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Examining Significant Factors Influencing Workers' Safety Behavior in Project Work Environments

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ABSTRACT

This study investigates the key factors influencing construction workers' safety behaviour, focusing on safety knowledge, safety awareness, safety intervention, and safety rules and procedures. A mixed-methods approach was employed, starting with a conceptual model developed through a literature review and validated via the Delphi method with safety experts. A quantitative survey was then conducted with construction workers, and data were analysed using partial least squares structural equation modeling (PLS-SEM) to test the hypothesised relationships. The findings show that safety knowledge and safety awareness have significant direct effects on safety behaviour. Safety rules and procedures impact safety behaviour both directly and indirectly by enhancing safety knowledge, while safety intervention plays a crucial role in shaping safe work practices. Additionally, importance–performance map analysis (IPMA) identified key areas that require immediate managerial focus for improving safety performance. This research contributes to the safety behaviour literature by providing an empirically validated model specific to the construction sector. Practically, it offers actionable insights for project managers and safety practitioners to develop targeted safety strategies that reduce occupational accidents in construction projects.

Keywords: *Safety behaviour; Construction safety; PLS-SEM; Importance–Performance Map Analysis; Occupational health and safety.*

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INTRODUCTION

Rapid developments across industries are driving organizations to become more adaptive and responsive to challenges, requiring them to carefully plan and control every ongoing job (Behie et al., 2023; Shan & Wang, 2024). Each work project has unique characteristics with a certain level of risk, including the execution of construction work. Construction work encompasses all or part of activities involving the construction, operation, maintenance, demolition, and redevelopment of structures (*Permen PUPR*, 2021). With increasing construction development, one key challenge is work planning, which affects future implementation.

In its implementation, each contractor must identify and determine construction safety hazards to outline them in the *Rencana Keselamatan Konstruksi* (*RKK*) document. This plan should cover engineering aspects, administrative controls, human behavior factors, and dynamic changes in construction work. It must also identify internal and external issues that could affect safety. Internal issues include the organization and mobilization of project resources, while external issues involve uncontrollable factors such as culture, the social environment, and aspects requiring cooperation with outside parties.

The absence or inadequacy of an appropriate *RKK* increases the risk of accidents due to poorly planned safety measures. According to *Permen Pekerjaan Umum* No. 05 of 2014, accident causes fall into two groups: individual factors (e.g., lack of knowledge, poor motivation, attitudes, and physical or mental issues) and work factors (e.g., poor work standards, inadequate planning, improper maintenance, and unconsidered design aspects).

Work accidents in the construction sector remain a significant problem, with workers' unsafe behavior as the primary cause. Unsafe work environment conditions, lack of *Keselamatan dan Kesehatan Kerja* (*K3*) training and awareness, and human error are the main factors contributing to accidents. Ineffective implementation of *K3* protocols by companies exacerbates this issue. In Indonesia, claims for Work Accident Insurance (*Jaminan Kecelakaan Kerja*, *JKK*) and Death Insurance (*Jaminan Kematian*, *JKM*) continue to rise annually, with the construction sector accounting for 40% of total work accident cases.

This problem is worsened by factors such as indifference to safety, age and experience, alcohol abuse, and mental distress, all leading to unsafe behavior. Efforts to mitigate work accidents—including improving safety behavior—are crucial for reducing risks, as various studies reveal a close relationship between unsafe behavior and work accidents (Afuaniyah et al., 2015; BPJS Employment, 2024; Gonçalves et al., 2008; Khosravi et al., 2014).

The purpose of this study is to identify dominant factors affecting workers' safety behavior in the construction sector and to develop strategic recommendations and prioritized follow-up actions applicable to construction projects for enhancing safety behavior and reducing work accident risks. Successful safety implementation depends heavily on workers' safety behaviors, supported by supervisors' and project management teams' commitment. Integrating contractors' and employers' experience and knowledge plays a significant role in risk reduction and project quality improvement.

This study examines relationships between variables influencing worker safety behavior in the workplace, using a model from prior research. According to Shin et al. (2015), safety behavior arises from complex interactions among safety climate factors, motivation, knowledge, and organizational commitment. Liang et al. (2022) note that construction workers' unsafe behavior is influenced by stress and insufficient safety awareness and knowledge. Meanwhile, Subramaniam et al. (2019) emphasize clear safety procedures for monitoring safety behavior, while Vinodkumar et al. (2010) show that such procedures enhance employees' safety knowledge, thereby improving safety behavior.

Zaira et al. (2017) also highlight effective safety interventions for changing workers' knowledge and attitudes toward safety. Based on this literature review, the study developed a conceptual model linking variables such as safety knowledge, safety awareness, safety procedures, and safety interventions—all influencing worker safety behavior in the work environment.

METHOD

The conceptual model for these safety behavior variables was compiled based on a combination of theoretical foundations and previous research. This model emphasizes the importance of several key factors that influence safety behavior, such as safety knowledge, safety awareness, and safety rules and procedures. For example, some studies have shown that safety behaviors are strongly influenced by consistent use of personal protective equipment (PPE), adherence to safety procedures, and a strong commitment to workplace safety (Shin et al., 2015; Ajayi et al., 2021; Liang et al., 2022).

In addition, safety knowledge, including understanding safety procedures, proper use of PPE, and awareness of potential hazards, plays an important role in creating a safe work environment (Kao et al., 2019; Aburumman et al., 2019). Safety awareness is also an important component, where workers who are aware of the risks in their environment tend to engage in safe practices (Liang et al., 2022; Xiang et al., 2023). Likewise, safety interventions, such as the responsibility to stop unsafe actions and support from superiors in ensuring safety, have been shown to significantly improve safety behaviors (Shin et al., 2015; Tear et al., 2020).

To ensure the validity and relevance of this conceptual model, the Delphi method is used to gather experts' opinions on its application in real-world construction projects. This process involves several rounds of evaluation by experts, leading to a consensus that confirms this model both theoretically and practically. By integrating theoretical insights and practical feedback, the model is designed to meet the construction industry's needs in improving safety behavior.

The study also used the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach to analyze the relationship between latent variables and observed indicators, ensuring a rigorous and comprehensive evaluation of factors influencing safety behavior (Vinzi et al., 2010). This approach not only strengthens the academic foundation of the research but also enhances its usefulness in workplace safety management.

RESULTS AND DISCUSSION

Determination of Safety Behaviour Variables

The variables that form *safety behavior* that have been collected are then validated by experts by filling out a questionnaire on five Likert scales consisting of 25 statements related to the observed variables that have been described. The purpose of this validation is to find out whether the observed variables can be used to measure the latent variables that have been determined by considering the parameters and aspects that affect the *safety behavior* of construction workers. The experts selected to validate come from several backgrounds, including teaching staff in the HSSE field and *supervisors* in the HSSE field for at least 2 years. Teaching staff are parties who provide materials and training in the field of HSSE, especially for field workers. Meanwhile, supervisors in the field of HSSE are field controllers who are responsible for ensuring the implementation of HSSE aspects in a company or project.

Table 1. Expert Profiles Validating Conceptual Models

Expert To	Departments	Experience in Related Fields
1	Supervisor HSSE	10 years
2	Supervisor HSSE	8 years
3	Supervisor HSSE	5 years
4	Teaching Staff	3 years
5	Teaching Staff	5 years
6	Supervisor HSSE	3 years
7	Supervisor HSSE	2 years
8	Supervisor HSSE	2 years
9	Supervisor HSSE	4 years
10	Teaching Staff	6 years

Furthermore, an expert assessment of the observed variables consisted of 25 statements. The selection of observed variables used in the study was carried out by calculating an average of 10 experts' assessments of each statement in the questionnaire. The assessment was carried out using a 5-point Likert scale, namely: (1) Very Not Appropriate, (2) Not Appropriate, (3) Doubtful, (4) Appropriate, and (5) Very Appropriate which can be seen.

Table 2. Results of Conceptual Model Validation According to Experts

Variable	Code	Questionnaire Description	Member Ratings										Average Score	Remarks
			1	2	3	4	5	6	7	8	9	10		
Safety Behaviour	SB1	I always use personal protective equipment (PPE) according to occupational safety standards.	5	5	5	5	5	5	4	4	4	4	4,6	Accepted
	SB2	I followed the established work safety procedures.	5	5	5	5	3	5	4	4	5	5	4,5	Accepted
	SB3	I immediately reported the unsafe conditions to my superiors.	5	5	5	5	5	5	3	5	4	5	4,6	Accepted
	SB4	I prioritize safety in every work activity.	5	5	5	5	4	5	4	4	3	4	4,3	Accepted
	SB5	I stop work if I find a potential serious hazard.	5	5	5	5	4	3	3	5	3	4	4,1	Accepted
Safety Knowledge	SK1	I understand the safety procedures that apply in this project.	5	5	5	5	3	3	3	5	5	5	4,3	Accepted
	SK2	I know how to use PPE correctly.	5	5	5	5	4	4	5	3	4	4	4,3	Accepted
	SK3	I understand the potential hazards associated with my work.	5	5	5	5	3	5	3	3	4	5	4,2	Accepted
	NQ4	I know the emergency response measures in case of an accident.	5	4	5	5	4	4	4	3	5	3	4,1	Accepted
	SK5	I regularly attend safety training on this project.	5	4	5	5	3	5	5	4	4	4	4,3	Accepted
Safety Awareness	SA1	I realized that my job had a high risk of accidents.	4	5	5	5	5	5	5	5	4	4	4,7	Accepted
	SA2	I always pay attention to the conditions of the work environment before starting work.	4	4	5	5	4	4	5	3	4	4	4,2	Accepted

	SA3	I am aware that careless actions can lead to fatal accidents.	5	5	5	5	4	3	3	4	5	3	4,1	Accepted
	SA4	I actively remind colleagues if there is an unsafe act.	4	5	5	5	3	5	4	5	3	4	4,2	Accepted
	SA5	I believe work accidents can be prevented with safe behavior.	4	5	5	5	4	4	3	5	4	5	4,3	Accepted
Safety Intervention	SC1	I feel responsible to stop work if I see an unsafe action.	4	5	5	5	3	3	4	4	3	5	4,0	Accepted
	SC2	I dare to reprimand colleagues who commit dangerous acts.	5	5	5	5	3	5	4	3	4	5	4,3	Accepted
	SC3	I believe that intervention against unsafe actions can save lives.	4	4	5	5	4	3	3	3	4	3	3,7	**Rejected**
	SC4	I felt supported by my superiors when I intervened in safety.	4	4	5	5	3	3	3	3	3	3	3,5	**Rejected**
	SC5	I actively encourage colleagues to keep each other safe.	4	4	5	5	4	4	3	3	4	5	4,0	Accepted
Safety Rules & Procedures	SR1	My company has clear and easy-to-understand safety rules.	4	4	5	5	3	5	3	4	5	5	4,2	Accepted
	SR2	I feel that I have received enough training regarding occupational safety rules and procedures.	5	5	5	5	3	5	3	5	5	3	4,3	Accepted
	SR3	Existing safety rules are consistently applied by all employees.	5	3	5	5	4	5	3	4	4	5	4,2	Accepted
	SR4	The regulations made by the company are in accordance with the company's business line	5	4	5	5	3	4	5	5	4	5	4,4	Accepted

	SR5	Safety procedures are well socialized to workers	4	4	5	5	3	5	5	4	5	3	4,2	Accepted

Pilot Test

The pilot test was carried out by collecting data on 20 questionnaire results which included 10 experts who tested the Conceptual Model to test the validity and reliability of research instruments and 10 data from workers referring to the results of the questionnaire that had been tested for validity and reliability by previous experts. This test was carried out on a number of indicators representing each variable in the research model with the main tests carried out in this stage being convergent validity measured through outer loading value and Average Variance Extracted (AVE), as well as internal reliability evaluated through Cronbach's Alpha using validated variables.

Table 3. Pilot Test Results

Variable	Code	Questionnaire Description	Outer Loading Value	Status Outer Loading	Average Variance Extracted (AVE)	Cronbach's Alpha	Status
Safety Behaviour	SB1	I always use personal protective equipment (PPE) according to occupational safety standards.	0,881	Meet the Criteria	0,674	0,876	Valid
	SB2	I followed the established work safety procedures.	0,706	Meet the Criteria			
	SB3	I immediately reported the unsafe conditions to my superiors.	0,870	Meet the Criteria			
	SB4	I prioritize safety in every work activity.	0,871	Meet the Criteria			
	SB5	I stop work if I find a potential serious hazard.	0,761	Meet the Criteria			
Safety Knowledge	SK1	I understand the safety procedures that apply in this project.	0,71	Meet the Criteria	0,657	0,867	Valid

	SK2	I know how to use PPE correctly.	0,869	Meet the Criteria			
	SK3	I understand the potential hazards associated with my work.	0,907	Meet the Criteria			
	SK4	I know the emergency response measures in case of an accident.	0,787	Meet the Criteria			
	SK5	I regularly attend safety training on this project.	0,764	Meet the Criteria			
Safety Awareness	SA1	I realized that my job had a high risk of accidents.	0,812	Meet the Criteria	0,604	0,833	Valid
	SA2	I always pay attention to the conditions of the work environment before starting work.	0,729	Meet the Criteria			
	SA3	I am aware that careless actions can lead to fatal accidents.	0,648	Not Meeting the Criteria			
	SA4	I actively remind colleagues if there is an unsafe act.	0,806	Meet the Criteria			
	SA5	I believe work accidents can be prevented with safe behavior.	0,874	Meet the Criteria			
Safety Intervention	SI1	I feel responsible to stop work if I see an unsafe action.	0,871	Meet the Criteria	0,748	0,833	Valid
	SI2	I dare to reprimand colleagues who	0,908	Meet the Criteria			

		commit dangerous acts.					
	SI5	I actively encourage colleagues to keep each other safe.	0,813	Meet the Criteria			
Safety Rules & Procedures	SR1	My company has clear and easy-to-understand safety rules.	0,635	Not Meeting the Criteria	0,544	0,787	Valid
	SR2	I feel that I have received enough training regarding occupational safety rules and procedures.	0,792	Meet the Criteria			
	SR3	Existing safety rules are consistently applied by all employees.	0,725	Meet the Criteria			
	SR4	The regulations made by the company are in accordance with the company's business line	0,692	Not Meeting the Criteria			
	SR5	Safety procedures are well socialized to workers	0,828	Meet the Criteria			

The validity of the convergence was tested by looking at *the outer loading value* of each indicator against the latent variable measured. Based on the criteria of Hair et al. (2017), the *accepted outer loading* value is ≥ 0.70 to state that the indicator has a strong enough contribution to latent constructs.

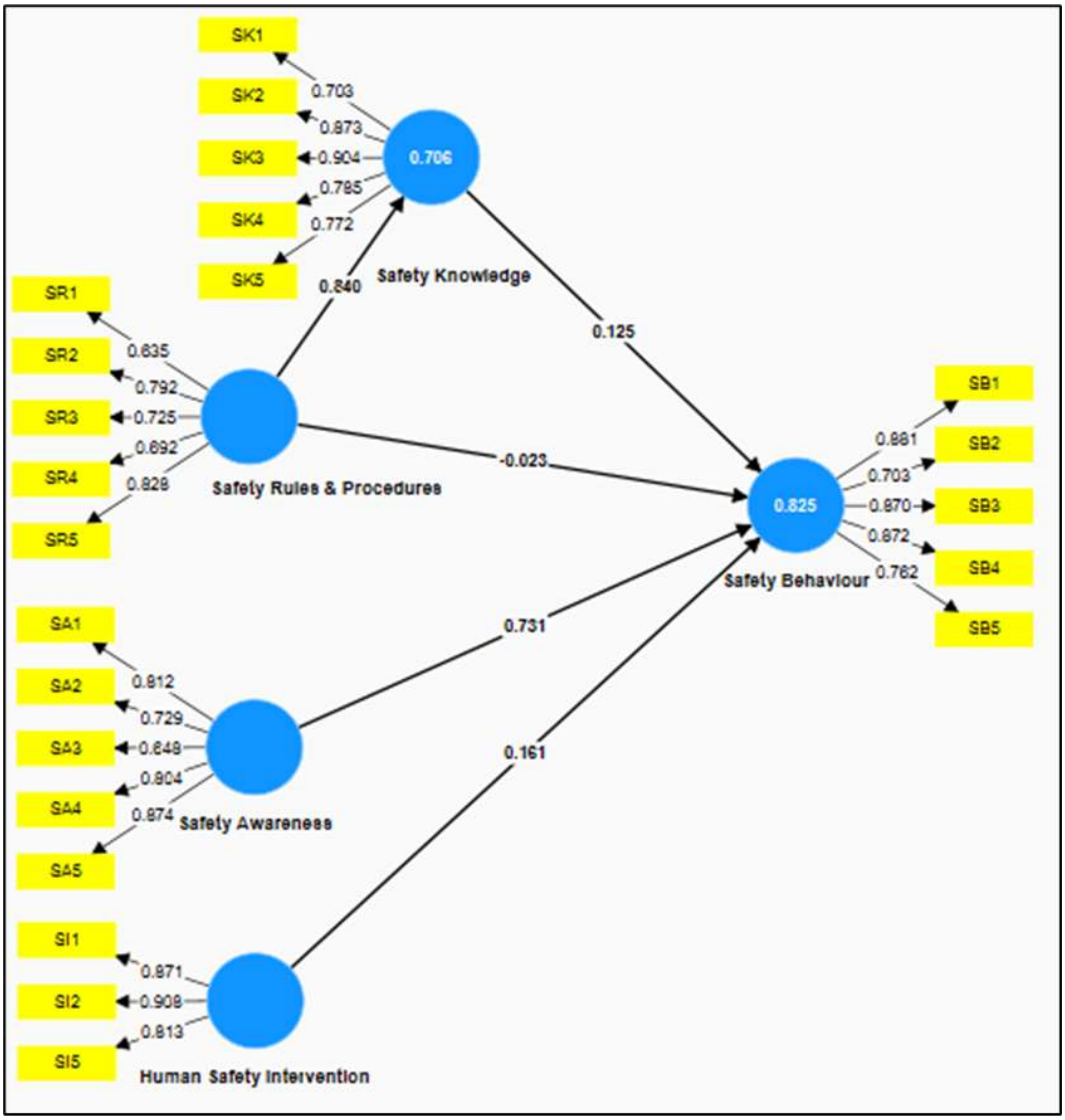

Figure 1. Research Models for Pilot Test Needs

From the test results, almost all indicators have an outer loading value above 0.70 so that it can be said to be valid in measuring the associated latent constructs. However, there are 3 indicators that are below the validity threshold so that these indicators are declared invalid and need to be removed from the model to improve the validity of the construct with the following list of statements: 1) SA3 (safety awareness), with a value of 0.648. 2) SR1 (safety rules & procedures), with a value of 0.635. 3) SR4 (safety rules & procedures), with a value of 0.692

In addition, the validity of the convergence was also evaluated through the Average Variance Extracted (AVE), where the AVE value ≥ 0.50 according to Hair et al. (2017) indicates that the standard latent variable is able to explain more than 50% of the variance of the indicators that measure it. The results of the analysis showed that all variables had an AVE value above 0.50 with the lowest value for the safety rules & procedures aspect of 0.544 while the highest value for the safety intervention aspect was 0.748 so that all variables were declared to have good convergent validity.

Next, the internal reliability of each construct is tested using Cronbach's Alpha, which measures the extent to which indicators in a single construct have internal consistency.

Cronbach's Alpha value that is considered good referring to Hair et al. (2017) is ≥ 0.70 which indicates that the instrument is reliable in measuring latent variables consistently.

The test results showed that all variables had a Cronbach's Alpha value above 0.70 with the lowest value of 0.787 for safety rules & procedures and the highest value of 0.876 safety behaviour. This shows that the whole construct has good reliability and can be used in further analysis.

Data Collection Process

Based on respondent profile data obtained from 187 respondents who met the research criteria, the characteristics of respondent data derived from various demographic factors, such as gender, age range, education level, and work location were conveyed. The analysis of the characteristics of the respondents provides a deeper understanding of the background and views of each individual on the implementation of safety behavior in the work environment of each respondent.

The distribution of respondents by gender showed that most of the respondents were men, namely 99 people (52.94%), while women amounted to 88 people (47.06%). This comparison illustrates that the composition of respondents is relatively balanced between men and women, although there is a slight dominance of male respondents so that perceptions or answers in the survey do not reflect a bias in the number of respondents referring to gender, as both groups are represented in almost equal numbers.

Respondents in this survey came from diverse age groups, ranging from 20 to 59 years old. The age group of 20-29 years is the category with the largest proportion, namely 57 respondents (30.48%). The age group of 30–39 years comprised 43 respondents (22.99%), while the 40–49 age group amounted to 46 respondents (24.60%). The oldest age group, which is 50–59 years, consisted of 41 respondents (21.93%). The distribution shows that respondents are dominated by young to middle-aged workers. This relatively even age composition provides a broad perspective on the phenomenon being studied, as it involves the views of workers of different ages.

In terms of education, respondents have diverse educational backgrounds. The majority of respondents were D4/S1 graduates, with a total of 97 people (51.87%), which shows that more than half of the respondents have a bachelor's education. High school graduates were the second largest group with 63 respondents (33.69%), followed by D3 graduates with 22 respondents (11.76%) and S2 graduates with 5 respondents (2.67%). This composition describes respondents having a secondary to high level of education.

Most of the respondents work in Batam, with a total of 131 people (70.05%). The second largest work location was Jakarta, with 49 respondents (26.20%). Meanwhile, other locations such as Cilegon, Medan, Sungai Pakning, Surabaya, and NTT only have 1-2 respondents, ranging from 0.53% to 1.07% each. The dominance of respondents from Batam shows that survey activities or the target population of the research are most likely concentrated in the region. Jakarta as the second center also makes a significant contribution, but not as much as Batam. Other locations have such a small representation that their contribution to overall outcomes is relatively limited.

Outer Model Processing

The evaluation of the outer model aims to measure how well the indicators in the model show the strength of the latent variables being measured. The outer model in this research was evaluated through validity and reliability testing. Validity ensures that the indicator actually measures the construct in question, while reliability indicates the consistency of the indicator in measuring the construct. This method is similar to the pilot test in the previous test, with the main tests performed in this stage being convergent validity measured through the outer loading value and Average Variance Extracted (AVE), as well as the internal reliability evaluated with Cronbach's Alpha.

Table 5. Outer Model Evaluation Results

Variable	Code	Questionnaire Description	Outer Loading Value	Status Outer Loading	Average Variance Extracted (AVE)	Composite Reliability	Cronbach's Alpha	Status
Safety Behaviour	SB1	I always use personal protective equipment (PPE) according to occupational safety standards.	0,883	Meet the Criteria	0,673	0,911	0,876	Valid
	SB2	I followed the established work safety procedures.	0,711	Meet the Criteria				
	SB3	I immediately reported the unsafe conditions to my superiors.	0,867	Meet the Criteria				
	SB4	I prioritize safety in every work activity.	0,873	Meet the Criteria				
	SB5	I stop work if I find a potential serious hazard.	0,754	Meet the Criteria				
Safety Knowledge	SK1	I understand the safety procedures that apply in this project.	0,698	Not Meeting the Criteria	0,658	0,905	0,867	Valid
	SK2	I know how to use PPE correctly.	0,876	Meet the Criteria				
	SK3	I understand the potential hazards associated with my work.	0,905	Meet the Criteria				
	NQ4	I know the emergency response measures in case of an accident.	0,79	Meet the Criteria				
	SK5	I regularly attend safety training on this project.	0,77	Meet the Criteria				
Safety Awareness	SA1	I realized that my job had a high risk of accidents.	0,865	Meet the Criteria	0,68	0,894	0,843	Valid
	SA2	I always pay attention to the conditions of the	0,735	Meet the Criteria				

		work environment before starting work.						
	SA4	I actively remind colleagues if there is an unsafe act.	0,845	Meet the Criteria				
	SA5	I believe work accidents can be prevented with safe behavior.	0,847	Meet the Criteria				
Safety intervention	SI1	I feel responsible to stop work if I see an unsafe action.	0,87	Meet the Criteria	0,748	0,899	0,833	Valid
	SI2	I dare to reprimand colleagues who commit dangerous acts.	0,909	Meet the Criteria				
	SI5	I actively encourage colleagues to keep each other safe.	0,813	Meet the Criteria				
Safety Rules & Procedures	SR2	I feel that I have received enough training regarding occupational safety rules and procedures.	0,825	Meet the Criteria	0,636	0,839	0,712	Valid
	SR3	Existing safety rules are consistently applied by all employees.	0,754	Meet the Criteria				
	SR5	Safety procedures are well socialized to workers	0,811	Meet the Criteria				

From the test results, almost all indicators have an outer loading value above 0.70 so that it can be said to be valid in measuring the associated latent constructs. However, for the SK1 aspect, it has an indicator that is below the validity threshold so that this indicator is declared invalid and removed from the model for inner model measurement.

In addition, the validity of the convergence was also evaluated through the Average Variance Extracted (AVE), where the AVE value ≥ 0.50 according to Hair et al. (2017) indicates that the standard latent variable is able to explain more than 50% of the variance of the indicators that measure it. The results of the analysis showed that all variables had an AVE value above 0.50 with the lowest value for the safety rules & procedures aspect of 0.636 while the highest value for the safety intervention aspect was 0.748 so that all variables were declared to have good convergent validity.

In the aspect of composite reliability, according to Cheung et al. (2023) the value is based on a congeneric model that does not require an equal loading factor between items, with a value greater than or equal to 0.7, it can be said that there is composite reliability in the measurement results. The test results showed that all variables had a composite reliability value above 0.70 with the lowest value of 0.839 for safety rules & procedures and the highest value of 0.911 for the safety behavior aspect. This shows that the whole construct has good reliability and is used in further analysis.

Next, the internal reliability of each construct is tested using Cronbach's Alpha, which measures the extent to which indicators in a single construct have internal consistency. Cronbach's Alpha value that is considered good referring to Hair et al. (2017) is ≥ 0.70 which indicates that the instrument is reliable in measuring latent variables consistently. The test results showed that all variables had a Cronbach's Alpha value above 0.70 with the lowest value of 0.712 for safety rules & procedures and the highest value of 0.876 safety behaviour. This shows that the whole construct has good reliability and can be used in further analysis.

To adjust to the research, the following is a research model that shows *outer loading* after the improvement where this improvement is in the form of removing the SK1 aspect as a parameter below the validity threshold.

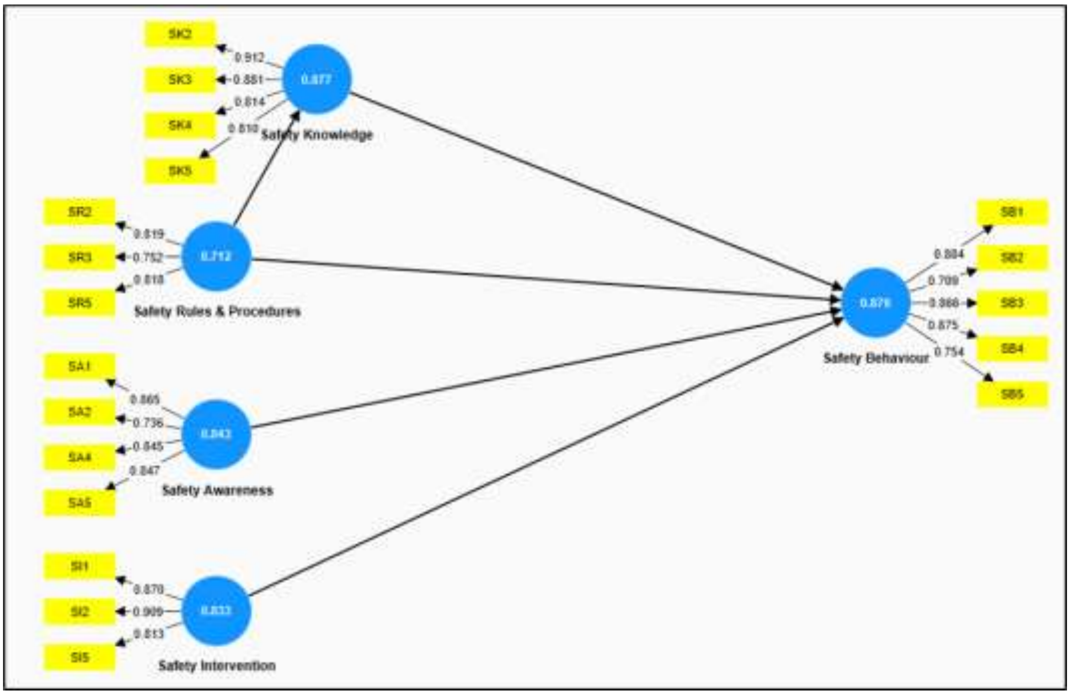

Figure 2. Research Model after Outer Loading Adjustment

From the measurement results, it is conveyed that all parameters of convergent validity & reliability have been met. The next process is the determination of cross loading which aims to ensure that the value of each indicator factor must be greater in each construct than in the other constructs. The cross loading test can be seen in Table 7 as follows.

Table 7 Cross Loading Each Indicator & Latent Variable

Indicator	Safety Awareness	Safety Behaviour	Safety Intervention	Safety Knowledge	Safety Rules & Procedures
SA1	0,865	0,646	0,005	0,517	0,479
SA2	0,736	0,598	0,492	0,785	0,55
SA4	0,845	0,739	0,43	0,62	0,71
SA5	0,847	0,84	0,488	0,501	0,507
SB1	0,796	0,884	0,31	0,706	0,552
SB2	0,651	0,709	0,489	0,763	0,749
SB3	0,728	0,866	0,261	0,506	0,539
SB4	0,742	0,875	0,648	0,667	0,525

SB5	0,627	0,754	0,56	0,397	0,364
SI1	0,491	0,488	0,87	0,317	0,137
SI2	0,373	0,556	0,909	0,576	0,379
SI5	0,252	0,367	0,813	0,353	0,324
SK2	0,667	0,652	0,477	0,912	0,568
SK3	0,719	0,821	0,57	0,881	0,758
NQ4	0,477	0,529	0,313	0,814	0,671
SK5	0,581	0,524	0,286	0,81	0,678
SR2	0,463	0,528	0,133	0,552	0,819
SR3	0,511	0,618	0,394	0,616	0,752
SR5	0,639	0,445	0,228	0,764	0,818

Evaluation of the Inner Model

The evaluation of the inner model aims to test the relationship between latent constructs in the structural model and assess the extent to which the model can explain the dependent variables. The evaluation of the inner model was carried out through several stages of testing the determination coefficient in the form of the determination coefficient (R^2), effect size (f^2), path coefficient, and significance test through P-Value.

The determination coefficient (R^2) test was to show how much proportion of the variance of endogenous (bound) variables could be explained by independent variables relying on assessments of 0.75, 0.50, and 0.25 which showed a large, medium, or weak level of prediction accuracy, respectively. The following are attached the results of the R^2 assessment as follows.

Table 8. Measurement Results R^2

Parameter	R^2	R^2 *Adjusted*
Safety Behaviour	0,809	0,758
Safety Knowledge	0,664	0,645

Table 9. Measurement results f^2

Parameter	Value f^2
Safety Awareness > Safety Behaviour	0,956
Safety Intervention > Safety Behaviour	0,114
Safety Knowledge > Safety Behaviour	0,044
Safety Rules & Procedures > Safety Behaviour	0,001
Safety Rules & Procedures > Safety Knowledge	1,975

Referring to measurement, a very large effect was obtained for the aspect of safety awareness > safety behavior and the aspect of safety rules & procedures > safety knowledge which means that the model is able to explain the significant proportion of effects on dependent variables. Furthermore, the aspects of safety intervention > safety behavior and safety knowledge > safety behavior are in the range of 0.02 to 0.35, so the effect is medium. However, in the aspect of safety rules & procedures, > safety behavior has a value below 0.02, so that this parameter has no effect on dependent variables from the aspect of safety knowledge.

The next procedure is to calculate the relationship between variables through the path coefficient which is the main parameter in the PLS-SEM structural model. This method is used to measure the strength and direction of the relationship between latent constructs. The greater the value of the path coefficient (closer to +1 or -1), the stronger the influence exerted by the independent construct on the dependent construct. The interpretation of this direct influence is the basis for confirming the main hypothesis in the research, as well as providing an initial understanding of the role of each variable in the developed model.

Meanwhile, the significance test was evaluated through *t-statistic* and *p-value values.* This calculation is carried out through a bootstrapping *procedure.*The decision-making methods based on Hair et al. (2019) that can be taken are: if *the p-values* > 0.05 or *the t-statistic* < 1.96, then Ho is accepted and Ha is rejected. if *the p-values* < 0.05 or *the t-statistic* > 1.96, then Ho is rejected and Ha is accepted. The following are the results of the *internal interpretation of the model* described in the form of *a* path *coefficient* model and hypothesis test through *the bootstrapping method* according to the following table.

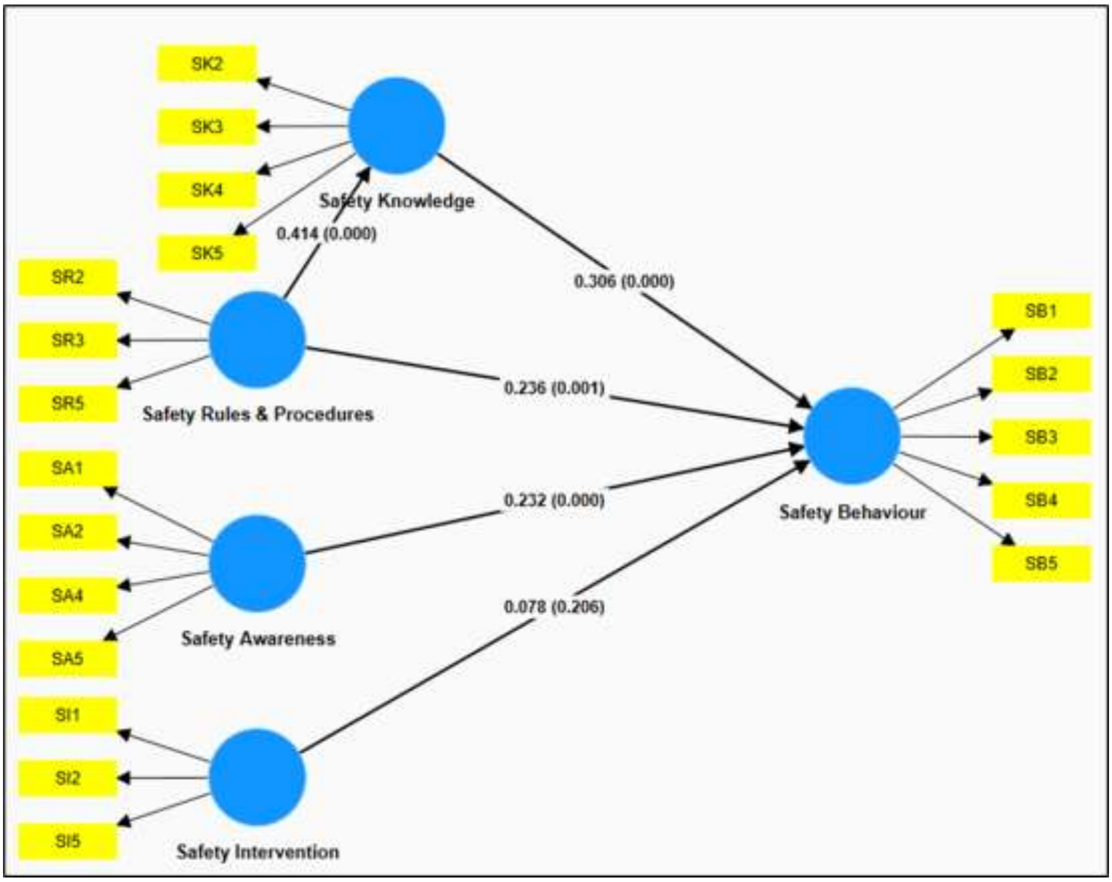

Figure 4. Results Path Coefficient

Table 10. Significance Test Results

Hypothesis	Parameter	Path coefficient	T-statistics (>1,96)	P-Value (<0,05)	Remarks
H1	*Safety Awareness > Safety Behaviour*	0,232	3,625	0,000	Positive, significant effect
H2	*Safety Intervention > Safety Behaviour*	0,078	1,266	0,206	Low level of influence, low level of significance
H3	*Safety Knowledge > Safety Behaviour*	0,306	4,378	0,000	Positive, significant effect
H4	*Safety Rules & Procedures > Safety Behaviour*	0,236	3,388	0,001	Positive, significant effect

H5	*Safety Rules & Procedures > Safety Knowledge*	0,414	5,782	0,001	Positive, significant effect

H1 (accepted): *safety awareness* has a significant positive effect on *safety behaviour*
H2 (accepted): *safety intervention* had no positive effect and did not significantly affect *safety behaviour*
H3 (accepted): *safety knowledge* has a significant positive effect on *safety behaviour*
H4 (accepted): *safety rules & procedures* have a significant positive effect on *safety behaviour*
H5 (accepted): *safety rules & procedures* have a significant positive effect on *safety knowledge*

In the results of the study, the hypothesis H1, H3, H4, and H5 have positive and significant information, which means that the relationship between these constructs has a significant effect between independent constructs and dependent constructs. Meanwhile, H2 has results that affect safety *behavior constructs,* but according to Hair et al. (2019) the level of significance and influence of the H2 hypothesis is not as high as other hypotheses.

Priority Parameter Determination Process through IPMA

Data processing using the IPMA method is carried out in several stages, namely checking IPMA requirements, calculating performance value, calculating importance value, and creating an importance and performance map which is carried out with the help of SmartPLS4 software.

The first check of IPMA requirements is to ensure that the scale used uses a metric scale. This first requirement has been met because this study uses a metric scale. Furthermore, it is necessary to ensure that all indicators have the same scale direction where all indicator values have positive values. The last check is to look at the estimated outer weight value of each indicator where the value must be positive. This value shows that all outer weight values have a positive value according to the previous study

The next stage is the calculation of performance values and importance values that will be used as a reference for making an importance-performance map with the target of constructing safety behavior. Performance value is the achievement or performance score of a latent variable against the target construct that has been scored in the range of 0-100. Meanwhile, the importance value is the total value of the effect of a latent variable on the target construct, where the value is obtained from the SmartPLS4 software. In this study, IPMA was carried out to find out which constructs need to be prioritized for improving the safety *behavior aspect*. Table 11 shows the performance value and *importance* of *the safety behavior* variable at the construct level.

Table 11. Performance and *Importance* Values at the Construct Level

Variable Leave	*Performance*	*Importance*
Safety Awareness	61,758	0,232
Safety Intervention	58,197	0,078
Safety Knowledge	66,026	0,306
Safety Rules & Procedures	63,815	0,363

Table 12. ***Performance*** **and** ***Importance*** **Values at the Indicator Level**

Indicator	Performance	Importance
SA1	0,103	67,558
SA2	0,102	58,021
SA4	0,102	59,358
SA5	0,079	62,834
SI1	0,036	58,556
SI2	0,043	58,289
SI5	0,037	57,754
SK2	0,153	56,150
SK3	0,170	71,658
NQ4	0,119	67,914
SK5	0,043	75,267
SR2	0,212	54,278
SR3	0,161	71,836
SR5	0,153	68,806

Final Discussion of Research Model

The research results reveal that the respondent distribution was nearly balanced in terms of gender, with an equal representation of male and female participants, suggesting that the study was not dominated by a particular gender perspective. Respondents spanned a wide age range (20-59 years), indicating variance in age, and 54.54% held at least a bachelor's degree (S1). These demographic characteristics suggest that the sample is representative in terms of gender, age, education, and the construction project environment. However, factors like gender, age, education, and work location can influence the variance in the data. Furthermore, the test results showed that safety awareness significantly positively affects safety behavior, with a path coefficient of $\beta = 0.232$, t-statistics of 3.625, and a p-value of 0.000. The high t-statistics value confirms that workers with greater safety awareness tend to exhibit better safety behavior, complying more with safety procedures.

In the relationship between safety intervention and safety behavior, the path coefficient value $\beta = 0.078$ with t-statistics of 1.266 and p-value of 0.206 was obtained. These results show that there is still a low positive influence and significance of the safety intervention aspect, because the t-value is below the minimum limit of 1.96 and the p-value exceeds 0.05. Thus, safety interventions such as periodic training, supervision, or safety campaigns have not been able to have a real impact on changes in worker safety behavior. This can indicate that the intervention program implemented is not optimal, inconsistent, or not effectively accepted by workers.

Safety knowledge showed a positive and significant influence on safety behavior with a path coefficient value of $\beta = 0.306$, t-statistics 4.378, and p-value 0.000. These results prove that the higher the workers' knowledge related to occupational safety, the better the safety behavior shown. Knowledge includes the ability to understand safety procedures, recognize potential hazards, and know accident prevention measures. Therefore, increasing the knowledge capacity of workers is one of the important factors in strengthening safety behavior.

The relationship between safety rules & procedures and safety behaviour also showed a positive and significant influence. The path coefficient value of $\beta = 0.236$, t-statistics 3.388, and p-value 0.001 indicate that clear, consistent, and easy-to-understand safety rules and procedures are able to improve worker safety behavior. This emphasizes that a good safety regulation system is an important guideline for workers in carrying out work activities safely.

Testing the relationship between safety rules and procedures and safety knowledge yielded a path coefficient value of $\beta = 0.414$, t-statistics 5.782, and p-value of 0.000. As such, the relationship is positive and significant, and is the strongest influence among all the relationships tested. This means that the proper implementation of safety rules and procedures is able to increase workers' knowledge related to work safety. Systematic and easy-to-understand procedures help workers gain a better understanding of the risks and how to prevent them.

The PLS-SEM analysis reveals that safety awareness, safety knowledge, and safety rules & procedures significantly influence safety behavior. However, safety intervention shows a low level of positive influence on safety behavior, indicating the need for a re-evaluation of the intervention program’s effectiveness. Safety rules & procedures play a key role in both safety behavior and improving workers' safety knowledge. Among the various aspects, safety knowledge has the most significant impact on safety behavior, as evidenced by the highest path coefficient, t-statistics, and the lowest p-value.

This is further supported by safety knowledge, which is shaped by safety rules & procedures, demonstrating a positive and significant influence in the bootstrapping results. In the IPMA analysis, safety awareness, safety knowledge, and safety rules & procedures fall into quadrant 1, signifying their strong and significant influence on safety behavior. In contrast, safety intervention is positioned in quadrant 2, suggesting that while it performs well, it is less important for shaping safety behavior. This is consistent with the inner model’s findings, where safety intervention lacks significant influence on safety behavior and is ranked lowest in terms of importance compared to other aspects. This indicates a challenge for management in prioritizing safety intervention as a crucial factor in fostering safety behavior within the company.

CONCLUSION

This study identifies four main variables that affect worker safety behavior in construction projects, namely safety knowledge, safety awareness, safety rules & procedures, and safety intervention. The results showed that safety awareness, safety knowledge, and safety rules & procedures had a positive and significant effect on safety behavior, while safety interventions showed a lower effect. To improve safety behavior, the main recommendation is to strengthen human-based safety systems, including increasing safety knowledge and safety awareness through safety training and briefing, as well as simplifying and affirming safety rules & procedures. In addition, the implementation of integrated technical interventions, such as technical protection, hazard control engineering, and periodic safety inspections, is also required. Strengthening the safety culture through the example of supervisors and the active participation of workers in safety activities will strengthen the implementation of safety behaviors and reduce the risk of accidents in the project environment. Future studies could longitudinally track the long-term efficacy of these interventions across diverse construction project scales and regions in Indonesia, incorporating quantitative metrics like accident rates and qualitative worker feedback to refine models and test moderating factors such as organizational culture or technological aids (e.g., AI-driven safety monitoring).

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