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The Influence of Safety Culture and Ship Engine Maintenance on Accident Prevention Which has Implications for Shipping Safety at PT Indo Container Lines

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Abstract: This study aims to analyze the influence of safety culture and ship engine maintenance on accident prevention, which in turn affects maritime safety at PT Indo Container Lines. This research uses a quantitative approach with a cross-sectional research design. The sample used in this study consists of 107 crew members of PT Indo Container Lines, selected using the Slovin formula to determine a representative sample size. The data collected includes primary data obtained through questionnaires and interviews, as well as secondary data from the company's reports on safety and ship maintenance. The collected data was analyzed using SmartPLS software to test the relationships between the variables involved. The results of the study show that safety culture has a positive and significant impact on accident prevention, which in turn leads to improved maritime safety. These findings indicate that a strong safety culture, including awareness and safe behavior, plays a key role in reducing the risk of accidents during voyages. Additionally, ship engine maintenance was found to have a positive and significant impact on accident prevention, with well-maintained engines reducing the potential for technical failures that could jeopardize maritime safety. Accident prevention, driven by good engine maintenance and an applied safety culture, contributes to the overall enhancement of maritime safety. This study recommends that PT Indo Container Lines continue to strengthen the safety culture among its crew and enhance ship engine maintenance to support better maritime safety. By creating a safer work environment and ensuring that ships operate in optimal conditions, PT Indo Container Lines can reduce the risk of accidents and significantly improve maritime safety in the future.

Keyword: Safety Culture, Ship Engine Maintenance, Accident Prevention, Maritime Safety.

INTRODUCTION

The shipping and logistics industry plays a vital role in supporting the global distribution of goods and services, requiring shipping companies to maintain the operational efficiency and safety of their fleets. Skilled human resources (HR), disciplined safety procedures, and a strong

safety culture are key elements in reducing the risk of accidents at sea. By implementing sound safety management practices, such as routine engine maintenance, crew training, and strict oversight of procedures, companies can create a safe and productive work environment.

PT Indo Container Lines (ICL), as a growing shipping company, faces increasingly complex safety challenges as its distribution volume increases. Accident data from 2024 shows that there are still gaps in the implementation of safety procedures, such as the slip of a crew member on the KM Filipi IV due to procedural negligence, a fire on the KM Icon Bravo due to an electrical short circuit, and a tanker leak due to misplaced containers. These incidents highlight that, despite the existence of safety procedures, oversight remains suboptimal.

The problem of accident prevention on ICL vessels is becoming increasingly apparent in several aspects, including improper container placement, ineffective cargo handling procedures, minimal routine cargo inspections, and the absence of a near-miss reporting system. These factors indicate weak operational risk management, necessitating improvements to the company's oversight system and strengthened implementation of safety procedures. Without a consistent prevention system, the potential for accidents will continue to recur and disrupt smooth operations.

Safety culture, machine maintenance, and accident prevention are three interrelated factors in maintaining shipping safety at PT Indo Container Lines. Lack of procedural oversight has resulted in crew accidents, while inadequate machine maintenance has been shown to increase the risk of fires due to electrical short circuits. Furthermore, weaknesses in ship cargo management increase the potential for damage and leaks. Therefore, the company must be more disciplined in building a safety culture, conducting regular machine maintenance, and implementing an effective monitoring and reporting system to minimize risks.

Various previous studies have highlighted the importance of safety culture, machinery maintenance, and accident prevention procedures separately. However, limited research has examined the direct relationship between these three factors in the context of shipping operations. Several studies confirm that safety culture contributes to accident reduction (Weda, 2022; Santoso, 2021), while ship machinery maintenance is often viewed solely from a technical perspective (Ricardianto et al., 2021; Hakim & Sitorus, 2023). Therefore, this study aims to fill this gap by holistically examining how the integration of safety culture, machinery maintenance, and accident prevention can improve shipping safety at PT Indo Container Lines.

METHOD

The research method used in this study is quantitative research with a descriptive approach. Descriptive research aims to describe current phenomena through observation, interviews, and questionnaires, thereby providing a factual picture of the conditions being studied (Sugiyono, 2019). Quantitative research was chosen because of its systematic, planned, and structured nature from the beginning, from research design to data analysis. This method allows researchers to test hypotheses and answer research questions objectively based on measurable data.

The population of this study was all crew members at PT Indo Container Lines in 2024, totaling 146 people, spread across 8 ships with a composition of 32 officers (captain and three other officers) and 114 ratings (deck ratings and engine room ratings). To determine the number of samples, the Slovin formula was used with a precision level of 5% (Ridwan & Kuncoro, 2020), resulting in a sample size of 107 respondents. The sample was taken randomly to ensure fair representation of the population, so that the research results can reflect real conditions in the field. The focus of the research was directed at identifying and analyzing the influence of safety culture and ship engine maintenance on accident prevention that has implications for shipping safety.

The data analysis technique in this study uses the Partial Least Squares (PLS) approach as one of the methods in variance-based Structural Equation Modeling (SEM). According to

Ghozali (2021), PLS is more predictive than covariance-based SEM, which is generally used for causality or theory testing. PLS was chosen because it does not require the assumption of a normal distribution and can be used on relatively small sample sizes. In addition to confirming the theory, PLS is also able to explain the relationship between latent variables formed by both reflective and formative indicators. With these advantages, PLS is considered suitable for analyzing the influence of safety culture and ship engine maintenance on accident prevention and shipping safety at PT Indo Container Lines.

RESULTS AND DISCUSSION

Research Result

Based on the distribution of questionnaires to 107 respondents who are crew members of PT Indo Container Lines, the following demographic profile was obtained: the majority of respondents were male, 103 people (96.3%), while only 4 women (3.7%). When viewed from age, the majority of respondents were in the 21–30 years range, 55 people (51.4%), followed by 41–50 years old, 21 people (19.6%), 31–40 years old, 19 people (17.8%), and the rest were over 50 years old, 12 people (11.2%).

In terms of position, the majority of respondents were officers, 91 people (85.0%), while only 16 people (15.0%) had ratings. As for education level, the majority of respondents had a Diploma, 59 people (55.1%), then 22 people (20.6%) had a High School degree, 23 people (21.5%), and only 3 people (2.8%) had a Master's degree. These data show that the research respondents were dominated by male crew members, young, with officer positions, and had a Diploma educational background.

Outer Model

The outer model results yielded 48 indicators from the 48 reflective indicators used in the research model. Figure 4.2 above demonstrates that all 48 indicators reliably measured their constructs, meeting the required outer loading values (Hair et al., 2019). The following is a detailed explanation of the outer model evaluation results.

Validity Indicator (Outer Loading)

Based on the results of the outer loading test, all 48 reflective indicators in the research model showed values above the minimum limit of 0.6 required (Hair et al., 2019). This indicates that each indicator is reliable in measuring the intended construct, so that no indicators were eliminated. Second-order dimension analysis shows that in the safety culture variable, the dimension with the highest contribution is Reporting Culture (0.927), while the lowest is Learning Culture (0.817).

In the ship engine maintenance variable, the highest contribution is found in predictive and routine maintenance (0.950), while the lowest is in Total Productive Maintenance (0.904). In the accident prevention variable, the highest contribution is shown by occupational safety (0.969) and the lowest is in appropriate action (0.875). Meanwhile, in the shipping safety variable, the highest contribution appears in maritime environmental protection (0.959) and the lowest is in ship seaworthiness and navigation (0.920).

Furthermore, the indicator with the highest loading factor is X17 (0.944) which states that “Accident reports are always well received and followed up,” while the lowest indicator is Z9 (0.775) which is “The ship is equipped with a well-functioning AIS system.” Overall, the indicators in this study are considered to be able to consistently represent the construct being measured.

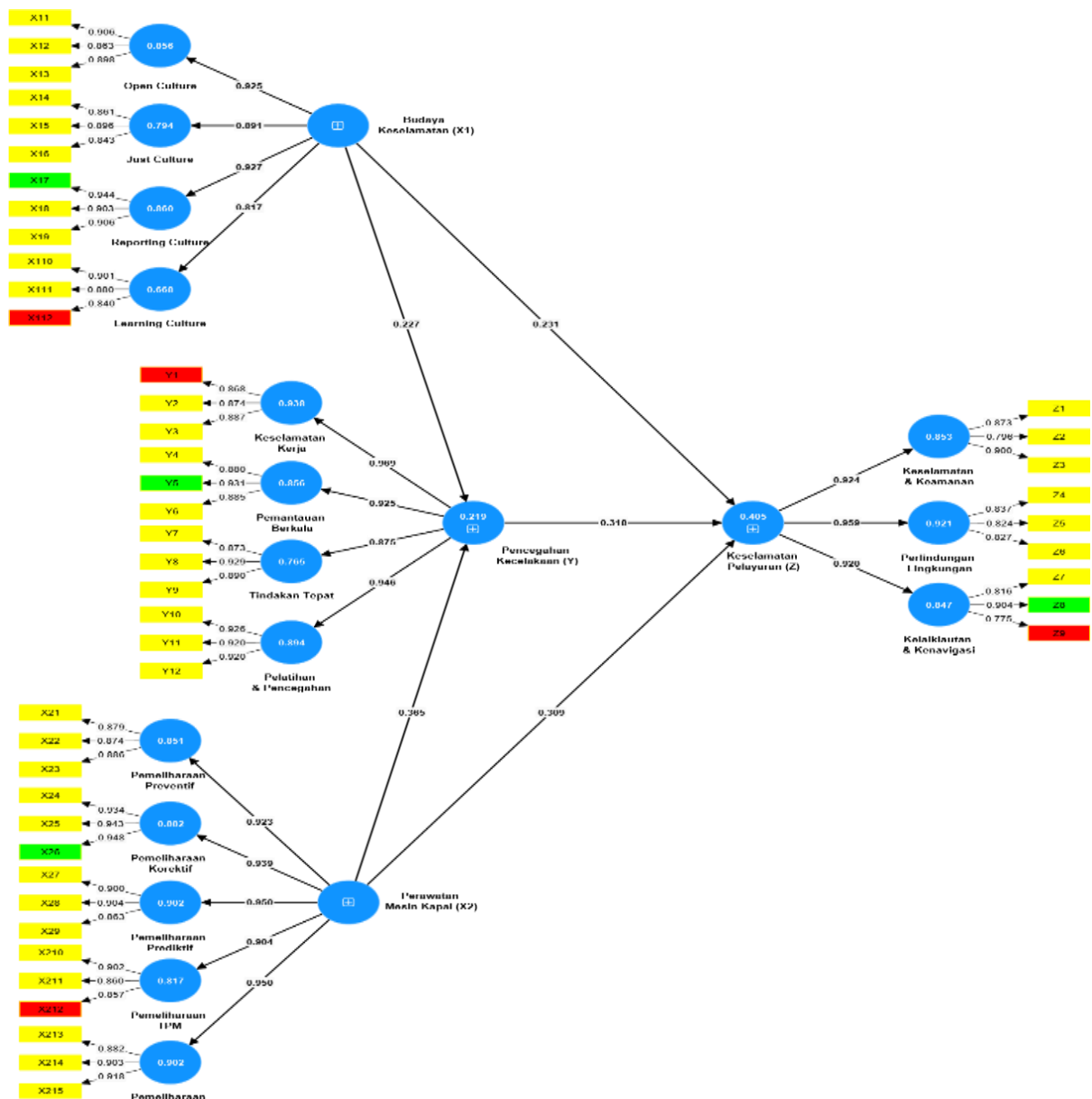


Figure 1 Outer Model Results

Construct Reliability

Construct reliability testing was conducted by assessing Cronbach's alpha and composite reliability values. The analysis results showed that all variables, namely safety culture, ship engine maintenance, accident prevention, and navigational safety, had Cronbach's alpha values above 0.7 and composite reliability values ranging from 0.923 to 0.970, which is within the 0.7–0.95 range recommended by Hair et al. (2019; 2020). These findings confirm that all constructs have met reliability requirements with good internal consistency. Thus, the research instrument is declared reliable for use in measuring the constructs studied.

Construct Validity (Convergent Validity)

The construct validity test was conducted by assessing the average variance extracted (AVE) value. Based on the data processing results, all research variables had an AVE value greater than 0.50, namely safety culture at 0.665, ship engine maintenance at 0.701, accident prevention at 0.697, and shipping safety at 0.615. This proves that the indicators in each construct are able to explain more than 50% of the variance they have, so it can be concluded

that they are convergently valid. In other words, the indicators used in this study are worthy of representing the constructs studied.

Discriminant Validity

The discriminant validity test was conducted using the Heterotrait-Monotrait Ratio of Correlations (HT/MT Ratio) method. The results of data processing showed that all HT/MT ratios between variables had values less than 0.9, which indicates that each indicator has the ability to measure its construct specifically and does not overlap with other constructs (Henseler et al., 2015). Thus, the indicators in this research model have met the discriminant requirements, so it can be said that the instrument used is able to distinguish between the variables studied accurately.

Overall, the results of the outer model evaluation using four statistical parameters—indicator validity, construct reliability, construct validity, and discriminant validity—indicate that all indicators in this study have been declared reliable and valid. This means that each indicator is able to measure its respective construct consistently, validly, and discriminate well. Thus, the measurement model used in this study can be declared feasible and can proceed to the next stage of analysis, namely testing the inner model (structural model).

Inner Model Results (Structural Model)

Multicollinearity

The results of the multicollinearity test indicate that all variables in the research model have VIF values below 3, thus confirming that there are no collinearity issues between the independent variables. This condition confirms that the research model constructed has met the acceptable criteria and does not experience distortion in coefficient estimates due to multicollinearity, allowing for more accurate analysis of the relationships between variables.

Coefficient of Determination (R-Squared)

The R-squared value for the Accident Prevention variable is 0.219, meaning that 21.9% of the variation in accident prevention can be explained by safety culture and ship engine maintenance. Meanwhile, the R-squared value for the Shipping Safety variable is 0.405, indicating that 40.5% of the variation in shipping safety can be explained by safety culture, ship engine maintenance, and accident prevention. This indicates that the model's predictive ability is in the weak to moderate category.

Effect Size (f-Squared)

The results of the effect size test indicate that most of the relationships between variables are weak, except for the influence of ship engine maintenance on accident prevention, which has a value of 0.163, which is classified as moderate. Therefore, it can be concluded that ship engine maintenance is a variable that makes a greater contribution than other variables in influencing accident prevention, while also emphasizing the importance of this technical aspect in maritime safety.

Predictive Relevance (Q² and Q²_predict)

The Q² value from blindfolding indicates that maritime safety has a small predictive relevance with a value of 0.239, while accident prevention is also in the small category with a value of 0.146. However, the test results using PLS_predict show an increase in predictive ability, where the Q²_predict value for maritime safety is 0.289 and is classified as medium predictive relevance. This finding indicates that the research model already has a fairly good ability to predict maritime safety, although predictions for accident prevention are still limited.

Below are the results of the inner model image from the PLS-SEM bootstrapping results accompanied by a description.

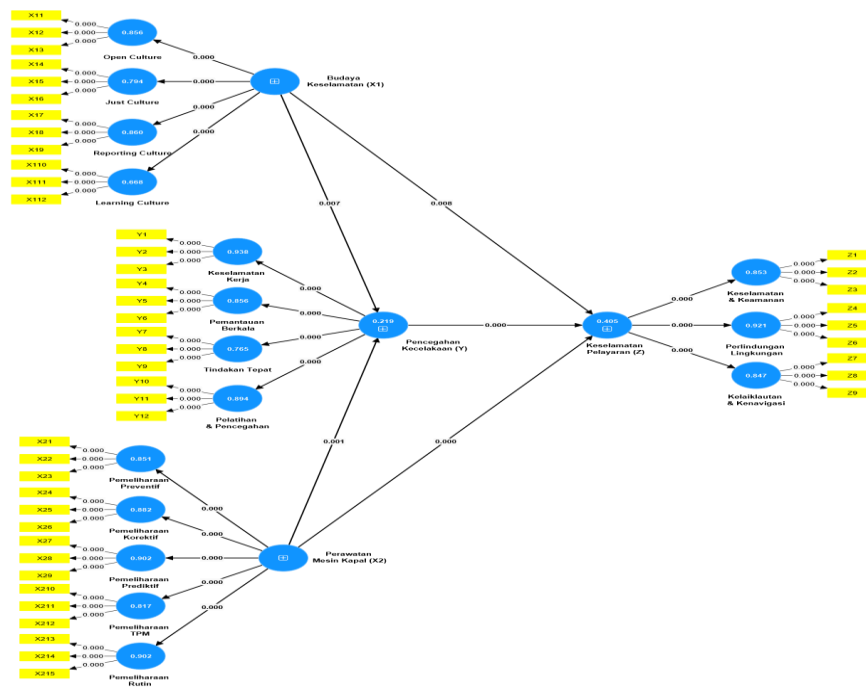


Figure 2 Inner Model Results

Research Hypothesis Test Results

The table below shows the results of PLS-SEM data processing to determine the results of the hypothesis test.

Table 1 Hypothesis Test Results

Hypothesis	Influence	Original sample (O)	T statistics (O/STDEV)	P values	Information
H1	Safety Culture (X1) -> Accident Prevention (Y)	0.227	2,478	0.007	Significant
H2	Ship Engine Maintenance (X2) -> Accident Prevention (Y)	0.365	3,235	0.001	Significant
H3	_Safety Culture (X1) -> Shipping _Safety (Z)	0.231	2,389	0.008	Significant
H4	Ship Engine Maintenance (X2) -> Sailing Safety (Z)	0.309	4,431	0.000	Significant
H5	Accident Prevention (Y) -> Shipping Safety (Z)	0.318	3,662	0.000	Significant
H6	_Safety Culture (X1) -> _Accident Prevention (Y) -> _Sailing _Safety (Z)	0.072	1,830	0.034	Significant
H7	Ship Engine Maintenance (X2) -> Accident Prevention (Y) -> Sailing Safety (Z)	0.116	2,471	0.007	Significant

The Influence of Safety Culture on Accident Prevention

The results of the study indicate that safety culture has a significant influence on accident prevention, as evidenced by the T-statistic value of 2.478, which exceeds the T-table (1.64) and the standard coefficient of 0.227. This finding confirms that the stronger the safety culture implemented, the higher the organization's ability to prevent accidents. A good safety culture encourages workers to comply more with operational standards, understand risks, and take

responsibility for their work safety. This is in line with Abdul Rahman (2024) who emphasized the importance of safety culture in reducing potential risks in shipping.

Furthermore, this finding is supported by Santoso & Dillyanto (2020), who stated that safety culture plays a significant role in improving occupational safety, and Fauzi et al. (2024), who demonstrated that implementing a safety culture can reduce the potential for accidents through risk mitigation. Thus, safety culture serves as the first line of defense in accident prevention efforts. In the shipping sector, consistent implementation of a safety culture not only reduces accidents but also increases stakeholder confidence in the company's operational quality.

The Impact of Ship Engine Maintenance on Accident Prevention

This study proves that ship engine maintenance has a significant effect on accident prevention, with a T-statistic value of 3.235, which far exceeds the T-table (1.64), and a standard coefficient of 0.365 indicating a positive relationship. This means that the better the engine maintenance is carried out, the smaller the potential for accidents due to mechanical failure. A well-maintained engine ensures optimal ship operations so that the risk of dangerous technical damage can be minimized. El Firdaus et al. (2024) emphasized the importance of engine maintenance in preventing accidents in the shipping sector.

Furthermore, research by Sitorus et al. (2024) shows that proper maintenance is crucial for crew safety, while Wahyuni et al. (2024) emphasize that routine vessel maintenance supports fishermen's welfare and operational sustainability. Therefore, vessel engine maintenance is not merely a technical factor but also a strategic factor that ensures continued safety at sea. Consistent maintenance significantly reduces the risk of incidents and improves vessel reliability in the long term.

The Influence of Safety Culture on Shipping Safety

The results of the H3 hypothesis test indicate that safety culture has a positive and significant influence on shipping safety, with a T-statistic value of 2.389, higher than the T-table (1.64), and a standard coefficient of 0.231. This indicates that the better the safety culture implemented, the higher the level of shipping safety achieved. Safety culture not only functions in preventing accidents but also creates a conducive, safe, and productive work environment. Santoso & Dillyanto (2020) emphasized that safety culture is closely related to leadership in efforts to improve shipping safety.

Similarly, Fauzi et al. (2024) stated that safety culture can strengthen risk mitigation in the shipping sector, while Iwan Weda (2022) highlighted safety culture as a crucial variable in shaping shipping safety. Therefore, it can be concluded that investing in safety culture is a long-term strategy that should be prioritized, given its significant impact in reducing accident risk while improving operational quality in the maritime sector.

The Influence of Ship Engine Maintenance on Shipping Safety

The H4 hypothesis test yielded very strong results, with a T-statistic value of 4.431, far exceeding the T-table value (1.64), and a standardized coefficient of 0.309. These results indicate that proper ship engine maintenance contributes significantly to improving shipping safety. Regularly maintained engines operate more efficiently and reduce the potential for damage that could endanger the ship and its crew. El Firdaus et al. (2024) support these findings by emphasizing that engine maintenance is a key factor in reducing work accidents on ships.

Furthermore, Wahyuni et al. (2024) linked the importance of engine maintenance to the welfare of fishermen, while Malau et al. (2021) emphasized that the quality of engine maintenance significantly impacts vessel performance and navigational safety. Thus, it is clear that engine maintenance is not only related to technical aspects but also concerns safety and

operational sustainability. A well-maintained vessel will provide a sense of security, increase crew confidence, and reduce the risk of serious accidents.

The Impact of Accident Prevention on Maritime Safety

Hypothesis H5 shows supportive results, where the T-statistic value of 3.662 is higher than the T-table (1.64), and the standard coefficient of 0.318 confirms that accident prevention has a positive effect on shipping safety. Accident prevention not only focuses on post-incident handling, but also includes proactive efforts to identify potential hazards and reduce risks early. Santoso & Dillyanto (2020) emphasize that a good safety culture is the foundation of an effective accident prevention strategy.

This is in line with Fauzi et al. (2024), who highlighted the role of risk mitigation in improving maritime safety, and Iwan Weda (2022), who emphasized that accident prevention serves as a crucial variable in reducing risks at sea. Therefore, the more intensive accident prevention efforts are implemented, the higher the level of maritime safety that can be achieved. Consistent implementation of prevention not only reduces the number of accidents but also enhances the organization's image as an entity responsible for occupational and maritime safety.

The Influence of Safety Culture on Maritime Safety through Accident Prevention

Hypothesis H6 proves that safety culture has an indirect influence on shipping safety through accident prevention, with a T-statistic value of 1.830 which is greater than the T-table (1.64), and a standard coefficient of 0.072. These results confirm that a good safety culture not only has a direct impact, but also plays a role in improving safety through strengthening accident prevention mechanisms. Santoso & Dillyanto (2020) emphasize that strong leadership in safety culture will trigger worker awareness in preventing accidents.

Abdul Rahman (2024) also supports the belief that safety culture can reduce the risk of accidents, while Fauzi et al. (2024) highlight its contribution to risk mitigation in the shipping sector. Thus, a strong safety culture can be seen as a driving factor that strengthens accident prevention while improving shipping safety. Strategies to improve safety culture at every organizational level need to be prioritized to create a safer work environment and minimize shipping incidents.

The Influence of Ship Engine Maintenance on Shipping Safety through Accident Prevention

Hypothesis H7 yielded significant findings, with a T-statistic value of 2.471, exceeding the T-table (1.64) and a standard coefficient of 0.116. This indicates that ship engine maintenance not only directly impacts shipping safety but also indirectly through accident prevention. With proper maintenance, the risk of engine damage can be minimized, thereby reducing the chance of an accident occurring. El Firdaus et al. (2024) corroborate these findings by emphasizing that engine maintenance is an integral part of ship accident prevention strategies.

Wahyuni et al. (2024) also highlighted the role of vessel maintenance in supporting fishermen's welfare, while Malau et al. (2021) showed that the quality of engine maintenance significantly impacts sailing performance and safety. Therefore, consistent engine maintenance not only maintains a vessel's technical performance but also contributes to overall sailing safety. Therefore, a structured and systematic maintenance system must be prioritized to support the safety and sustainability of vessel operations.

CONCLUSION

Safety culture has a positive and significant impact on accident prevention. At PT Indo Container Lines, the implementation of a strong safety culture—such as adherence to procedures, the use of personal protective equipment, and regular training on occupational

risks—contributes significantly to minimizing the potential for accidents in the workplace, particularly in shipping operations and container loading and unloading. A well-established safety culture has proven to be a preventative factor against workplace incidents.

Ship engine maintenance has a positive and significant impact on accident prevention. Maintaining ship engines through regular maintenance and routine inspections at PT Indo Container Lines has proven to be a crucial step in preventing sudden breakdowns that could lead to accidents, both while the ship is sailing and during berthing. This means that the better the quality of ship engine maintenance, the less likely an accident is to occur due to technical failure.

Safety culture has a positive and significant impact on shipping safety. The safety culture consistently implemented by the crew and management of PT Indo Container Lines not only impacts accident prevention but also directly improves overall shipping safety. This includes ensuring smooth sailing, protecting crew and cargo, and managing maritime risks.

Ship engine maintenance has a positive and significant impact on shipping safety. The performance of ship engine maintenance at PT Indo Container Lines is crucial for a ship's reliability at sea. Well-maintained engines not only prevent accidents but also ensure safe navigation, such as preventing engine failures at sea, navigation system disruptions, or fires due to overheating. Optimal maintenance reflects high standards of maritime safety.

Accident prevention has a positive and significant impact on shipping safety. Accident prevention implemented through various programs at PT Indo Container Lines—such as emergency simulations, safety audits, and standard operating procedures—directly improves shipping safety. The lower the accident rate, the greater the assurance of the safety of the crew, vessel, and cargo during shipping.

Safety culture has a positive and significant impact on shipping safety through accident prevention. The safety culture at PT Indo Container Lines not only directly impacts shipping safety but also indirectly strengthens it through accident prevention. This means that a work culture that prioritizes safety can influence incident prevention measures, which in turn impacts the smooth and safe operation of shipping.

Ship engine maintenance has a positive and significant impact on shipping safety through accident prevention. At PT Indo Container Lines, ship engine maintenance has a dual effect: first, preventing technical accidents and second, ensuring safe shipping operations. This mechanism explains how proper engine maintenance can reduce the risk of accidents and ultimately improve safety during shipping.

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