management must establish clear procedures focused on worker safety, systematically inform workers of job-specific hazards, and consistently demonstrate commitment through daily toolbox meetings and regular safety inductions supervised by Quality Health Safety Environment (QHSE) personnel (Gu & Guo, 2022; Jung et al., 2020).

Safety induction specifically educates new workers on potential hazards they may encounter. This approach is supported by previous research. It emphasizes that updating work procedures and maintaining high standards for safety are integral components of effective safety management, ensuring workers consistently follow established protocols (Ladewski & Al-Bayati, 2019). Project practitioners from contractor management should regularly enhance employee awareness of job-related hazards through targeted training. Integrating personnel from various organizational levels into cohesive work teams is essential. These teams should include experienced staff capable of overseeing physical work environments and managing necessary safety actions (Jung et al., 2020; Shalimova et al., 2019).

Regular updates of work procedures are vital to maintaining safe construction practices. Employees must clearly understand new procedures through systematic safety inductions whenever new tasks or methods are introduced.

Previous studies emphasize that conducting periodic safety inspections and audits significantly enhances safety by proactively identifying hazards and continually refining procedures (Burlov et al., 2019; Haas & Yorio, 2019). Despite their importance, indicators relating to goal-oriented and target-oriented safety measures record lower effectiveness, indicating areas for improvement. Concerning goal orientation, management must regularly report and review safety Key Performance Indicator (KPI) at scheduled intervals (e.g., semi-annually), addressing incidents and near misses proactively to ensure continuous improvement toward zero accidents. Poor performance in target-oriented indicators suggests that some employees perceive safety programs as conflicting with productivity goals (Ghahramani & Salminen, 2019; Haas, 2020; Hoque & Shahinuzzaman, 2021). Hence, management must enhance employees' understanding through focused training, particularly for high-risk operations, such as casting, steel welding, and concreting at heights. Management should emphasize that robust safety programs facilitate rather than hinder achieving organizational targets.

The results of H2 confirm that TSM positively and significantly shapes safety behavior within construction projects. This finding aligns with a previous study that effective TSM significantly improves safety behaviors and reduces accident incidents by positively influencing human factors within safety management systems in the petrochemical industry in the European Union (EU) (Kontogiannis et al., 2017). Indicators of personal protective equipment, safe operational tools, attitude towards damaged materials, safety obedience, safety supervision, safety equipment, equipment examination, hygiene, and waste removal measure the safety behavior. The highest loading factor values in the safe operational tools and safety supervision indicators suggest these as key areas requiring emphasis. Regarding the implementation of the safe operational tool indicator in the field, workers apply their knowledge of safely operating tools gained through regular safety training provided by contractor management. Furthermore, the company recruits only experienced, skilled, and certified workers. Regarding safety supervision, regular monitoring by safety officers significantly enhances worker discipline. This finding aligns with previous studies (Jung et al., 2020; Lee, 2022), which highlight that active field inspections and hazard mitigation (e.g., installing hazard signs) directly influence safer worker behavior.

The analysis reveals that the indicators with the lowest loading factors for safety behavior are safety obedience and equipment examination. The low loading factor for safety obedience suggests a persistent lack of compliance among workers, specifically regarding Personal Protective Equipment (PPE) usage and smoking in restricted areas. To improve compliance, contractor management must implement stricter enforcement measures, such as issuing fines or removing non-compliant workers from the project site. Introducing clear incentives and disciplinary actions will also promote greater discipline among workers (Mambwe et al., 2021).

Similarly, the low loading factor for equipment examination highlights insufficient worker diligence in checking equipment before use, aligning with the low-scoring maintenance indicator under total safety management. To address this issue, contractor management should implement regularly scheduled equipment inspections and maintenance. It should be supported by providing employees tasked with equipment handling and safety checks with appropriate certifications and training programs.

The results for H3 confirm that safety culture has a positive and significant influence on safety behavior. This finding highlights that a strong safety culture effectively shapes safer behaviors among workers (Hu et al., 2021), emphasizing that robust safety behaviors stem from active employee involvement and consistent adherence to safety procedures. It is essential for management to demonstrate a clear and consistent safety commitment, actively involving employees in safety processes to foster a strong safety culture and positive behaviors. Moreover, a supportive work environment significantly enhances the formation of a safety culture, which is reinforced through direct managerial intervention (Jung et al., 2020; Shalimova et al., 2019). Proactive management intervention, including field supervision and direct communication, significantly influences workers' discipline, attitude, awareness, and adherence to safety standards, effectively embedding safety behaviors into daily practices (Nkrumah et al., 2021).

The results for H4 confirm that safety culture positively and significantly influences safety performance, highlighting that a strong safety culture directly contributes to enhanced project safety outcomes. These findings align with research by Hu et al. (2021), which suggests that active participation by workers and subcontractors, supported by strong managerial commitment, substantially reduces accidents on construction projects. Among the six indicators measuring safety performance—first aid injuries, recordable injuries, safety violations, severity, eligibility, and lost workdays—eligibility and lost workdays exhibit the highest factor loadings, indicating their critical role in assessing performance.

Furthermore, the reduced severity of incidents, observed as another significant indicator, corroborates Kim et al. (2019) that robust safety policies, effective safety control measures, and active involvement from subcontractors significantly mitigate severe incidents. Additionally, according to Jung et al. (2020), maintaining reliable and well-maintained equipment through regular management-supervised inspections and scheduled maintenance contributes significantly to improved safety performance. Thus, regular equipment maintenance programs, such as scheduled service of heavy equipment, become essential. Given that mechanical staff are often outsourced or temporary, contractor management should ensure that consistent and thorough safety inductions, training sessions, and daily toolbox meetings are provided for all personnel involved, regardless of their employment status, to maintain high safety standards.

The analysis indicates that first-aid injuries and safety violations have lower effectiveness scores. To mitigate risks related to first aid injuries, contractor management should implement comprehensive risk transfer strategies, including mandatory insurance coverage, readily accessible first aid kits, and the availability of an on-site emergency response team. According to Haas and Yorio (2019), proactive emergency preparedness significantly enhances workplace safety. Observations have noted insufficient preparedness in some projects, particularly those involving high-rise sites. Consequently, it is recommended that emergency response teams and first aid kits be strategically located on each floor of high-rise buildings. Then, according to Su (2021) and Winge et al. (2019), reinforcing emergency response capabilities is crucial to addressing safety violations, enhancing safety KPI, and improving overall organizational attention to safety practices.

The results of H5 indicate a positive and significant impact of safety behavior on safety performance, suggesting that improved safety behaviors directly lead to enhanced safety performance in construction projects. This finding aligns with previous research by Behie et al. (2020) and Ladewski and Al-Bayati (2019), emphasizing that observation and supervision significantly foster proactive worker attitudes toward safety. Regular documentation and reviews of incidents and near-misses should be systematically incorporated into KPI meetings to achieve zero fatal incidents. Safety improvements in the project environment require consistent changes in worker behaviors, including strict compliance with regulations and heightened safety awareness (Al-Bayati, 2021; Lee, 2022; Wang et al., 2019). Additionally, proactive management support is crucial to promptly addressing safety-related concerns. Given that tight project schedules significantly increase fatigue-related risks, it is recommended that contractor management systematically monitor worker fatigue levels, provide adequate staffing, introduce shift rotations, and utilize technological tools to maintain optimal worker alertness and ensure ongoing safe behaviors (Caldwell et al., 2019; Gu & Guo, 2022).

The combined hypotheses testing results demonstrate that strong indicators within TSM, safety culture, and safety behavior significantly support the achievement of sustainable safety performance. Thus, indicators with high loading factors should be consistently maintained and enhanced, while indicators with lower values require further managerial intervention and corrective actions. Specifically, the path coefficient analysis reveals that enhancing safety performance through TSM practices mediated by safety culture and behavior yields the most substantial impact. This result indicates that an effective and comprehensive safety management system, underpinned by robust managerial commitment, is critical for continuous improvements in project safety performance (Hu et al., 2021; Su, 2021; Winge et al., 2019).

These theoretical findings offer a comprehensive contribution by clearly identifying linkages between TSM, safety culture, and safety behavior in achieving sustainable safety performance. The research notably enhances the fields of OHS and construction project management by integrating safety management principles with human resource practices, providing a cohesive framework for understanding, and improving safety outcomes. Practically, the findings deliver actionable insights for industry practitioners by emphasizing the importance of adopting TSM principles to cultivate effective safety cultures and behaviors, thereby significantly enhancing safety performance in construction projects (Ladewski & Al-Bayati, 2019). It underscores the necessity for contractor management to closely monitor worker attitudes, risk perceptions, and fatigue levels, advocating for an integrated and comprehensive safety management system underpinned by strong managerial commitment, which is critical to continual safety improvement.

Ultimately, the successful implementation of TSM relies on the ongoing commitment and active participation of all organizational stakeholders, underscoring the continuous nature of quality management in OHS. One strategic approach for implementing TSM involves clearly defining health and safety objectives and standards, which all employees are collectively responsible for consistently applying in practice. Moreover, it is crucial for management to systematically identify and assess potential health and safety hazards in the workplace. This process includes risk identification, careful evaluation of potential impacts, and implementation of preventive measures.

Employee participation is essential in the development and refinement of health and safety procedures, underscoring the importance of regular and open employee feedback and sufficient safety training. Organizations must also establish ongoing mechanisms for measuring and evaluating their occupational health and safety performance, utilizing tools such as regular safety inspections, internal audits, and comprehensive performance data analysis. Subsequently, the results obtained should guide the continuous improvement of organizational quality management systems, focusing on promptly addressing identified weaknesses, devising corrective measures, and meticulously monitoring their effectiveness and implementation.

CONCLUSIONS

The findings demonstrate that both direct and indirect effects of TSM, safety culture, and safety behavior significantly enhance safety performance in construction projects. These results underscore the importance of integrating comprehensive safety practices and strong management commitment to achieving sustainable improvements in workplace safety. Contractor management must prioritize safety targets, such as zero fatal accidents, through periodic review meetings (at least once per semester) to evaluate safety performance and implement preventive measures. Encouraging worker compliance with safety rules and procedures through a combination of positive also reinforcement and appropriate disciplinary actions is critical to fostering a disciplined and safety-conscious workforce. Explicit managerial involvement is essential in shaping a safe workplace culture by promoting worker discipline, enhancing awareness of workplace hazards, and reducing unsafe conditions, close calls, and accidents. Regular and targeted training programs are necessary to ensure that employees are well-versed in safety procedures and develop safe work habits. Implementing a robust safety management system with regular monitoring and evaluations can significantly improve workers' discipline, concern for safety, attitudes, perceptions, and overall safety awareness. Workers' knowledge of risks and hazards can be enhanced through various interventions, such as safety inductions, safety audits, routine management-worker safety meetings, and daily toolbox meetings. This program is particularly beneficial in high-risk construction activities, such as casting, concrete work, welding, and working at elevated heights, where safety hazards are more prevalent. Moreover, contractor management must address worker fatigue, as it significantly compromises focus and concentration, increasing unsafe behaviors. Implementing sufficient rest breaks, shift rotations, and real-time fatigue monitoring systems should be integral components of safety management strategies.

Despite its valuable insights, the research has several limitations that should be acknowledged. First, the geographical focus is limited to four cities in East Java, Indonesia, which may affect the generalizability and applicability of the findings to other regions or countries. Second, the cross-sectional nature of the research limits its ability to effectively capture long-term changes in safety culture, behavior, and performance. Future research can benefit from adopting a longitudinal approach, which will enable researchers to observe the evolution and sustainability of safety practices over an extended period.

Practically, the research offers actionable insights for construction project managers and policymakers. The findings clearly highlight the importance of continuous safety training and integrating behavior-based safety interventions to promote a proactive and sustainable safety culture. Establishing explicit and measurable safety performance indicators, alongside their regular evaluation, can significantly assist organizations in achieving lasting improvements in safety outcomes.

Future research should explore additional critical factors influencing safety performance, such as the role of safety climate and psychological safety in shaping day-to-day workplace safety practices and perceptions. Investigating the impact of technological innovations, including real-time monitoring systems, predictive analytics, and digital safety tools, can provide valuable enhancements to current safety management strategies. Additionally, broadening the research scope to encompass various types of construction projects and different geographical regions will offer a deeper and more comprehensive understanding of factors affecting safety performance. Addressing these identified limitations and actively pursuing these recommended research directions will significantly contribute to the ongoing development of a robust and effective safety management framework within the construction industry.

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AUTHOR CONTRIBUTIONS

Conceived and designed the analysis, R. A., H. A. P., and W. S.; Collected the data, H. A. P. and B. I. P.; Contributed data or analysis tools, H. A. P., D.; Performed the analysis, R. A., H. A. P., D., W. S., and B. I. P.; and Wrote the paper, R. A.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of the research are available within the article [and/or] its supplementary materials.

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