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The Functional Contribution of Ship Safety Inspectors in Nautical, Technical, and Communication (Radio) Inspection Processes to Workload and Maritime Transportation Safety

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Abstract: Maritime transportation safety is a strategic priority in Indonesia's national logistics system as an archipelagic country. However, high shipping intensity and limited inspection resources pose serious challenges to the effectiveness of ship inspections. Ship Safety Inspectors (PPKK) play a crucial role in ensuring the seaworthiness of ships through inspections of nautical, technical, and communication (radio) aspects; however, their functional contributions have rarely been systematically examined. This study employs a quantitative approach using survey methods and Structural Equation Modeling–Partial Least Squares (SEM-PLS) analysis techniques. A sample of 64 CSOs from three strategic ports (Tanjung Priok, Soekarno-Hatta, Makassar, and Sorong-Pelra) was analyzed to examine the relationship between inspection functions, workload, and maritime safety. The results indicate that technical, nautical, and communication functions significantly influence workload, while technical functions and workload have a direct impact on maritime safety. Work volume acts as a mediating variable in the model. The implications of these findings emphasize the importance of enhancing the competence of PPKK and developing risk-based inspection policies. This study provides empirical contributions to the reform of the maritime safety supervision system and opens opportunities for cross-national validation to strengthen the generalizability of the model.

Keywords: Marine science; Port safety management; Nautical functions; Techniques; Radio communication; Work volume; SEM-PLS

1 Introduction

Shipping safety is a crucial aspect of the maritime industry that demands serious attention from various parties. In Indonesia, with its vast territorial waters and high shipping activity, the role of the Vessel Safety Inspection Officer (VSIO) is vital in ensuring the seaworthiness of ships through nautical, technical, and communication (radio) inspections. VSIOS, or Marine Inspector, serves as the spearhead of the Directorate General of Sea Transportation in supporting the realisation of "zero accident" in shipping [1–3]. However, in carrying out its duties, VSIOS faces various challenges. Setiyantara et al. [4] point out that the loading and unloading process has encountered several obstacles due to the maintenance and inspection of loading and unloading equipment, which is often neglected because of the short sailing distance. In fact, maintenance and inspection are mandatory tasks for ship inspection. This shows the need for good coordination between various related parties to ensure a smooth inspection process. In addition, a ship inspection conducted by maritime inspectors at the Tanjung Pakis Class III KOSP revealed several cases of ship accidents that were suspected to have been caused by the Tanjung Pakis Class III KSOP's suboptimal supervision [5].

The phenomenon of an increasing number of marine accidents in recent years also shows that there are still weaknesses in the ship inspection and supervision system. Data shows that from 2018 to 2021, there was an increase in the number of ship accidents compared to the previous year, mostly due to technical factors and human error. This indicates the need for an in-depth evaluation of the role and contribution of PVRM in the ship inspection process [3]. One of the challenges faced in the inspection process is the limited number of competent and trained human resources. Although the Ministry of Transportation has inaugurated and revalidated VSIOS and Assistant Marine Inspectors, there are still gaps in competence and understanding of the latest regulations. In addition, the rapid development of technology and international regulations requires KDPK to continuously update their knowledge and skills [6, 7].

This research was conducted at three strategic port locations, namely Sorong Pelra Port, Tanjung Priok Port, and Ujung Pandang Port. They represent different port typologies geographically and operationally. Pelra Port of Sorong in Southwest Papua is a collecting port that serves people's shipping with characteristics of small vessels that are often not well standardized. On the other hand, Tanjung Priok Port in North Jakarta is the main and busiest port in Indonesia, with international standard commercial and container ship traffic. Meanwhile, Ujung Pandang Port in Makassar has a dual role as a commercial port and a major hub in Eastern Indonesia. These different characteristics are important in understanding the variation in the functional contribution of PVRM in the inspection process at each location.

Several findings indicate that the communication equipment used on ships still experiences problems such as delays in sending emergency signals while the ship is sailing [8, 9]. Then, in the context of Occupational Safety and Health (OHS) on ships, research by Sahri et al. [10] shows that the implementation of the OSH program for the Shipbuilding Industry in Indonesia has been carried out correctly and in accordance with applicable regulations. This includes the use of Personal Protective Equipment (PPE), safety training, and strict supervision. Effective OHS implementation can support the duties of the VSIOS in ensuring the overall safety of the ship [10, 11].

Although various efforts have been made to improve the competence and performance of VSIOS, there is still a gap in the literature that specifically discusses the functional contribution of VSIOS in the nautical, technical, and communication (radio) inspection process to the volume of work. Most previous studies focus more on technical or regulatory aspects, without examining in depth the role of VSIOS in an operational and managerial context. Therefore, this study aims to fill this gap by analyzing the functional contribution of VSIOS in the inspection process and how it affects the volume of work.

Globally, PSC systems under the Paris Memorandum of Understanding (Paris MoU) and Tokyo MoU have implemented a more structured and internationally competency-based inspection approach, supported by digitization systems, international standard training (PSC Officers), and focused inspection campaigns (Concentrated Inspection Campaign—CIC). Studies show that the Paris MoU systematically manages ship risks through multivariate data analysis to prioritize inspections, while the Tokyo MoU applies deterministic models such as Bayesian Networks to improve PSC efficiency in the Asia-Pacific region [12–14]. These practices differ significantly from Indonesia, which has not yet adopted risk-based inspection models or digitalised its PSC system.

So far, literature on PSC in Indonesia is still very limited and generally descriptive and regulatory in nature. Existing studies, such as Setiyantara et al. [4], only discuss the constraints of maintaining and inspecting ship loading and unloading equipment without measuring the functional contribution of PSC to workload and shipping safety. Global research on PSC more often highlights the effectiveness of inspections on foreign vessels and minimizes discussion of the institutional role of inspectors (Port State Control Officers) in mediating safety outcomes holistically.

This study aims to bridge this gap by developing a structural model based on SEM-PLS to quantitatively test the influence of PPKK functions (nautical, technical, and communication) on the volume of work and maritime transportation safety. By involving three strategic ports (Tanjung Priok, Makassar, Sorong-Pelra) as representatives of western, central, and eastern Indonesia, this study provides substantial empirical and conceptual contributions to the reform of the national maritime safety inspection system, while also serving as an initial reference for comparing the institutional role of PSC in Indonesia with more advanced global PSC practices.

The urgency of this research is increasing with the IMO Member State Audit Scheme (IMSAS) audit that will be conducted in 2025, where Indonesia as an IMO member must ensure that its shipping safety system meets international standards. In this context, the role of PVRM becomes very important in ensuring that ships operating in Indonesian waters have met the established safety requirements. The purpose of this study is to evaluate the functional contribution of VSIOS in the nautical, technical, and communication (radio) inspection process, and analyze its impact on the volume of work. By understanding the roles and responsibilities of VSIOS in more depth, it is hoped that an effective strategy can be found to improve the efficiency and effectiveness of the ship inspection process. The benefits of this research are not only for the Ministry of Transportation in formulating more appropriate policies, but also for the shipping industry in improving ship safety and operational standards.

Hypothesis

Shipping safety is a fundamental aspect of the maritime industry that demands serious attention from various parties. In Indonesia, Marine Inspectors have a vital role in ensuring the seaworthiness of ships through inspections of nautical, technical, and communication (radio) aspects. This role is becoming increasingly important considering Indonesia is an archipelago with high shipping activity. In an effort to improve the performance of VSIOS, the Ministry of Transportation has inaugurated and revalidated VSIOS and Assistant Marine Inspectors. In 2021, 127

VSIOSs were inaugurated as part of a commitment to improve and enhance performance in ensuring shipping safety. The Director General of Sea Transportation emphasized that VSIOS is the spearhead in supporting the realization of "zero accident" in shipping. However, in carrying out their duties, VSIOS faces various challenges. Research by Setiyantara et al. [4] highlights that loading and unloading processes in Indonesia have faced several obstacles due to the maintenance and inspection of loading and unloading equipment, which is often neglected due to short shipping distances. This shows the need for good coordination between various related parties to ensure that the inspection process runs smoothly.

In addition, a ship inspection conducted by maritime inspectors at the Tanjung Pakis Class III KOSP revealed several cases of ship accidents that were suspected to have been caused by the Tanjung Pakis Class III KSOP's suboptimal supervision. This emphasises the importance of supervision by maritime inspectors to ensure that ships meet safety requirements before sailing [5]. In the context of OHS on ships, research by Sahri et al. [10] shows that the implementation of the OSH program for the Shipbuilding Industry in Indonesia has been carried out properly and in accordance with applicable regulations. This includes the use of PPE, safety training, and strict supervision. Effective OHS implementation can support the duties of the VSIOS in ensuring overall ship safety [11, 15]. Based on the problems and theories that have been found, the following is the hypothesis in this study:

H1: Functional Engineering Has a Significant Effect on Work Volume Technical aspects include the inspection of mechanical components and technical systems of the ship, including engines, electrical systems and other technical safety. According to operational management theory, the complexity and intensity of engineering inspections greatly affect inspectors' workload [16]. Previous studies have shown that the technical aspects of ships require a high level of inspection skills and detailed processes, thereby increasing the volume of work in maritime inspection [17].

H2: Functional Nautical Has a Significant Effect on Job Volume

The nautical function is related to aspects of navigation, shipping equipment, and shipping documentation. According to workload theory, the more complex the system being inspected, the greater the volume of work required [18]. Research by Schröder confirms that nautical inspections require verification of documents, navigational equipment, and procedural testing, which adds to the work intensity of KDP inspectors [19].

H3: Functional Communication Has a Significant Effect on Volume

Communication in shipping includes VHF radio communication systems, GMDSS, as well as other emergency communication systems. Along with the digitalization of shipping systems, the testing of communication systems has become more complex. According to Febriansyah et al. [5], ship safety is not only achieved through equipment monitoring but also through communication between all personnel. Fan et al. [20] also noted that modern ship communication systems demand comprehensive oversight, including data security and signal reliability.

H4: Functional Engineering Has a Significant Effect on Transportation Safety

The engineering system is a crucial component in ensuring ship safety. The Safety Management System (SMS) theory in the ISM Code emphasizes that the maintenance and feasibility of technical systems is the main foundation of shipping safety [21]. Study by Yungratog et al. [22] shows that defects in engineering systems are often the main cause of marine accidents, so thorough engineering inspections can improve transportation safety.

H5: Functional Nautical Has a Significant Effect on Transportation Safety

The nautical function is responsible for navigation and safe sailing. The human error theory in the shipping industry [23] states that human error, especially in navigation, is the dominant factor in accidents. Hetherington et al. [24] emphasized that many marine accidents are caused by navigational negligence or improper procedures. Therefore, good supervision of nautical functions will have a positive impact on the safety of marine transportation.

H6: Functional Communication Has a Significant Effect on Transportation Safety

Communication systems serve as the main link between ships and port authorities. Failure of the communication system can lead to serious accidents. Based on the Maritime Safety Communication theory, the reliability and effectiveness of communication is a major factor of operational safety [25]. Research by Chauvin et al. [26] shows that 60% of marine accidents are related to communication failures.

H7: Volume of Work Has a Significant Effect on Transportation Safety

The volume of work indicates the number and scope of supervisory activities performed. In organizational effectiveness theory [27], high work productivity in inspection and surveillance will contribute to the achievement of safety objectives. Baughen [28] shows that ports with high supervision intensity have a lower number of marine accidents compared to ports with minimal supervision.

2 Method

This research is a quantitative study with an explanatory approach that aims to examine the functional contribution of Ship Safety Inspectors (VSPs) in the Nautical, Technical, and Communication (Radio) inspection process to the volume of work and safety of sea transportation handled at the port. This approach was chosen because it allows testing the causal relationship between the variables studied objectively and measurably. The research locations were set at three strategic ports that represent the geographical division of Indonesia, namely the central, western and eastern regions. The three locations are Soekarno-Hatta Port in Makassar, representing the central region; Tanjung Priok Port in Jakarta, representing the western region; and Sorong-Pelra Port in West Papua, representing the eastern region of Indonesia. The selection of these locations considers the significance of the three ports in supporting national logistics flows and the intensity of ship safety inspection activities, so as to provide a representative picture of the dynamics of the implementation of PVRM functions in various geographical and operational contexts.

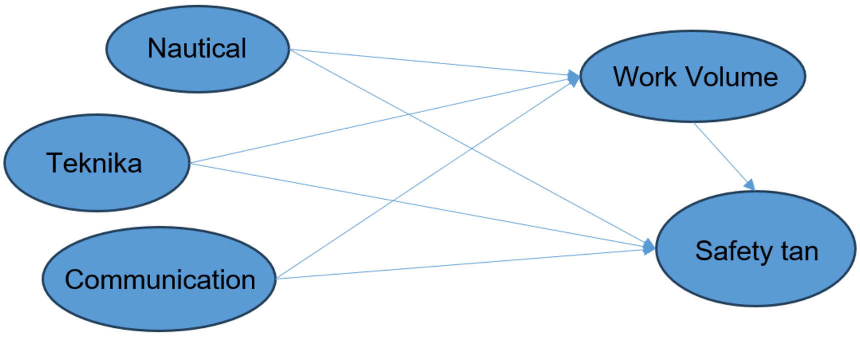

Figure 1. Research design

Table 1. Instrument grid

No.	Variabel	Indicators
1	Nautical Function	Inspection of navigation equipment or ECDIS Inspection of Automatic Radar Plotting Aid (ARPA) Inspection of Magnetic Compass Inspection of nautical charts etc.
2	Technical Function	Ship machinery and electrical systems Inspection of Oil Water Separator (OWS) Inspection of Oil Discharge Monitoring (ODM) Inspection of Main Engine Equipment Inspection of Auxiliary Engine Equipment etc.
3	Communication Functions (Radio)	Duration of inspection Marine Telephone Inspection VHF/HF Radio Inmarsat inspection duration PIRB inspection
4	Work Volume	Inspection following actual data in the field Number of items inspected etc.
5	Keselamatan Kapal	Ship under laws and regulations Inter-island connectivity Responsible for transportation safety etc.

The population in this study included all VSIOS officers who were actively on duty at each of the research ports. Based on the data obtained, there were 33 VSIOS officers at Soekarno-Hatta Port Makassar, 15 at Tanjung Priok Port Jakarta, and 16 at Sorong-Pelra Port. With a total population of 64 people, and considering that this number is still within the limits that can be reached to be thoroughly analysed, the sampling technique used in this study is saturated (census sampling). This technique is considered appropriate because all members of the population are used as research respondents, so that no element of the population is excluded from the data collection process. The utilisation of saturated sampling also allows the research results to reflect the real conditions in the field more accurately, without the risk of bias due to sample selection. Data collection was conducted through the distribution of structured questionnaires developed based on KDP functional indicators, namely the implementation of nautical, technical, and communication (radio) inspections, as well as the volume of work handled within a certain period of time. The questionnaire was designed using a Likert scale with five levels of assessment to facilitate quantitative measurement of perceptions. The following is a complete description of the causality research design between the variables constructed in Figure 1.

Figure 1 is a research design showing the variables studied in this research, namely Nautical Function, Technical

Function, Communication, Volume, and Ship Safety. Meanwhile, the variable indicators that form the basis of the research instrument can be seen in Table 1.

Data analysis was conducted through two main stages. First, descriptive analysis was used to describe the characteristics of respondents and their perceptions of each research variable. This analysis included the calculation of frequency, percentage, mean value, and standard deviation. Secondly, to examine the relationship and influence between the independent variables (KDP functional contribution to nautical, technical, and communication aspects) and the dependent variables (volume of work and marine transportation safety), a Structural Equation Modeling (SEM) analysis based on Partial Least Squares (PLS) was used. The SEM-PLS method was chosen because of its ability to analyze models with a relatively small sample size, does not demand strict data normality, and is flexible in accommodating reflective and formative latent indicators. This study also uses the help of application tools such as ChatGPT which helps in finding suitable word equivalents for interpreting the analysis results, then grammerly to help in profeeading sentences.

3 Result and Discussion

3.1 Summary of Descriptive Findings

Based on the results of the descriptive analysis of the overall volume of VSIOS work in carrying out ship inspections, it is illustrated that the majority of respondents assess the volume of work they carry out is in the appropriate category. This is indicated by 57% of respondents who chose the "Appropriate" category. Meanwhile, 18% of respondents stated that the volume of work they handled was "Very Suitable", indicating that there were a small number of officers who felt that the volume of work was truly balanced with the work capacity and resources available. The following is detailed information work volume condition chart about the graph in Figure 2.

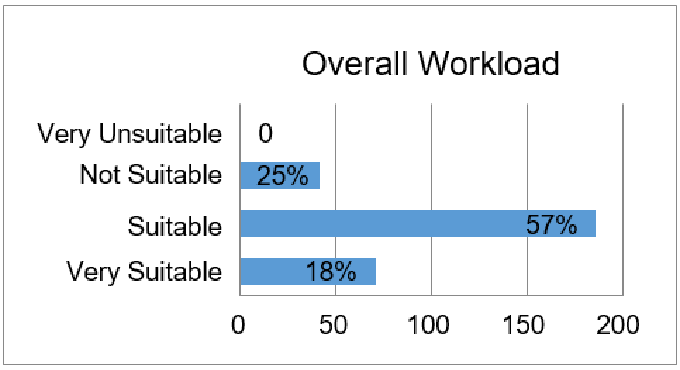

Figure 2. Work volume condition chart

However, there were still 25% of respondents who stated that the volume of work was in the "Not appropriate" category. This proportion cannot be ignored, as it indicates that one in four officers experience workloads that may be disproportionate or not supported by adequate work systems and facilities. Interestingly, there were no respondents who rated the volume of work as "Very Unsuitable", indicating that at an extreme level, the unsuitability of the volume of work is not yet a dominant issue.

In general, these findings reflect that although most PVRMs feel that their work volume is appropriate, there is still room for improvement, particularly in workload management and the distribution of responsibilities among personnel. The balance of work volume is an important factor in ensuring the effectiveness of ship inspections and is indirectly related to shipping safety. Workloads that are too heavy or disproportionate can hurt the quality of inspections, the thoroughness of officers, and even on the safety of marine transportation as a whole.

Thus, these results provide an initial indication that strengthening human resource management, equitable distribution of tasks, and workload adjustments based on port complexity or the number of ship visits can be appropriate strategies to improve the performance and effectiveness of PVRM in the field.

3.2 SEM Results

3.2.1 Validity and reliability

Next is the result of the SEM analysis. Where the first is the outer model test results show that all indicators of each latent variable have an outer loading value above 0.70. This value statistically indicates that each indicator has a strong correlation with the construct it represents. According to Williams et al. [29], the outer loading value ≥ 0.70 is the minimum limit that indicates convergent validity has been achieved. Thus, all indicators in this model can be said to be convergently valid because they are able to adequately represent their latent constructs. Convergent validity is one of the important aspects in testing the quality of the measurement model in the Partial Least Squares Structural

Equation Modelling (PLS-SEM) approach. When the outer loading value exceeds the recommended threshold, this indicates that the indicators are not only theoretically relevant but also consistent in measuring the dimensions of the construct empirically. Therefore, the measurement model in this study can be declared to meet the requirements of convergent validity and is suitable for use in the structural model testing stage. The accumulated details of the outer loading values, Cronbach's alpha, composite reliability, AVE, and HTMT are presented in Table 2.

Table 2. Outer loading, Cronbach's alpha, composite reliability, AVE and HTMT

	Outer Loading > 0.70	**Cronbach's Alpha > 0.70**	**Composite Reliability (rho_c)**	**AVE > 0.50**	**Heterotrait-Monotrait Ratio (HTMT)**
Nautical ↔ Transportation Safety					0.325
Nautical ↔ Communication					0.187
Functional Nautical		0.901	0.925	0.711	
N1	0.877				
N2	0.827				
N3	0.868				
N4	0.817				
N5	0.825				
Communication ↔ Transportation Safety					0.523
Functional Communication		0.813	0.886	0.721	
R1	0.813				
R2	0.845				
R3	0.888				
Engineering ↔ Transportation Safety					0.655
Engineering ↔ Communications					0.577
Engineering ↔ Nautical					0.134
Functional Technician		0.895	0.923	0.705	
T1	0.758				
T2	0.893				
T3	0.834				
T4	0.855				
T5	0.854				
Transportation Safety		0.862	0.899	0.641	
ks1	0.734				
ks2	0.809				
ks3	0.720				
ks4	0.852				
ks5	0.877				0.816
Volume of Work ↔ Transportation Safety					0.712
Work Volume ↔ Communication					0.322
Volume of Work ↔ Nautical					0.663
	Volume of Work ↔ Engineering				
Work Volume		0.866	0.903	0.652	
v1	0.823				
v2	0.822				
v3	0.785				
v4	0.844				
v5	0.761				

The results of testing discriminant validity in Table 2 show that all constructs in the model have met the required criteria. This is indicated by the Average Variance Extracted (AVE) value of each variable, which is all above the minimum threshold value of 0.50 as suggested by Williams et al. [29]. The highest AVE value was recorded for the Communication construct (0.721), followed by Nautical (0.711), Technical (0.705), Volume of Work (0.652), and Transportation Safety (0.641). These values indicate that more than 50% of the variance of the indicators in each construct is successfully explained by the construct itself, which means that discriminant validity is well met.

In addition, the Composite Reliability (CR) value for all variables is above 0.70, with a range between 0.886 to 0.925. This indicates that each construct has excellent internal consistency in measuring the intended concept. The highest value of CR is found in the Nautical construct (0.925), followed by Engineering (0.923), Volume of Work (0.903), Transportation Safety (0.899), and Communication (0.886). This consistency is reinforced by the Cronbach's Alpha values, which are all also above 0.80, reinforcing the conclusion that the instruments used have high reliability.

Overall, this finding confirms that each construct in the model has the ability to clearly distinguish itself from the other constructs, without overlapping significantly. This is particularly important in the context of structural model testing, as good discriminant validity ensures that each variable truly represents a distinct theoretical concept and does not simply reflect similar dimensions. Thus, it can be concluded that the measurement model in this study has met the discriminant validity requirements and is suitable for further analysis in the structural model (inner model).

3.2.2 Inner model

The results of testing the inner model through path analysis provide a comprehensive picture of the influence between latent variables in this study. Hypothesis testing is done by considering the t-statistic value and p-value, where the effect is considered significant if the t-statistic value > 1.96 at the 5% significance level (p-value < 0.05). The detailed results of the significance test can be seen in Table 3.

Table 3. Significance test results (Hypothesis)

	T Statistics (|O/STDEV|)	P-Values	Decision
Communication → Transportation Safety	0.192	0.848	Rejected
Communication → Volume of Work	5.565	0.000	Accepted
Nautical → Transportation Safety	1.278	0.201	Rejected
Nautical → Volume of Work	2.498	0.013	Accepted
Engineering → Transportation Safety	2.738	0.006	Accepted
Engineering → Volume of Work	4.784	0.000	Accepted
Volume of Work → Transportation Safety	4.559	0.000	Accepted

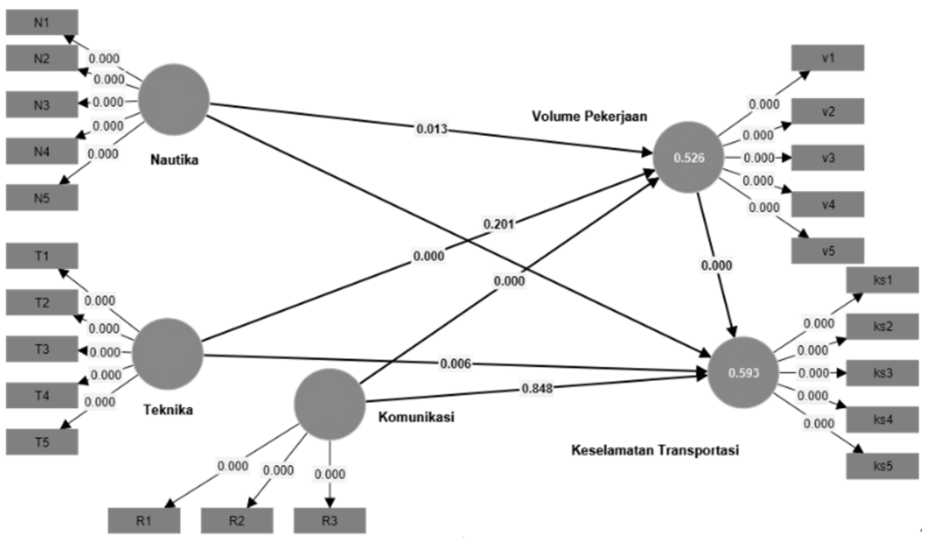

Figure 3. SEM mode path coefficient graph

Based on Table 3 analysis results, it is known that the Communication variable has a significant effect on the Volume of Work (t = 5.565; p = 0.000), but has no significant effect on Transportation Safety (t = 0.192; p = 0.848). This means that although an effective communication system supports an increase in the volume of PVRM work, it does not directly improve the perception or reality of marine transportation safety. This may be because safety is more determined by other technical and operational aspects. Furthermore, the Nautical variable was shown to have a significant effect on the Volume of Work (t = 2.498; p = 0.013), but did not have a significant effect on Transportation Safety (t = 1.278; p = 0.201). This indicates that the nautical function contributes more to an increase in the workload or intensity of KDPs, but does not necessarily directly affect the perception or condition of shipping safety.

Unlike the previous two variables, the Technics variable showed a significant influence on both the Volume of Work (t = 4.784; p = 0.000) and Transportation Safety (t = 2.738; p = 0.006). This finding confirms that the technical aspect, which relates to the system and condition of the ship's machinery and structure, plays a crucial role in improving the safety of shipping operations, as well as having an impact on the volume of work that must be handled by PVRM officers. Most striking is the effect of Work Volume on Transportation Safety, which is significant with a value of t = 4.559 and p = 0.000. This indicates that an increase in the volume of work managed professionally and efficiently by PVRM officers has a direct impact on improving marine transportation safety. In other words, successful management of work volume is an important determinant in creating a safe shipping system. The results of the analysis on the initial model are shown in Figure 3.

Overall, the structural model in this study shows that Technics and Volume of Work variables have a direct and significant influence on marine transportation safety. Meanwhile, Communication and Nautical contribute to increasing the volume of work, which then indirectly supports shipping safety. These results support the importance of strengthening technical functions and optimizing PVRM workload as a strategy to improve marine transportation safety in Indonesia. Next, the following are the results of the R-Square (R^2) value analysis. For further details, see Table 4.

Table 4. R^2 value

	$\boldsymbol{R^2}$	**Adjusted** $\boldsymbol{R^2}$
Transportation Safety	0.593	0.565
Work Volume	0.526	0.502

The R^2 value is used to explain how large a proportion of the variance of the dependent variable can be explained by the independent variables in the structural model. In this study, there are two main dependent variables, namely Work Volume and Transportation Safety. Based on the results of the analysis, it is known that the R^2 value for the Transportation Safety variable is 0.593, which means that 59.3% of the variation in marine transportation safety can be explained by the combined influence of the Communication, Nautical, Technical, and Volume of Work variables. The remaining 40.7% is explained by other factors outside this research model. The adjusted R^2 value of 0.565 shows the adjustment to the number of predictors in the model and provides a more conservative estimate, but still shows a fairly good predictive power. Meanwhile, for the Job Volume variable, an R^2 value of 0.526 was obtained, which means that 52.6% of the variation in job volume can be explained by the Communication, Nautical, and Technical variables. The adjusted R^2 value of 0.502 confirms that more than half of the variability in the volume of work of KDP officers can be interpreted through the three functional dimensions tested in the model.

In general, both R^2 values are in the moderate to strong category, as stated by Williams et al. [29], that the R^2 value of 0.50–0.70 indicates a moderate level of relationship. Thus, the model used in this study has sufficient predictive ability and is reliable in explaining the relationship between functional PVRM and work volume and its impact on marine transportation safety in Indonesia.

3.2.3 Goodness of fit

The Goodness of Fit (GOF) test is carried out to evaluate the extent to which the structural model built is in accordance (fit) with empirical data. The result of the GOF test on the initial model is listed in Table 5.

Table 5. GOF analysis results

	Saturated Model	**Estimated Model**
SRMR	0.084	0.084
d_ULS	1.96	1.96
d_G	1.108	1.108
Chi-square	347.86	347.86
NFI	0.691	0.691

Based on the analysis results, the Standardized Root Mean Square Residual (SRMR) value for the estimated model is 0.084. This value is below the maximum threshold of 0.10 as recommended by Sarstedt et al. [30], so it can be concluded that the model has a good level of fit in absolute terms. Then the Normed Fit Index (NFI) value was recorded at 0.691. Although this value has not reached the "good" category (generally NFI $>$ 0.90), a value close to 0.70 already indicates that the model tends to provide an adequate representation of the data. In the context of exploratory models with complex structures and latent variables, as in this study, this value can be considered sufficient to explain the relationship between variables in the model. In this research, the GOF criteria reference refers to the opinion where the SRMR value is smaller than 1, then the model is said to be fit.

So overall, based on the indicators of SRMR, NFI, and other values, it can be concluded that the SEM model used in this study has met the general model feasibility criteria, and is suitable for use in interpreting the relationship between functional nautics, technics, communication, work volume, and marine transportation safety.

3.2.4 Final SEM model

After removing statistically insignificant relationship paths, the final structural model (final SEM model) shows five significant influence paths. the functional variables of Communication, Nautical, and Technical were found to have a positive influence on Work Volume, while Technical and Work Volume each had a significant influence on Maritime Transportation Safety. The following are the results of the analysis showing the SEM final model, as shown in Figure 4.

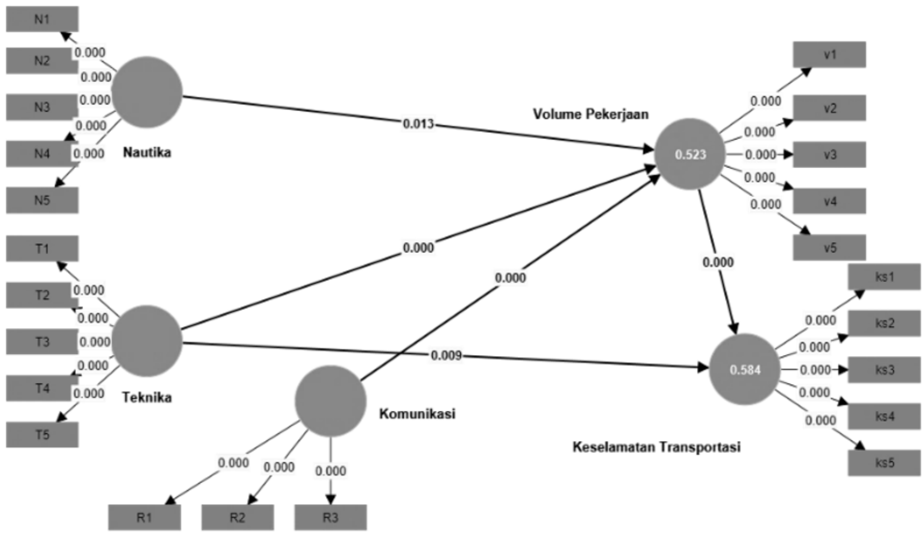

Figure 4. Final SEM model

The results in Figure 4 confirm that technical and communication functions in the inspection process play a strategic role in increasing the workload of PPKK, which in turn has a direct impact on the overall effectiveness of shipping safety. Next are the GOF test results for the final model. More details can be seen in Table 6.

Table 6. GOF final SEM model

	Saturated Model	Estimated Model
SRMR	0.085	0.086
d_ULS	1.976	2.063
d_G	1.105	1.112
Chi-square	346.966	348.182
NFI	0.692	0.691

The results of the GoF test of the final SEM model in Table 6 show that the model fit remains within the acceptablerange. The SRMR value for the saturated model is 0.085, and for the estimated model is 0.086, both of which are below the maximum threshold of 0.10, indicating that the final model has a good absolute fit. Although there was a slight increase in the SRMR value compared to the initial model (initial SRMR = 0.084), the difference was very small and insignificant, so it can be concluded that model simplification (through the removal of insignificant paths) did not reduce the overall model validity. From the NFI perspective, there was a slight decrease from 0.691 to 0.692 in the saturated model and 0.691 in the estimated model. Although this value is still below the perfect fit category (NFI > 0.90), for PLS-based models with moderate complexity, a value close to 0.70 is acceptable, as explained by Hair et al. [31], especially since PLS-SEM focuses more on predictive ability than overall model fit.

4 Discussion

This research makes a significant contribution to understanding the determinants of marine transportation safety in Indonesia through an integrative approach involving four key functional dimensions: nautical, technical, communication, and the volume of work of the Vessel Safety Inspectors. This approach offers a new perspective that has not been widely explored in previous literature, especially in the context of strategic ports in western, central and eastern Indonesia. The results of the analysis show that technical aspects have a direct and significant influence on marine transportation safety. This finding is in line with previous studies that emphasise the importance of ship technical conditions in ensuring shipping safety. For example, sophisticated communication and navigation equipment on ships can reduce the number of accidents and casualties in shipping [32]. In addition, effective ship management, including careful route planning and efficient resource allocation, that contributes positively to ship safety by reducing the risk of accidents and ship damage [33].

However, the communication aspect, although having a significant effect on the volume of PVRM work, did not show a significant direct effect on marine transportation safety in this study. This may be due to the complexity of other factors that mediate the relationship between communication and safety, such as safety culture and operational pressure. Previous research emphasised the importance of applying Standard Maritime Communication Phrases (SMCP) in communication at sea to overcome language barriers and prevent misunderstandings that could lead to accidents [34]. In addition, also emphasised that effective communication between vessels is essential for operational coordination, preventing incidents, and ensuring safety. PVRM work volume was shown to have a significant influence on marine transportation safety. This finding indicates that the workload managed professionally and efficiently by VSIOS officers has a direct impact on improving shipping safety. This is in line with research that showed that the ability to communicate and the use of international signal codes by ship crews had a positive effect on the level of shipping safety [35, 36].

This research also has a strategic position in the development of maritime science, considering that studies related to the functional contribution of VSIOS—especially in the aspects of nautics, technics and communication (radio)—are still very limited in Indonesia. Most previous studies have highlighted the safety aspects of shipping from the technical perspective of the ship or safety regulations alone, without examining the strategic role of VSIOS in the inspection process that has a direct impact on the safety of sea transportation. Therefore, the findings in this research not only enrich the national scientific literature in the shipping safety domain but also serve as a practical reference for port authorities and policy makers in optimising the function of PVRM as the frontline in the national maritime safety system.

Meanwhile, the final SEM model of this study not only shows a significant relationship between technical, communication, and nautical functions and the volume of work and maritime safety, but also reflects a systematic approach similar to global PSC inspection practices. For example, the PSC system under the Paris MoU consistently uses multivariate analysis such as HJ-Biplot to categorise ship profiles based on risk and inspection characteristics [12, 37]. This approach aligns with the structural model concept in this study, which analyses functional variables and the mediation of work volume as predictors of safety. On the other hand, other studies examining Tokyo MoU data indicate that technical vessel variables (deficiency records and vessel attributes) significantly influence detention probability using a Bayesian Network model [38].

Overall, this study confirms that the integration of the engineering and volume management aspects of PVRM work is key to improving marine transportation safety in Indonesia. This holistic approach that considers multiple functional dimensions provides new insights into the development of more effective and efficient shipping safety policies and practices.

5 Conclusion

This study found that the technical, nautical, and communication (radio) functions performed by Ship Safety Inspectors (PPKK) significantly influence the volume of inspection work, while technical functions and work volume were found to have a direct influence on maritime transportation safety. These findings confirm that technical aspects and workload management are key determinants in ensuring the effectiveness of the maritime safety system in Indonesia. Using a quantitative approach based on Structural Equation Modeling–Partial Least Squares (SEM-PLS), this study successfully mapped the causal relationships between variables that have not been explored simultaneously in the context of national maritime institutions.

Theoretically, this study expands the framework of maritime safety studies by placing human actors—in this case, PPKK—as a latent construct that mediates and bridges the performance of the inspection system with safety outcomes. This approach offers a new dimension to the literature on shipping oversight, which has traditionally focused on technical characteristics of vessels or normative regulations, without examining the structural contributions of port institutional functions directly. The policy implications of these findings include the need to enhance the technical capacity of PPKK through international standard training, develop uniform inspection guidelines across ports, and optimize workloads through the digitalization of surveillance systems. The government, through the Ministry of Transportation, is expected to formulate policies to improve the efficiency and accountability of ship inspections based on valid empirical data and risk-based approaches.

However, it must be acknowledged that this study has geographical limitations as it focuses solely on three ports in Indonesia. Therefore, validation of the findings through cross-country studies is highly recommended, particularly by comparing Indonesia's PPKK system with the Port State Control (PSC) model in Europe or the Asia-Pacific region. Such efforts are important to strengthen the generalizability of the model and enrich the global literature on maritime safety.

Author Contributions

Conceptualization, H.S. and G.S.; methodology, G.S.; validation, H.S., G.S., A.S., and M.S.S.A.; formal analysis, G.S.; investigation, A.S. and M.S.S.A.; writing—original draft preparation, H.S. and A.S.; writing—review

and editing, H.S. and M.S.S.A.; supervision, H.S. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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