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The Effect of Occupational Health and Safety (OHS) Knowledge and Heavy Equipment Maintenance in Coal Bulk Carrier Loading–Unloading Operations on Hazard Control and Its Implications for Work Safety at PT Puradika Bongkar Muat Makmur, Taboneo Sea, South Kalimantan

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Abstract: Loading and unloading activities involve a high risk of accidents, particularly in the operation of wheel loaders, bulldozers, and ship cranes, thus requiring strengthened occupational safety and health (OSH/K3) competence and optimal equipment maintenance. This study aims to examine and analyze the effect of OSH knowledge and heavy equipment maintenance for ship-based loading and unloading on hazard control and its implications for occupational safety at the work area of PT Puradika Bongkar Muat Makmur Laut Taboneo, South Kalimantan. The study employed a quantitative approach with a cross-sectional design. The population consisted of 53 wheel loader and bulldozer operators (organic employees) and 50 ship crane operators (subcontract workers), totaling 103 respondents using a total sampling technique. Data were collected through questionnaires and OSH report documentation, and analyzed using SmartPLS. The results indicate that OSH knowledge and heavy equipment maintenance have a positive and significant effect on hazard control, with equipment maintenance showing the most dominant influence. Furthermore, OSH knowledge, equipment maintenance, and hazard control have positive and significant effects on occupational safety, both directly and indirectly through hazard control as a mediating variable. These findings highlight that improved risk understanding, effective condition monitoring, and the implementation of technical controls contribute to reducing workplace accident potential in loading and unloading operations. The study recommends enhancing emergency response training through simulation-based programs, strengthening digital-based spare parts management systems, and optimizing engineering controls in the work area to minimize risks. In addition, reinforcing behavior-based safety programs and conducting periodic safety evaluations are essential to reduce accident rates and property damage. These strategies are expected to improve occupational safety performance in a sustainable manner.

Keyword: OHS Knowledge, Heavy Equipment Maintenance, Hazard Control, Work Safety.

INTRODUCTION

PT Puradika Bongkar Muat Makmur (PBMM) is a cargo handling company that operates professionally and efficiently by implementing reliable operational procedures and utilizing adequate, high-quality equipment. As part of the coal supply chain within the Adaro Group, PBMM has, up to 2024, secured a captive market from Adaro's shipping operations, serving PT Adaro Indonesia and PT Maruwai Coal in coal loading and unloading activities in Taboneo waters, Banjarmasin, South Kalimantan. As the largest stevedoring company in the region, PBMM has become a role model for similar companies. To enhance coal throughput and human resource quality, PBMM conducts weekly evaluations and continuous knowledge-sharing programs, including regular updates of SOPs and work instructions.

Figure 1. Work Area of PT PBMM in Central and South Kalimantan

In its operations, PBMM relies heavily on the competence of heavy equipment operators working on vessels in Taboneo waters. Occupational Health and Safety (OHS) knowledge among operators includes fundamental understanding of coal loading techniques, maintenance and inspection procedures (P2H) for wheel loaders and bulldozers, and safety practices on board. In addition, operators are required to possess practical skills in operating and maintaining heavy equipment properly, as well as comprehensive knowledge of workplace safety procedures, accident risks, and preventive measures.

However, workplace accidents in Taboneo operations remain a concern and may involve various factors. These include accident frequency, types of incidents such as equipment-related injuries or property damage, and human errors during operations. Furthermore, investigations into accident causes often reveal issues such as insufficient training, procedural violations, and malfunctioning equipment. The severity of damage and injuries is also documented, along with preventive actions such as additional training, improved maintenance, and procedural adjustments.

Adequate OHS knowledge equips operators with the ability to identify, prevent, and respond to hazardous situations effectively. Through proper training and guidance, workers can better understand risks associated with offshore loading activities. However, several issues have been identified, including insufficient training programs and the absence of standardized OHS manuals or handbooks. Additionally, limited training time for proper operation of wheel loaders and bulldozers during coal loading activities reduces the effectiveness of skill development among operators.

Another critical issue lies in the condition of heavy equipment used by PBMM. As of 2024, a significant proportion of wheel loaders and bulldozers have exceeded the recommended operational lifespan of five years. Approximately 83% of the equipment is categorized as aged, with visible deterioration such as rust and corrosion, particularly in critical components like buckets. This condition poses a serious risk to operational safety and increases the likelihood of equipment failure.

Proper equipment condition is essential to ensure safe and efficient operations. Routine inspections (P2H), timely maintenance, and repair are necessary to prevent hazards such as equipment breakage or coal contamination caused by damaged components like blades or end bits. Failures may occur when corroded parts break upon impact, such as when hitting a manhole inside a barge. Therefore, maintaining equipment reliability is crucial in minimizing operational risks and ensuring safety compliance.

Based on initial Gemba inspections conducted in early 2024, numerous heavy equipment units were found to be in poor condition, requiring immediate maintenance and repair. Common types of damage include structural wear, component failure, and corrosion-related issues. These findings highlight the urgent need for systematic evaluation of equipment conditions, identification of potential hazards, and implementation of corrective actions to prevent accidents and operational disruptions.

Several research gaps have also been identified. Previous studies, such as Novi Indah Susanthi and Iqlima Puspa Seruni (2016), primarily focused on the relationship between training and OHS performance without examining the role of equipment condition and hazard control. Similarly, studies by Prasadja (2021) and R. Fitriana & L.R. Sari (2020) emphasized individual behavior and PPE compliance, while Yogendra Bhattacharya (2015) explored safety culture without linking it to equipment conditions. Therefore, this study aims to address these gaps by investigating how heavy equipment conditions and hazard control contribute to improving OHS knowledge and, ultimately, reducing workplace accidents among PBMM operators.

METHOD

This study adopts a quantitative research design using a survey approach, which enables systematic, measurable, and objective data analysis through statistical procedures (Sekaran & Bougie, 2020). The research is non-interventional, as data are collected without manipulating the subjects, relying instead on questionnaire responses from workers at PT Puradika Bongkar Muat Makmur Laut Taboneo, South Kalimantan. It also applies a case study approach, focusing on a single organizational context to ensure respondent homogeneity and consistent evaluation of the same work environment. Based on the time dimension, this study is classified as a cross-sectional study, where data were collected once during the period of February to July 2026. The use of hypothesis testing with inferential statistics aims to determine whether relationships among variables are statistically significant and generalizable to a broader population (Sekaran & Bougie, 2016; 2020).

The data used in this research consist of both primary and secondary data. Primary data were collected directly from respondents through structured questionnaires distributed online using Google Forms, following predetermined criteria to ensure respondent relevance (Sugiyono, 2016). The questionnaire employed a Likert scale with five response options, ranging from strongly disagree to strongly agree, to measure variables such as OHS knowledge, heavy equipment maintenance, hazard control, and work safety. In addition, observations were conducted using a non-participant and unstructured approach to capture real conditions in the field. The study population consisted of 103 heavy equipment operators involved in coal loading and unloading activities, including wheel loader, bulldozer, and crane operators. Due to the relatively small population size, a saturated sampling technique (total sampling) was applied, allowing all members of the population to be included as respondents (Sugiyono, 2019).

Data analysis in this study utilizes Structural Equation Modeling (SEM) with the Partial Least Squares (PLS) approach, which is suitable for predictive analysis and does not require strict assumptions such as normal data distribution or large sample sizes (Ghozali, 2017; Suliyanto, 2019). The analysis includes evaluation of the outer model to assess validity and reliability through indicators such as loading factors, Average Variance Extracted (AVE), Composite Reliability, and Cronbach's Alpha. The inner model is evaluated using R-square, Q-square, and goodness-of-fit indices such as SRMR and NFI to determine the strength and predictive relevance of the model. Hypothesis testing is conducted using bootstrapping to examine the significance of path coefficients, where a T-statistic greater than 1.96 and a p-value less than 0.05 indicate significant relationships. Furthermore, mediation analysis is performed to assess indirect effects through hazard control, providing a comprehensive understanding of both direct and indirect relationships among variables in the model.

RESULTS AND DISCUSSION

Results

Outer Model Result

In this study, inferential analysis was conducted using a multivariate statistical approach through Partial Least Squares–Structural Equation Modeling (PLS-SEM). The evaluation of the outer model (measurement model) aims to assess the relationship between reflective indicators and their respective latent constructs using SmartPLS 4 (Calculate – PLS Algorithm). The results show that all 60 indicators have outer loading values ≥ 0.70, indicating strong indicator reliability and internal consistency as suggested by Hair et al. (2019). This confirms that all indicators are valid and reliable, and no indicators need to be eliminated. Therefore, the measurement model is considered adequate and can be further analyzed in the structural model stage.

Figure 2. Outer Model Results (PLS Algorithm)

Table 1. Summary of Outer Model

Variable / Relationship	Key Result	Interpretation
Outer Loading	≥ 0.70	All indicators valid and reliable
AVE	0.596 – 0.721	All constructs valid (> 0.50)
Cronbach's Alpha	0.951 – 0.972	High internal consistency
Composite Reliability	0.957 – 0.975	Strong construct reliability
Coefficient Path		
X1 → Y	0.374	Positive, moderate effect
X2 → Y	0.590	Strongest effect on hazard control
X1 → Z	0.256	Positive effect
X2 → Z	0.376	Stronger than X1
Y → Z	0.348	Positive effect
X1 → Y → Z	0.130	Indirect effect
X2 → Y → Z	0.205	Stronger indirect effect

Source: SmartPLS Output (2026)

a. Convergent Validity

The convergent validity assessment shows that all indicators have outer loading values above 0.70, confirming their validity in measuring their respective constructs. The highest dimension in OHS Knowledge (X1) is Risk and Consequence Understanding (0.964), with indicator X1.10 (0.960) as the strongest reflection, while Decision-Making Ability (0.926) is relatively lower but still strong. For Heavy Equipment Maintenance (X2), the highest dimension is Condition Monitoring (0.939), with X2.9 (0.926) as the strongest indicator, while Spare Part Planning (0.786) requires improvement. In Hazard Control (Y), Risk Assessment (0.949) is dominant with indicator Y5 (0.908), while Technical Control (0.910) is relatively lower. In Work Safety (Z), Nearmiss & Incident Reporting (0.898) is the strongest dimension, while Accident Ratio (0.860) is relatively lower but still within the strong category.

b. Average Variance Extracted (AVE)

The AVE results indicate that all constructs meet the threshold of > 0.50, confirming good convergent validity at the construct level. Specifically, OHS Knowledge (0.721), Heavy Equipment Maintenance (0.622), Hazard Control (0.632), and Work Safety (0.596) all demonstrate sufficient variance explained by their indicators. This confirms that each latent variable adequately captures the variance of its indicators and supports the validity of the measurement model.

c. Discriminant Validity

Discriminant validity testing using cross loadings and the Fornell-Larcker criterion shows that all constructs are distinct and do not overlap conceptually. Each indicator has a higher loading on its own construct compared to others, and all cross loading values exceed 0.70. Furthermore, the square root of AVE for each construct is higher than its correlations with other constructs, confirming that each variable measures a unique concept. These results indicate that the measurement model satisfies discriminant validity requirements and ensures the credibility of the constructs.

d. Construct Reliability

Construct reliability evaluation using Cronbach's Alpha and Composite Reliability confirms strong internal consistency across all variables. Cronbach's Alpha values range from 0.951 to 0.972, exceeding the threshold of 0.70, while Composite Reliability values (rho_c) range from 0.957 to 0.975, indicating high reliability without redundancy issues. Additionally, rho_a values fall between Cronbach's Alpha and Composite Reliability, supporting the robustness of the measurement model. These results confirm that all constructs are consistently measured by their indicators.

e. Coefficient Path

The path coefficient analysis shows positive relationships among all variables in the structural model. OHS Knowledge (X1) has a coefficient of 0.374 on Hazard Control (Y), while Heavy Equipment Maintenance (X2) has a stronger effect at 0.590. For Work Safety (Z), OHS Knowledge (0.256), Heavy Equipment Maintenance (0.376), and Hazard Control (0.348) all show positive influences, with maintenance having the strongest effect. Indirect effects through Hazard Control are also observed, with OHS Knowledge (0.130) and Heavy Equipment Maintenance (0.205) contributing to Work Safety. Overall, Heavy Equipment Maintenance is the most dominant factor influencing both Hazard Control and Work Safety.

Inner Model Result

After evaluating the outer model, the next step in PLS-SEM analysis is assessing the inner model (structural model), which aims to examine the relationships among latent variables and evaluate the predictive capability of the research model (Ringle et al., 2015; Memon et al., 2021).

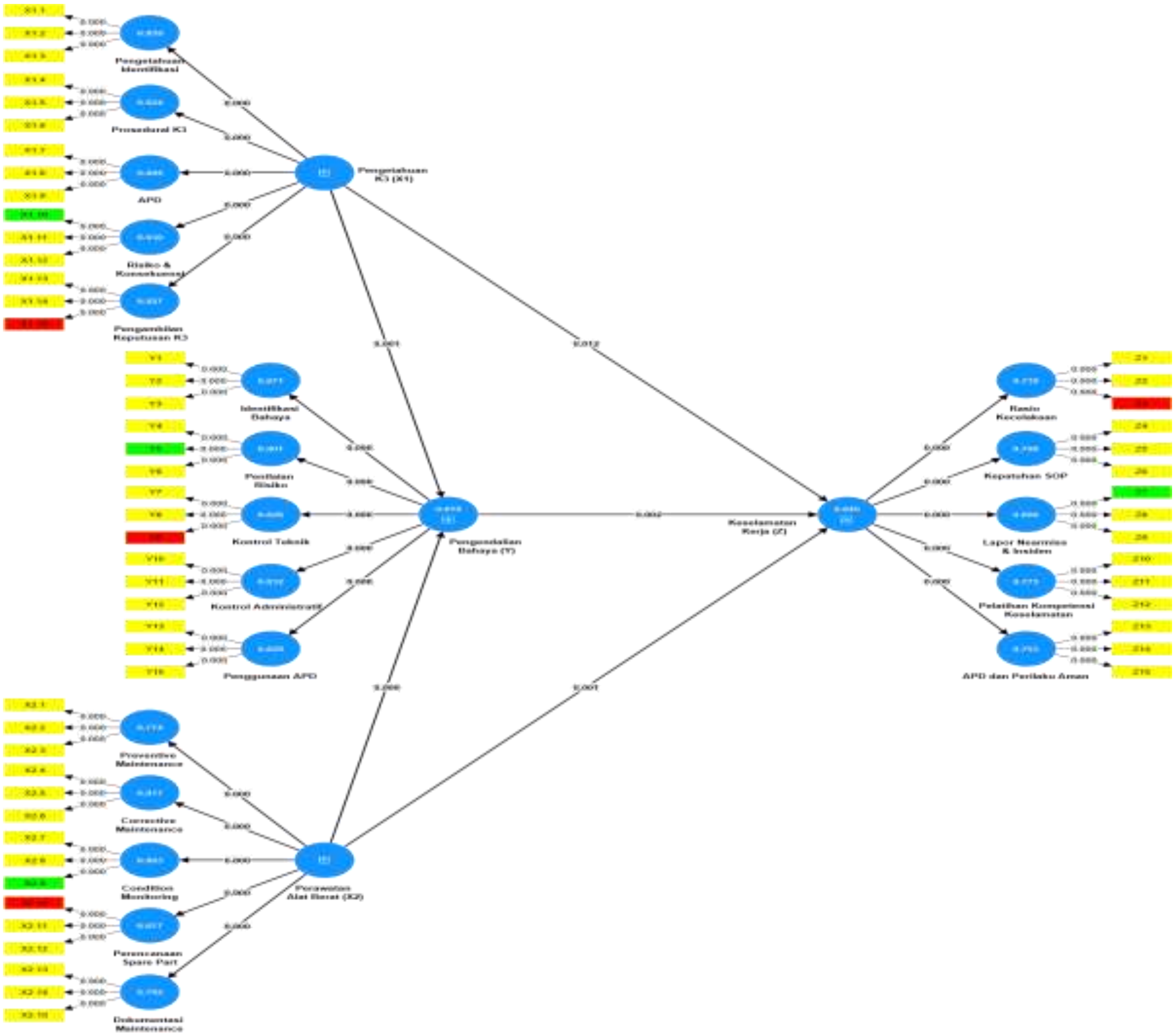

Figure 3. Inner Model Results (Bootstrapping)

Table 2. Summary of Inner Model Evaluation

Test	Variable / Indicator	Value	Interpretation
R-Square	Hazard Control (Y)	0.819	Strong explanatory power
R-Square	Work Safety (Z)	0.845	Strong explanatory power
Q-Square	Model Predictive Relevance	0.972	Very strong predictive capability
SRMR	Saturated Model	0.083	Acceptable fit
SRMR	Estimated Model	0.089	Acceptable fit
d_ULS	Saturated Model	49.740	Evaluated via bootstrap
d_ULS	Estimated Model	57.606	Evaluated via bootstrap

Source: SmartPLS Output (2026)

a. R-Square Test

The R-Square (R^2) test indicates the extent to which exogenous variables explain the variance of endogenous variables. The results show that Hazard Control (Y) has an R^2 value of 0.819, meaning that OHS Knowledge and Heavy Equipment Maintenance jointly explain 81.9% of its variance, while the remaining 18.1% is influenced by other factors outside the model. Similarly, Work Safety (Z) has an R^2 value of 0.845, indicating that OHS Knowledge, Heavy Equipment Maintenance, and Hazard Control explain 84.5% of its variance, with 15.5% explained by other variables. According to Chin (1998) and Hair et al. (2017), both values fall into the strong (substantial) category as they exceed 0.75.

b. Q-Square Test (Predictive Relevance)

The Q-Square (Q^2) value is used to evaluate the predictive relevance of the model. Based on the calculation $Q^2 = 1 – (1 – 0.819)(1 – 0.845)$, the result is 0.972, which is greater than 0 and close to 1. This indicates that the model has very strong predictive capability, explaining 97.2% of the variance in endogenous variables, while only 2.8% is influenced by external factors. Therefore, the structural model demonstrates high predictive relevance and is considered fit for further hypothesis testing.

c. Goodness of Fit

The Goodness of Fit (GoF) test evaluates the overall suitability of the model in representing empirical data. The results show that the SRMR values for both saturated (0.083) and estimated (0.089) models are close to the acceptable threshold of 0.08, indicating a reasonably good model fit. Although the d_ULS values (49.740 and 57.606) suggest some discrepancy between empirical and estimated correlation matrices, this measure is further assessed through bootstrap procedures to confirm statistical insignificance. Other indices such as Chi-square and Normed Fit Index (NFI) are not primary indicators in PLS-SEM. Overall, the model demonstrates an acceptable level of fit, meaning it is adequate for hypothesis testing, although there remains room for further refinement.

Hypothesis Testing Results

Table 3. Hypothesis Testing Results

Hypothesis	Relationship	Original Sample (O)	T-Statistics (|O/STDEV|)	P-Values	Result
H1	Occupational Safety Knowledge (X1) → Hazard Control (Y)	0,374	3,438	0,001	Supported
H2	Heavy Equipment Maintenance (X2) → Hazard Control (Y)	0,590	5,797	0,000	Supported
H3	Occupational Safety Knowledge (X1) → Work Safety (Z)	0,256	2,513	0,012	Supported
H4	Heavy Equipment Maintenance (X2) → Work Safety (Z)	0,376	3,351	0,001	Supported

Hypothesis	Relationship	Original Sample (O)	T-Statistics (|O/STDEV|)	P-Values	Result
H5	Hazard Control (Y) → Work Safety (Z)	0,348	3,107	0,002	Supported
H6	Occupational Safety Knowledge (X1) → Hazard Control (Y) → Work Safety (Z)	0,130	2,186	0,029	Supported
H7	Heavy Equipment Maintenance (X2) → Hazard Control (Y) → Work Safety (Z)	0,205	2,740	0,006	Supported

Source: SmartPLS Output (2026)

Discussion

The Effect of OHS Knowledge (X_1) on Hazard Control (Y)

Based on the hypothesis testing results, OHS knowledge (X_1) has a positive and significant effect on hazard control (Y). This is evidenced by a T-statistic value of 3.438, which exceeds the threshold of 1.96, and a P-value of 0.001, indicating significance at the 95% confidence level. The original sample value of 0.374 reflects a positive relationship, meaning that higher levels of OHS knowledge among workers lead to more effective hazard control. OHS knowledge includes the ability to identify risks, understand safety procedures, and make appropriate decisions, all of which are essential in minimizing workplace accidents. Therefore, hypothesis H1 is empirically supported.

The findings also indicate that OHS knowledge plays a critical role in enhancing hazard control effectiveness. Workers with strong understanding of risks and consequences tend to be more vigilant and capable of identifying hazards before work begins. They are also more compliant with standard operating procedures (SOP) and consistent in using personal protective equipment (PPE), which directly reduces workplace risks. These results are consistent with studies by Yeremia Giovanny (2016), who found that OHS training significantly influences accident prevention, and Wexley and Yulk in Mangkunegara (2009), who emphasized that training improves employee knowledge and safe work behavior. Similar findings were reported by M. Zaidan R et al. (2025) regarding risk control through HIRARC, Eka Putri Rahayu (2022) on SMK3 implementation, and Andi Hendrawan (2020) on the importance of OHS programs.

The Effect of Heavy Equipment Maintenance (X_2) on Hazard Control (Y)

The hypothesis testing results show that heavy equipment maintenance (X_2) has a positive and significant effect on hazard control (Y). This is supported by a T-statistic value of 5.797, which is far above 1.96, and a P-value of 0.000, indicating strong statistical significance. The original sample value of 0.590 suggests a strong positive relationship, meaning that better maintenance practices lead to more effective hazard control. Maintenance activities include routine inspections, condition monitoring, and spare parts availability, all of which help prevent equipment failure and potential hazards. Therefore, hypothesis H2 is empirically supported.

The findings highlight that equipment maintenance is a dominant factor in reducing workplace hazards. Well-maintained equipment has a lower risk of operational failure, which reduces the likelihood of accidents. Regular monitoring allows early detection of damage, while spare parts availability ensures quick repairs without disrupting operations. These results are in line with Gusrah (2021), who emphasized the importance of routine crane maintenance, and Yoga Aji (2021), who found that optimal maintenance improves loading and unloading processes. Furthermore, Shane Atsya Amara Dien and Ratna Purwaningsih (2024) and M. Zaidan R et al. (2025) confirmed that hazard control is closely related to equipment conditions, while Eka Putri Rahayu (2022) highlighted the role of technical control in OHS systems.

The Effect of OHS Knowledge (X_1) on Work Safety (Z)

The results indicate that OHS knowledge (X_1) has a positive and significant effect on work safety (Z). This is shown by a T-statistic of 2.513, exceeding 1.96, and a P-value of 0.012, confirming significance at the 95% confidence level. The original sample value of 0.256 indicates a positive relationship, meaning that higher OHS knowledge contributes to improved work safety. OHS knowledge involves understanding risks, following procedures, and using personal protective equipment properly, which directly influences safe work behavior. Thus, hypothesis H3 is empirically supported.

The findings suggest that OHS knowledge is essential in improving safety performance in operational environments. Workers with higher knowledge tend to be more disciplined, more compliant with safety procedures, and more proactive in anticipating hazards. This leads to a reduction in accidents and workplace incidents. These findings are consistent with Yeremia Giovanny (2016), Wexley and Yulk in Mangkunegara (2009), and Eka Putri Rahayu (2022), who all emphasize the importance of training and SMK3 in improving safety outcomes. Additionally, Andi Hendrawan (2020) and M. Zaidan R et al. (2025) confirmed that OHS knowledge contributes significantly to reducing workplace accidents.

The Effect of Heavy Equipment Maintenance (X_2) on Work Safety (Z)

Hypothesis testing shows that heavy equipment maintenance (X_2) has a positive and significant effect on work safety (Z). This is indicated by a T-statistic of 3.351, which is greater than 1.96, and a P-value of 0.001, confirming statistical significance. The original sample value of 0.376 indicates a positive relationship, meaning that better maintenance practices enhance work safety. Maintenance activities such as inspections, repairs, and condition monitoring help prevent equipment failure and reduce accident risks. Therefore, hypothesis H4 is supported.

The findings reveal that well-maintained equipment significantly contributes to safer working conditions. Equipment in optimal condition has lower failure risks, reducing the likelihood of accidents. Regular inspections enable early detection of issues, and workers feel safer operating properly maintained machinery. These results align with Gusrah (2021), Yoga Aji (2021), and Shane Atsya Amara Dien and Ratna Purwaningsih (2024), who emphasized the relationship between equipment condition and safety. M. Zaidan R et al. (2025) and Eka Putri Rahayu (2022) also confirmed that technical control and equipment reliability are essential components of workplace safety.

The Effect of Hazard Control (Y) on Work Safety (Z)

The hypothesis testing results indicate that hazard control (Y) has a positive and significant effect on work safety (Z). This is supported by a T-statistic value of 3.107, which exceeds 1.96, and a P-value of 0.002, indicating statistical significance. The original sample value of 0.348 shows a positive relationship, meaning that better hazard control leads to improved work safety. Hazard control includes risk identification, risk assessment, and implementation of technical controls, which are essential in minimizing workplace accidents. Therefore, hypothesis H5 is supported.

The findings demonstrate that hazard control is a key factor in ensuring workplace safety. Proper hazard identification before work begins helps prevent accidents, while risk assessment enables appropriate preventive actions. Technical controls and consistent supervision further strengthen safety outcomes. These findings are consistent with Shane Atsya Amara Dien and Ratna Purwaningsih (2024), M. Zaidan R et al. (2025), and Eka Putri Rahayu (2022), who emphasize the importance of risk management and SMK3. Additionally, Andi Hendrawan (2020) and Wexley and Yulk in Mangkunegara (2009) highlight the role of structured systems in promoting safe work behavior.

The Effect of OHS Knowledge (X_1) on Work Safety (Z) through Hazard Control (Y)

The results show that OHS knowledge (X_1) has a positive and significant indirect effect on work safety (Z) through hazard control (Y). This is indicated by a T-statistic value of 2.186, exceeding 1.96, and a P-value of 0.029, confirming mediation significance. The original sample value of 0.130 indicates a positive indirect relationship. This means that OHS knowledge not only directly affects safety but also indirectly through hazard control. Thus, hypothesis H6 is supported.

The findings indicate that hazard control acts as a mediating variable that strengthens the relationship between OHS knowledge and work safety. Workers with higher OHS knowledge are better able to identify and control hazards, which in turn enhances safety outcomes. This is consistent with M. Zaidan R et al. (2025), Shane Atsya Amara Dien and Ratna Purwaningsih (2024), Eka Putri Rahayu (2022), Wexley and Yulk in Mangkunegara (2009), and Andi Hendrawan (2020), all of whom highlight the importance of integrating knowledge and risk control systems.

The Effect of Heavy Equipment Maintenance (X_2) on Work Safety (Z) through Hazard Control (Y)

The hypothesis testing results show that heavy equipment maintenance (X_2) has a positive and significant indirect effect on work safety (Z) through hazard control (Y). This is evidenced by a T-statistic value of 2.740, which exceeds 1.96, and a P-value of 0.006, indicating statistical significance. The original sample value of 0.205 shows a positive indirect relationship, meaning that maintenance influences safety through hazard control. Therefore, hypothesis H7 is supported.

The findings reveal that hazard control serves as a crucial link between equipment maintenance and work safety. Well-maintained equipment reduces operational risks and facilitates better hazard identification and control. Routine monitoring also prevents system failures, enhancing overall safety. These findings align with Gusrah (2021), Yoga Aji (2021), Shane Atsya Amara Dien and Ratna Purwaningsih (2024), M. Zaidan R et al. (2025), and Eka Putri Rahayu (2022), who emphasize that maintenance and technical control are integral to effective OHS systems.

CONCLUSION

Occupational Health and Safety (OHS) knowledge has a positive and significant effect on hazard control in the work area of PT Puradika Bongkar Muat Makmur Laut Taboneo, South Kalimantan. The dimension of Risk and Consequence Understanding (0.964), which has the highest contribution, indicates that workers' ability to understand the risks associated with coal loading and unloading activities on board is the key factor in improving hazard control. This is reflected in indicator X1.10 (0.960), namely the workers' ability to assess risk levels before operating heavy equipment on board. Hypothesis testing results show a t-statistic value of 3.438, which is greater than the t-table value of 1.96, with a path coefficient of 0.374 or a contribution effect of 37.4%. This means that higher OHS knowledge among workers leads to more effective hazard control in coal loading and unloading operations on bulk carriers. In addition, heavy equipment maintenance also has a positive and significant effect on hazard control. The Condition Monitoring dimension (0.939), as the dominant factor, shows that monitoring the condition of equipment such as cranes, bulldozers, and wheel loaders plays a crucial role in controlling workplace hazards, supported by indicator X2.10 (0.932) regarding the availability of spare parts during operations. The test results show a t-statistic of 5.797 (>1.96) and a path coefficient of 0.590 (59.0%), indicating that better maintenance systems significantly enhance hazard control effectiveness.

Furthermore, OHS knowledge has a positive and significant effect on work safety. The dominant dimension, Risk and Consequence Understanding (0.964), highlights that workers who are capable of assessing risks before performing tasks on bulk carriers tend to exhibit higher safety levels. This is supported by indicator X1.10 (0.960). The hypothesis test shows a t-statistic of 2.513 (>1.96) with a path coefficient of 0.256 (25.6%), meaning that improved OHS knowledge contributes directly to increased work safety. Similarly, heavy equipment maintenance also significantly affects work safety. The Condition Monitoring dimension (0.939) demonstrates that well-monitored equipment conditions are essential in ensuring operator and worker safety. Indicator X2.9 (0.926), which relates to performance evaluation to prevent operational failure, further supports this finding. The test results show a t-statistic of 3.351 (>1.96) with a path coefficient of 0.376 (37.6%), indicating that optimal maintenance leads to higher safety levels in coal loading and unloading activities.

Hazard control itself has a positive and significant effect on work safety. The Risk Assessment dimension (0.949), as the most dominant, emphasizes the importance of identifying and evaluating potential hazards before operations. This is evident in indicator Y5 (0.908), which refers to evaluating hazard impacts prior to equipment use. The hypothesis test yields a t-statistic of 3.107 (>1.96) and a path coefficient of 0.348 (34.8%), indicating that better hazard control directly improves work safety. Moreover, OHS knowledge and heavy equipment maintenance also indirectly influence work safety through hazard control. OHS knowledge shows a t-statistic of 2.186 (>1.96) with a path coefficient of 0.130 (13.0%), while heavy equipment maintenance shows a t-statistic of 2.740 (>1.96) with a coefficient of 0.205 (20.5%). These findings indicate that both variables enhance work safety more effectively when supported by strong hazard control mechanisms in the operational environment.

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