



*Regular Research*

# Shipping Safety Performance Models on Solid Shipping Lanes: An Internal and Environmental Factors Perspective

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**Abstract:** The global shipping lane for international trade in logistics and maritime is a shipping lane that has a high traffic density. Shipping on congested shipping lanes has great potential for the risk of ship damage. To improve shipping safety on dense shipping lanes, the purpose of this study is to analyze the relationship between ship's internal factors and shipping safety performance on dense shipping lanes, analyze the relationship between environmental factors and shipping safety performance on dense shipping lanes and obtain a model of shipping safety performance on dense shipping lanes. The method chosen to achieve the objectives of this study is a quantitative method with the Structural Equation Model (SEM) analysis technique with Smart PLS. The data of this research was obtained from the answers to a questionnaire that will be distributed to the crew of Indonesian-flagged commercial ships that have travelled through dense shipping routes, with a total of 150 crew members. The novelty of the research is a model of shipping safety performance in dense shipping lanes from the perspective of internal and environmental factors. The model shows the relationship between internal ship factors to shipping safety on dense shipping lanes by 30.9% and environmental influences on shipping safety on dense shipping lanes by 14.5%.

**Keywords:** cruise safety performance; congested cruise lines; congested shipping lane environment

## 1. Introduction

Shipping safety on congested lanes is now a serious concern due to the high risk of accidents. Congested lanes are defined based on historical data on ship traffic and refer to high-density areas. [1]. Including left-right shipping boundaries that direct the flow of ships in and out of ports as well as part of the global maritime trade and logistics network [2]. Areas such as the Singapore Strait and the Strait of Malacca experience traffic spikes and accidents [3], [4]. (In Indonesia, congested routes such as the Sunda Strait, Makassar, Sumbawa, Malacca, and Singapore have a high potential for accidents [5].

The movement of ships is influenced by internal factors such as speed, which affects navigation safety. [6], as well as cargo conditions such as the short length of the crane [7]. Integrated safety management strategies through technology contribute to increasing situational awareness. However, the use of improper technology can trigger accidents [7]. The psychological aspect also plays an important role in the crew's readiness to face emergencies. [8]. Captain experience, training, and crew collaboration are highly influential in reducing accidents [9]. Therefore, continuous training and monitoring are important in dealing with changes in the shipping environment [10]. In addition, external factors such as weather and

sea conditions also affect safety. The marine environment poses significant challenges to ship control [11]. Extreme weather and low visibility increase the risk of accidents [12].

Previous research has not developed a cruise safety model on congested lanes that considers a combination of internal and environmental factors. Several studies have focused on vessel movement, such as zig-zag models [13] and rotation [14], as well as the influence of competence, discipline, and environmental factors on ship control [11]. Other research shows that leadership, communication, and teamwork are significant to shipping safety [15] [16]. Navigation training using bridge simulators has also been shown to be influential [17]. However, with the increase in ship traffic, the allegation that internal factors such as technology, load conditions, and ship speed also affect safety is becoming increasingly relevant. Therefore, it is important to conduct a study entitled: "Shipping Safety Performance Models on Solid Shipping Lanes: Perspectives of Internal and Environmental Factors". The urgency of the research is important to reduce the risk of accidents triggered by increased traffic on congested shipping lanes. The general objective is to develop a model of the safety performance of shipping on congested lanes. The main purpose is to analyze the relationship between internal factors and shipping safety performance, and to analyze the influence of environmental factors on shipping safety performance.

Previous research has shown that lane width and traffic density have a major impact on safety, with narrow lanes increasing the risk of collisions and runs aground. [18]. The study emphasizes the importance of traffic and environmental conditions but has not focused on congested lanes. The emotional resilience of the crew has an impact on communication and decision-making [19]. Synchronization of technology and crew capabilities in ship operations is also important [20]. Crew competence and collaborative training have been shown to influence accidents [9]. However, the focus of this study is more on the operational aspect, not yet targeting congested paths specifically.

Extreme weather and risky working conditions are cited as the main causes of accidents. [21] But have not discussed the safety of cruising on congested lanes [22] shows that wind, currents, and waves affect the movement of ships, but has not explained their contribution to safety performance on congested paths. Research in rivers and the Straits of Malacca shows a correlation between traffic density and accident risk, as well as the importance of adherence to navigation guidelines [23] [24]. However, these studies have not discussed in detail the effect of environmental conditions on shipping safety on congested lanes.

The author has published several articles on shipping safety, and his research on leadership and teamwork skills affecting shipping safety [15]. The ability to communicate and use international sign codes has a significant effect on shipping safety [16]. Public speaking affects the performance of the crew. [25]. The application of the P2TI rule during the guard service affects shipping safety. [26]. Training in navigation and communication tools on bridge simulators affects shipping safety [17]. Variables of maritime environmental conditions and crew competencies affect ship movement [11]. In the strategy of improving safety, training is required for the crew [22]. The research that has been published by the author still focuses on shipping safety, not yet focused on shipping safety on congested shipping lanes.

The novelty expected in this study is the model of shipping safety performance on solid shipping lanes from the perspective of internal and environmental factors. This model analyzes internal factors such as technology, ship loading conditions, and ship speed that have not existed in previous research. This research not only analyzes the internal factors of ships but also analyzes environmental factors on solid shipping lanes, namely weather conditions, traffic density, narrow topography, and the existence of lane boundaries.

## 2. Materials and Methods

## 2.1 Research Concept Framework

Based on a previous research literature review, it is suspected that there is a relationship between internal ship factors and environmental factors on shipping safety performance in solid shipping lanes. Previous studies have indicated the relationship between internal factors and shipping safety performance, namely, ship speed control affects navigation safety [6], the use of technology and loading conditions affect navigation safety [7], Experience, training, and collaboration of crew members are very influential in reducing accidents. [9], Environmental training and monitoring are essential for shipping safety.

[10]. Competence and discipline affect ship control [11]. Leadership, communication, and teamwork are essential for shipping safety. [15] [16]. Bridge simulator training affects shipping safety. [17]. Meanwhile, previous studies that indicated the relationship between environmental factors and shipping safety performance showed that maritime environmental conditions affect the movement of ships. [11], Extreme weather and low visibility increase the risk of accidents [12]. Wind, currents, and waves affect the movement of vessels [22]. So that based on previous research studies, a research concept framework can be made that shows the research hypothesis (H) shown in Figure 1.

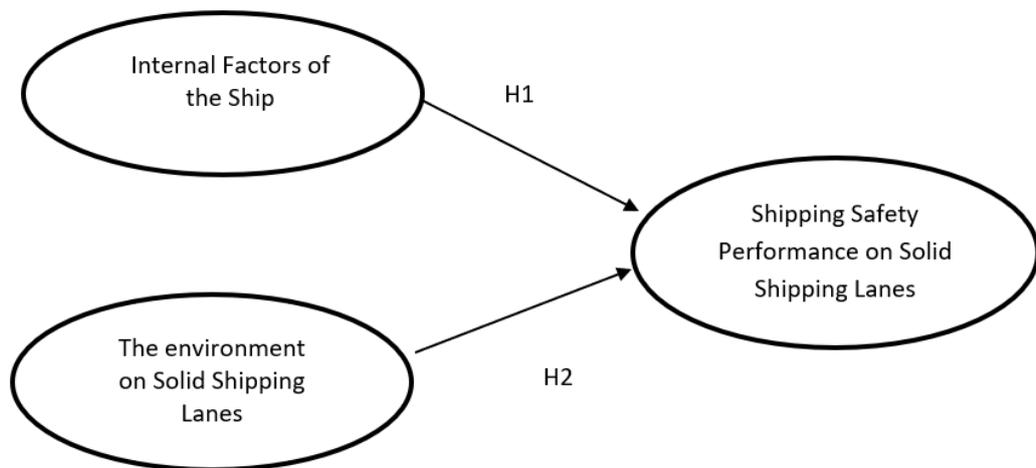


Figure 1. Research Concept Framework

Based on Figure 1. Framework The concept of the study can be explained that there is a positive and significant relationship between internal factors and shipping safety performance on solid shipping lanes (H1), and it is suspected that there is a positive and significant relationship between environmental factors and shipping safety performance on solid shipping lanes.

## 2.2 Methods

To test the safety model of shipping on

dense shipping lanes, we analyze the influence of internal and environmental factors on safety on dense shipping lanes using a quantitative method with SmartPLS Structural Equation Modeling (SEM) analysis. Testing the model begins with testing the validity and reliability of the research instrument. The research instrument in the form of a questionnaire was made based on research variables and indicators with exogenous variables of ship internal factors (X1) and ship environmental factors on solid shipping lanes (X2), as well as endogenous variables, namely shipping safety performance on solid shipping lanes (Y1). The

indicators of the research variables are shown in Table 1.

Table 1. Shipping Safety Performance Indicators on Solid Shipping Lanes

Variable Symbols	Variable	Indicators
X1	Variable Exogens: Internal Factors of the Ship	X1.1 Loading Conditions X1.2 Ship Speed X1.3 Crew Training X1.4 Crew Experience X1.5 Crew communication X1.6 Technology
X2	Variable Exogens: The environment on Solid Shipping Lanes	X2.1 Traffic congestion X2.2 Path limiter power X2.3 Strip depth X2.4 Weather conditions X2.5 Current strength X2.6 Wind direction and strength
Y1	Endogenous variable: Shipping Safety Performance on Solid Shipping Lanes	Y1.1 Avoid collisions with other ships Y1.2 Avoid running aground Y1.3 Not exiting the right and left lane dividers

All the indicators of this study are 15, with details of exogenous variables, internal factors of the vessel consisting of 6 indicators, environmental variables of the solid shipping line consisting of 5 indicators, and 3 endogenous variables of shipping safety performance on solid shipping lines. According to data from the Director General of Sea Transportation in 2024, the number of Indonesian seafarers is 1,556,521 [27], so the population in this study is 1,556,521. With the aim that the results of this study can be generalized to all Indonesian seafarers, the selection of this sample uses the maximum

probability estimation method, the recommended sample size is between 100 to 200, or as much as 5 to 10 times the number of parameters in the model, or equal to 5 to 10 times the overall manifest variable/indication contained in the model. [28] [29] [30] [31]. So that the sample in this study was determined to be 150 sailors of Indonesian-flagged ships. The number of samples obtained from 15 indicators in this study multiplied by 10 equals 150. The characteristics of the sample in this study are shown in Table 2.

Table 2. Characteristics of the Research Sample

No.	Characteristic	Description
1	Flag Country: The ship where the sailor works	Indonesia
2	Seafarer nationality	Indonesia
3	Type of Ship where sailors work	Merchant Ships
4	Cruise Routes	Belawan / Dumai / Batam / Singapore → Straits of Malacca → Straits of Singapore → Karimata Strait → Java Sea → West Shipping Lane of Surabaya →

No.	Characteristic	Description
5	Seafarer Experience	Tanjung Perak (Surabaya) More than 1 year
6	Seafarer competence	Nautia/ Technician

The research questionnaire gave alternative answers with scores according to the Likert scale. This Likert scale has 5 alternative answers, namely a score of 5 with the option Strongly Agree, a score of 4 with the option Agree, a score of 3 with the option Quite Agree, a score of 2 with the option Disagree, and a score of 1 with the option Strongly Disagree. Furthermore, the respondents' answers were tabulated, and then the outer model and inner model were tested using SEM-SmarPLS analysis.

Outer models or external relationships describe how each indicator relates to latent variables. Testing the outer model using convergent validity is declared valid if the value of outer loadings is more than 0.7, Cronbach's Alpha is more than 0.6, the composite reliability is  $\geq 0.7$ , and the Average Variance Extracted (AVE) is more than 0.5. The

hypothesis is considered significant if the P value  $< 0.05$ . The inner test of the model is carried out by evaluating the value of VIF. If the collinearity statistics (VIF) value is less than 5, then all variable indicators in the study are free from multicollinearity problems. In addition, the inner model was also tested using the R-squared value [32].

### 3. Results

#### 3.1 Outer Model Test Results

Based on the results of the analysis of the SEM-SmartPLS outer model with a convergent validity test, it was obtained that all variable indicators of internal factors of the ship, the environment on the shipping line, and the safety performance of shipping on the solid shipping lane are shown in Table 3.

Table 3. Outerloading research indicators

Variable	Indicators	Outer loadings
Internal Factors of the Ship	X1.1 Loading Conditions	0.919
	X1.2 Ship Speed	0.734
	X1.3 Crew Training	0.742
	X1.4 Crew Experience	0.878
	X1.5 Crew communication	0.876
	X1.6 Technology	0.866
Environments on Solid Shipping Lanes	X2.1 Traffic congestion	0.734
	X2.2 Path limiter power	0.879
	X2.3 Strip depth	0.767
	X2.4 Weather conditions	0.738
	X2.5 Current strength	0.701
	X2.6 Wind direction and strength	0.859
Shipping Safety Performance on Solid Shipping Lanes	Y1.1 Avoid collisions with other ships	0.921
	Y1.2 Avoid running aground	0.716
	Y1.3 Not exiting the right and left lane dividers	0.929

Based on Table 3, it can be explained that all indicators of research variables are valid because they obtain an outer loadings value of 0.7. Based on the results of the Smart-PLS analysis, the output of the construct reliability

and validity test was obtained from the variables in the shipping safety performance model on solid shipping lanes: the perspective of internal and environmental factors is shown in the following Table 4.

Table 4. Reliability and Validity of research variables

Variables	Cronbach Alpha	Composite Reliability	AVE
Internal Factors of the Ship	0.914	0.934	0.704
The environment on Solid Shipping Lanes	0.817	0.895	0.742
Shipping Safety Performance on Solid Shipping Lanes	0.877	0.904	0.612

Based on Table 4 Construct Reliability and Validity, Cronbach's Alpha values obtained > 0.6, Composite reliability  $\geq$  0.7, and Average Variance Extracted (AVE) > 0.5, so that it can be stated that all indicators and variables in the Shipping Safety Performance Model in Solid Shipping Lanes: Internal and Environmental Factors Perspective valid and reliable so that it

is worthy of further analysis with the inner test of the SEM-Smart PLS model.

### 3.2 Inner Model Test Results

The results of the SEM-SmartPLS inner model test through the VIF (Collinearity Statistic) test obtained the result that all variables in this study received a VIF value of < 5, as shown in the following Table 5.

Table 5. Inner VIF values

Variable	Shipping Safety Performance on Solid Shipping Lanes
Internal Factors of the Ship	1,415
The environment on Solid Shipping Lanes	1,415

Based on Table 5, it can be explained that the variables of internal factors of the ship, the environment on the solid shipping lane, and the safety performance of the cruise on solid shipping lane obtained a VIF value of < 5 so that it can be stated that all research variables are free of multicollinearity.

The direct relationship between the research variables of the Shipping Safety Performance Model on Solid Shipping Lanes: Perspectives of Internal and Environmental Factors between the research variables can be carried out by hypothesis testing, as shown in Table 6.

Table 6. Path Coefficients

Variable	Original Sample of Control Ship (O)	T Statistics	P Values
Internal Factors of Ships → Shipping Safety Performance on Solid Shipping Lanes	0.309	3.196	0,001
Environment on Solid Shipping Lanes → Shipping Safety Performance on Solid Shipping Lanes	0,145	1.508	0,132

Based on Table 6 Path Coefficient, it can be explained that internal ship factors have a direct effect on shipping safety performance in dense shipping lanes of 0.309 positively and significantly, with a P value of 0.001. The environment in dense shipping lanes has a positive effect on shipping safety performance

in dense shipping lanes of 0.145, but is not significant because the P Value > 0.05, which is a value of 0.132. In addition, the internal test conducted with R-Square analysis in the study of Shipping Safety Performance Model in Dense Shipping Lanes: Internal and Environmental Factor Perspectives has an R Square value of

0.166.

The result of the SEM-PLS analysis obtained a shipping safety performance model on solid shipping lanes: the

perspective of internal and environmental factors on solid shipping lanes is shown in the following Figure 2.

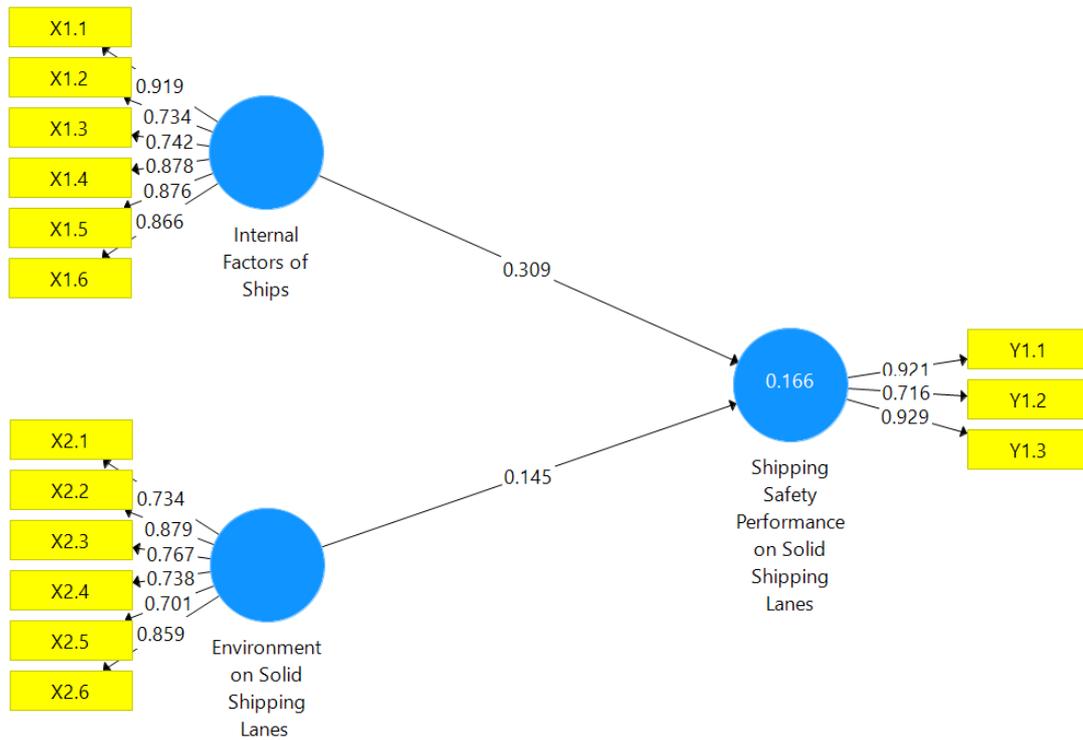


Figure 2. Shipping Safety Performance Models on Solid Shipping Lanes: An Internal and Environmental Factors Perspective

Figure 2 shows the Shipping safety performance model on solid shipping lanes: internal and environmental factors perspectives on solid shipping lanes analyzed with SEM-SmartPLS. Based on the analysis with SEM-SmartPLS, it was shown that all exogenous variables of the study, namely internal factors of the ship and the environment on the dense shipping lane influenced the endogenous variables in the study, the safety performance variable on the solid shipping lane which was shown by the R square value of 0.166 units or 16.6%. Based on the analysis of the strongest lanes that affect the performance of shipping safety on congested shipping lanes, the variable of the ship's internal factor of 0.309 units or 30.9%.

#### 4. Discussion

Based on the results of the hypothesis test

with SEM-SmartPLS analysis, it can be explained that the safety performance of shipping in dense shipping lanes is positively influenced by 0.309 units or 30.9%, and is significant as indicated by P Values of 0.001 by internal ship factors. These results are in line with developing research [19]. Communication influences decision making, and technology influences movement [20]. Ship speed influences ship control. [6], Crew competence influences ship movement [11], and crew training influences the level of ship accidents [9]. It can be shown based on the results of the outer loadings test that the indicators that influence internal factors include ship loading conditions, ship speed, crew training, crew experience, crew communication, and technology, where the most influential is the ship loading condition of 0.919.

In addition, based on the results of the hypothesis test, it also shows that the

performance of shipping safety on solid shipping lanes is positively influenced by the environment on solid shipping lanes, namely by 0.145 units or 14.5%. But not significant because the P Values are 0.132. This is not in line with the developing research [11], that maritime environmental conditions affect ship movements. The insignificant relationship between maritime environmental conditions and safety performance on solid shipping lanes in this study is likely due to the presence of environmental variable indicators that have not been included in this research model, which affect safety performance on solid shipping lanes. In addition, the strong positive and significant relationship between environmental variables and shipping safety performance in shipping lanes is likely due to the presence of intermediate variables that are not yet in this model.

Based on the results of R Square, it can be explained that the shipping safety performance on solid shipping lanes is jointly influenced by internal factors of ships and the environment on dense shipping lanes by 0.166 or by 16.6%. The results of this study indicate a weak influence between internal ship factors and maritime environmental conditions on shipping safety performance on solid shipping lanes, because 84.4% of the shipping safety performance model on shipping lanes is influenced by other variables outside this model that have not been explained. The possibility of a strong relationship between internal ship and environmental factors on shipping safety on solid shipping lanes may occur through intermediate variables that are not yet in this research model. Although the results of this study are weak, these results indicate a positive relationship between internal ship and environmental factors on shipping safety performance on solid shipping lanes supporting research that internal factors such as ship speed control affect navigation safety [6], use of technology and loading conditions affect navigation safety [7], Experience, training, and collaboration of ship crew members have a great influence on reducing accidents [9], Training and environmental monitoring are very important for shipping safety. [10]. Competence

and discipline affect ship control [11]. Leadership, communication and teamwork are essential for safety at sea [15][16], and environmental variables such as maritime environmental conditions affect ship movement [11], Extreme weather and low visibility increase the risk of accidents [12], wind, currents, and waves affect ship movement [22].

So the novelty of this study is a model of shipping safety performance on solid shipping lanes: the perspective of internal and environmental factors that can have implications for ship crews to improve shipping safety performance in dense shipping lanes and for future research to develop variables in the shipping safety performance model on solid shipping lanes because from this study internal and environmental factors affect together still The weak category was 16.6% while 84.4 was influenced by other variables outside the variables in the safety performance model on solid shipping lanes: internal and environmental factors perspectives.

## 5. Conclusions

The safety performance of shipping on solid shipping lanes is positively and significantly influenced by the ship's internal factor of 0.309 units or 30.9%, so it is recommended for the commercial ship crew to improve the ship's internal factors which include ship loading arrangements, ship speed regulation, increased crew training, recruitment that pays attention to crew work experience and crew ability to master navigation technology on ship.

The safety performance of shipping on solid shipping lanes is also positively affected by 0.145 units or by 14.5%, so it is recommended for ship crews to pay attention to the environment on dense shipping lanes, namely by paying attention to the movement of other ships, lane barriers, lane depth, weather conditions, current strength and current direction and strength so that they are safe when sailing on solid shipping lanes.

Shipping safety performance model on solid shipping lanes: internal and environmental factors perspective is recommended for the crew and the government to improve shipping

safety performance in congested shipping lanes, namely by increasing the ship's internal factors, because internal factors are the strongest factors that affect shipping safety performance. In addition, it is recommended for future researchers to be able to develop variables in the shipping safety performance model on congested shipping lanes because there are still 84.4% of other factors outside the model that are suspected to affect shipping safety.

This study has limitations because the shipping safety performance model on solid shipping lanes in this study is included in the weak category, which may be influenced by other variables outside the model or may require intermediate variables in the model. The limitations of the study are also from the number of samples used, only 150 Indonesian crew members with domestic shipping routes, the results of which can be generalized to all Indonesian sailors, even though the population of Indonesian sailors in 2024 is 1,556,521 people with diverse Indonesian cultural contexts.

This study has practical implications for ship crews as ship operators to improve internal factors such as increasing competence, training, mastery of technology, and ship communication in improving shipping safety performance on solid shipping lanes. In addition, these results have practical implications for shipping companies to provide support to ship crews in improving ship internal factors. The theoretical implications of this study for readers and academics are that it can increase knowledge about internal factors, ship environment, on shipping safety performance on solid shipping lanes. The weak model in the study (R-Square 0.166), so that it is hoped that future research can involve intermediate factors or explore internal and environmental factors that have not been explained in this study, so that it can develop a safety performance model on solid shipping lanes from the perspective of internal and environmental factors. In addition, future research is expected to increase the sample size so that the results can be generalized to all Indonesian sailors.

**Supplementary Materials:** There are no supplementary materials.

## Appendix 1

There is no Appendix 1 in this article

## Appendix 2

There is no Appendix 2 in this article.

**Author contributions:** Compile research instruments, collect research data, process and analyze data: Author 1; Petrified in data analysis and correcting writing and language: Author 2; Help collect data: Author 3

**Competing interests:** We, as authors, declare that we have no competing interests

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