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Handling Waste on Ships: A Model Based on Safety and Awareness

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Abstract: Internationally, waste handling on ships is regulated in Annex V of the Marine Pollution (MARPOL) regulation 1973/1978. Crews' knowledge and competence in waste management and safety are specified in the Standards of Training, Certification, and Watchkeeping for Seafarers, Manila 2010. However, research shows that waste is still discharged into the sea, which disturbs the aesthetics and negatively impacts the marine environment, ecosystem, and people's safety and security. This study investigates waste handling by container ship crews. Data were collected through a survey with 180 container ship crews at Tanjung Perak Port, Surabaya, Indonesia; and analysed using Structural Equation Modelling-Partial Least Square (SEM-PLS) software. The finding suggested a positive and significant impact of the crews' roles in preventing marine pollution, at 31.5%. This finding confirms the need for a waste handling model on ships that considers safety and awareness. This study suggests improvements in ship management and crews' awareness of waste handling aimed at environmental protection.

Keywords: Waste management, Indonesia, SEM-PLS, ship crew, sea transportation

1. Introduction

The increasing amount of waste in the sea is an urgent environmental problem that needs to be addressed immediately. The accumulated waste in the sea comes from land and ships, which includes plastic, food and household waste [1]. In international trade, almost 90 % of goods are transported by sea [2]. Nearly 80% of goods transported by sea are transported by cargo ships [3]. With the increasing number of ships, pollution and threats to the marine environment also rise, so environmental protection has become more important than ever [2]. In 2021, the same volume of goods was expected to be transported using container ships with an increasing gross tonnage [4]. At

Tanjung Perak, the second largest port in Indonesia, it was recorded that container ships for cargo were the most docked (35.6%) compared to other general cargo ships, Ro-Ro Ferry, tugboats, and tankers. The deadweight tonnage (DWT) and gross tonnage (GT) of container ships were also the largest, at 2,473,667 (50.9%) and 1,950,285 (46.3%), respectively [5]. With the increasing number and gross tonnage of container ships entering Tanjung Perak Port, Indonesia, the concern is not only about safety but also the environment. With more ships and gross tonnage, there will be more ship crews, hence, more waste disposal. In sum, the growth in marine transportation causes marine environmental problems due to the increased waste disposal volume [6].

In Indonesia, experts estimate that 80% of waste comes from the land and 20% from the sea. The amount of waste on the coast of Surabaya amounts to 22,059.19 grams, the second-highest after the city of Padang [7]. Of the 20% of waste from the sea, some come from ships, although the Law of the Republic of Indonesia No. 17 /2008 on Shipping states that ship crews are responsible for the maritime environment's safety, security and protection. Waste handling on ships that is non-compliance with the regulation can jeopardise the environment and the safety of the crew and the ships. For example, in one case study, waste discharge into the sea caused a fire in the engine room. The fire damaged the ship and let water enter the ship's engine. The cooling system was blocked by the waste during the discharge, disrupting the ship's main engine, auxiliary wind, and pumps [8].

The main goal of maritime transport is to facilitate the flow of goods and people by considering the factors of safety, security, and protection [9]. On merchant ships, garbage handling is also governed by the international regulations for preventing pollution at sea regulated in Annex V of Marine Pollution Prevention (MARPOL) 1973/1978. Country members must comply with the regulations. Certification, knowledge, skills, and competence of seafarers for monitoring and protecting the marine environment have also been regulated in the international Standards of Training, Certification and Watchkeeping for Seafarers (STCW) 1995. The Manila 2010 Amendment was issued by the IMO (International Maritime Organization) on the competency and professional requirements of ship crews [6].

Despite the regulations and bills, ships still discharge waste into the sea, significantly deteriorating the environment [10]. The international conventions aim to protect the maritime environment, but the issue of waste disposal into the sea and oceans is a global problem, affecting the ecosystem and shipping navigation. Safety measures have been introduced but have not been complied with [11]. This is unfortunate because ship crews' active roles could prevent 31.5 % of marine pollution [12]. Electronic waste management on ships identifies and determines the amount and type of waste, separates, and classifies waste automatically during a journey [13]. However, previous research shows that models for waste handling on ships have not considered all types of garbage according to Annex V of MARPOL 1973/1978, especially a model that includes safety

factors. The current study thus aims to analyse waste handling on container ships while considering safety, crew knowledge, safety behaviour, awareness, as well as ship safety.

2. Data and Methods

This study uses quantitative methods with statistical analysis and Structural Equation Modelling-Partial Least Square (SEM-PLS). The respondents in this study were 180 container ship crews at Tanjung Perak Port, Indonesia. The crew refers to people who work on ships, including the captain, or are employed by ship owners or shipping companies to carry out their duties and responsibilities in accordance with the crew certificate [9]. The container ship crew in this study worked on 11 Motor Vessels (MV) that carry out inter-port shipping in Indonesia, summarised in Table 1.

Table 1 Ship Particulars. Source: Ship Particulars, 2021

No	Ship's Name	Route	GRT (Ton)
1	MV. A	Surabaya-Amamapare-Jakarta	4591
2	MV. B	Surabaya-Banjarmasin-Surabaya	5737
3	MV. C	Surabaya-Kupang- Surabaya	8203
4	MV. D	Surabaya-Jakarta-Bitung	9320
5	MV. E	Surabaya-Kendari- Surabaya	2207
6	MV.F	Surabaya-Kendari	4369
7	MV. G	Surabaya-Palu-Surabaya	3837
8	MV. H	Surabaya-Palu-Surabaya	4909
9	MV. I	Surabaya-Kupang- Surabaya	3577
10	MV. J	Surabaya-Makassar-Surabaya	3461
11	MV. K	Surabaya-Medan-Surabaya	3976

Data were collected through a survey with 28 questions to discover the waste management practices on ships during the journeys. The questionnaire was tested for validity and reliability using the SPSS 23 IBM Statistics for Windows program with a sample of 30 container ship crews. The validity of the research indicators is confirmed if each indicator's significance level is <0.05. the reliability of the variable based on Cronbach's alpha is considered reliable if the value is greater than 0.6. The tested instruments were distributed to 180 container ships carrying out loading and unloading activities at Tanjung Perak Port, Surabaya, Indonesia. The questionnaire asks about garbage handling on ships during inter-port shipping in Indonesian waters. The data from the completed questionnaires were tested for validity using discriminant analysis, and the reliability was tested using composite reliability tests. A constructed variable is perceived as valid if the average variance extracted (AVE)

value > 0.5 and the composite reliability value is greater than 0.70. The variable test is deemed reliable if Cronbach's alpha > 0.6. The data were then analysed to test the research hypotheses.

The relationship between crews' safety knowledge, awareness, safety behaviour, the ship's safety, and waste handling on ships was analysed using Structural Equation Modelling (SEM) Smart PLS 3.2 analysis performed on SEM-PLS Smart PLS software [14]. The level of significance to accept or reject the hypothesis is if the p-value < 0.05. The model of waste handling on container ships is accepted if the collinearity analysis (VIF) test results have a value < 5. The assessment of the waste handling model on container ships using Smart PLS is based on the R-Square value for each dependent latent variable. The research model is perceived as strong if the value of the endogenous latent variable in the structural model has an R-Square value of > 0.75; moderate if the R-Square has a value of 0.50-0.75; weak if the R-Square value is 0.25 [15].

3. Results and Discussion

The results of the validity and reliability tests of the research instruments are as follows: AVE value > 0.5, composite reliability value > 0.7, Cronbach alpha > 0.6. This indicates a valid and reliable instrument. Meanwhile, the results of the statistical collinearity analysis test (VIF) indicator variable for waste handling research concerning the safety and awareness of container ship crew has a VIF value < 5, which means the research variable indicator is good or free of multicollinearity, as shown in Table 2.

Table 2 Results of Collinearity Statistic (VIF) Test for Garbage handling on Ships based on the Safety and Awareness of Container Ship Crews. Source: Research Primary Data, 2022

Research variable	Ship Safety VIF Value	On Ship Garbage handling VIF Value
Safety Knowledge	1.637	1.687
Safety Behaviour	2.106	2.404
Crew awareness	2.476	2.756
Ship Safety		3.614

The research hypothesis tests showed that the variables of crews' safety knowledge, safety behaviour, and awareness had a positive and significant effect on ship safety (p-value < 0.050). Safety knowledge increases ship safety by 0.118 or 11.8%, crew awareness of safety by 0.278 or 27.8% and safety behaviour by 0.287 or 28.7 % (see Table 3).

Table 3 Hypothesis Test Results on Direct Effect of Safety Knowledge, Safety Behaviour, Crew Awareness on Ship Safety. Source: Primary Data, 2022

Research variable	Ship Safety Original Sample (o)	P Values
Safety knowledge	0.118	0.026
Safety behaviour	0.287	0.000
Crew awareness	0.278	0.000

Based on the analysis of SEM-PLS 3.2, the direct influence between knowledge of ship safety and safety behaviour is positive and significant at 0.118 (Table 3), which means the deeper the knowledge of the crew, the better the ship's safety. The proposed hypothesis (H1) stating that knowledge of safety affects ship safety can thus be accepted. This is in line with the results of research conducted by [16] and [17], revealing that safety knowledge significantly affected safety practices. Likewise, the crew's competence and knowledge affect the ship's operation [18]. Therefore, if container ships at Tanjung Perak Port Surabaya need to improve ship safety, the management must pay attention to the extent to which their crew's safety knowledge follows the STCW standards, the Manila amendment 2010 A-VI/1-4. Competence in identifying and dealing with hazards that threaten the ship's safety should adhere to emergency certificates through safety training and standard safety equipment.

The results of hypothesis testing also show a positive and significant relationship between safety behaviour on ship safety (the value of 0.278 in Table 3). Therefore, the hypothesis on the direct relationship between safety behaviour and ship safety (H3) is accepted, which is in line with [19], stating a positive and significant relationship between safe climate behaviour and conditions and the crew's safety [20]. This proves that discharging waste into the sea, as observed by the Indonesian National Transportation Accident Committee (KNKT) in 2019, is not per waste handling and safety provision. As mentioned previously, hazardous incidents can happen, such as the case of a ship fire caused by waste blocking the engine coolant. This means that the safety behaviour of the crew can determine safety on container ships at Tanjung Perak Port. Therefore, safety improvement is sought, and ship management needs to pay attention to the crews' safety behaviour.

Based on the hypothesis testing results on the direct influence of crew awareness, it was found that crew awareness had a positive and significant effect on ship safety (the value of 0.278 in Table 4), so (H6) is accepted. Likewise, ship safety at Port Tanjung Perak can be improved by raising the crews' awareness. The relationship between the two variables is positive and significant, which means the higher the awareness, the better the safety. This is in line with [21] and [22] stating that the awareness of the surroundings and righteous environmental actions affect ship safety.

Similarly, safety knowledge, safety behaviour, and ship safety have a positive and significant effect on waste handling, as shown by the p-value < 0.050, 0.369, 0.266, and 0.222, respectively. In contrast, crew awareness has no significant effect on garbage handling on ships, as shown in Table 4.

Table 4 Hypothesis Test Results concerning Direct Effect of Safety Knowledge, Safety Behaviour, Awareness of Ship Crew on Garbage handling on Ships, Source: Research Primary Data, 2022

Research variable	Original Sample (O) On Ship Garbage handling	P Values
Safety knowledge	0.369	0.000
Safety behaviour	0.226	0.002
Crew awareness	0.158	0.063
Ship safety	0.222	0.050

Safety knowledge has a positive and significant effect on waste handling on ships by 0.369 (Table 4). This means that the hypothesis (H2) on the influence of safety knowledge on waste handling is accepted. This is in line with [17], stating that knowledge can improve sound environmental behaviour and vice versa. If left unaddressed, poor environmental behaviour can threaten the environment and safety management [23]. For example, to improve the behaviour, the ship crews at Tanjung Perak Port should be reminded that, when sailing on Indonesian waters, ship safety factors must be checked, including using personal protective equipment such as gloves, head protection, safety belts, and safety shoes. This is in accordance with Annex V Marine Pollution 1973/1978, namely in separating garbage, disposing of waste into the sea, burning waste in incinerators, or waste storage to be disposed of at the nearby port's waste disposal facilities.

The hypothesis that safety behaviour has a positive and significant effect on waste management on ships (H5) is accepted, as shown by the value of 0.226 (Table 4). This means that the better the safety behaviour of the crew, the better the waste handling, which means safety aspects are in line with [24]. The Standards of Training, Certification and Watchkeeping for Seafarers, Manila amendment 2010 A-VI/1-4 states that when seafarers are on duty, they must use personal protective equipment in accordance with the provisions in Annex V of MARPOL 1973/1978.

The hypothesis stating that ship safety has a positive and significant effect on waste handling on the ship (H4) is accepted, as shown by the value of 0.222 (Table 4), which means that ship safety influences waste handling on container ships at Tanjung Perak Port Surabaya. If container ships at the Tanjung Perak Port aim to improve waste handling, they must improve their ship safety.

However, crew awareness did not significantly affect ship waste handling (see the value of 0.158 in Table 4), with a p-value > 0.05. This means that the hypothesis concerning the awareness of ship crews on waste handling (H7) is rejected. This implies that waste handling on container ships at

Tanjung Perak Port Surabaya cannot be simply improved by raising awareness. The influence of these two variables is positive, which means that the higher the awareness, the better the waste handling on the ship, but not significantly. This result is not in line with a previous study by [25], stating that environmental awareness has a positive and significant effect on pro-environmental behaviour and that sustainability requires awareness of all relevant stakeholders [26]. However, the results of this research are in line with research by [10], stating that ship crews may not care about waste handling but rather prioritise their work on the ship. Sea disposal is a common practice despite the regulations [10]. Therefore, the Port State Control must carry out supervision and regular inspections of waste handling on ships in accordance with Regulation No. 8 Annex V of MARPOL 1973/1978 and introduce strict sanctions for violations of MARPOL regulations 1973/1978.

Based on the results R-Square value, it can be concluded that safety knowledge, crew awareness, and safety behaviour affect the ship safety variable by 0.723, which indicates a moderate model. Similarly, safety knowledge, crew awareness, safety behaviour, and ship safety affect garbage handling on ships by 0.546, which indicates a moderate model (see Table 5)

Table 5 R-Square Value of Garbage handling on Ships based on Safety and Awareness of Container Crews. Source: Research Primary Data, 2022

	R -Square
Ship Safety	0.723
Ship Garbage handling	0.546

Based on the results of the SEM SmartPLS 3.2 analysis, as seen from the R-Square value 0.50-0.75 (Table 5), the waste handling model on container ships based on the safety behaviour and awareness of the ship crew is moderate. This means that the variables of safety knowledge, safety behaviour, and crew awareness affect ship safety variables by 0.723, and safety knowledge, safety behaviour, crew awareness, and ship safety affect garbage handling on ships by 0.546.

This study creates a model for waste handling per the provisions of the MARPOL Annex V Regulation by considering the safety factor and crew awareness. This robust model can be further developed to overcome marine environmental problems, as seen from the data provided in [7], by considering waste separation and safety measures. The model was created based on the data obtained from the Indonesian waters, as well as safety and environmental issues resulting from ship operations as stated by [2], [27], and [6] and research conducted by [28], a ship-based waste handling model. It was found that waste that arrives at the port has not been separated and could thus impact safety and costs at the port. The previous model by [13] used electronic sorting on ships but did not consider the safety factor and awareness of the ship crew. The proposed model in this study is developed based on hypothesis testing using SEM SmartPLS 3.2 analysis, as shown in Figure 1.

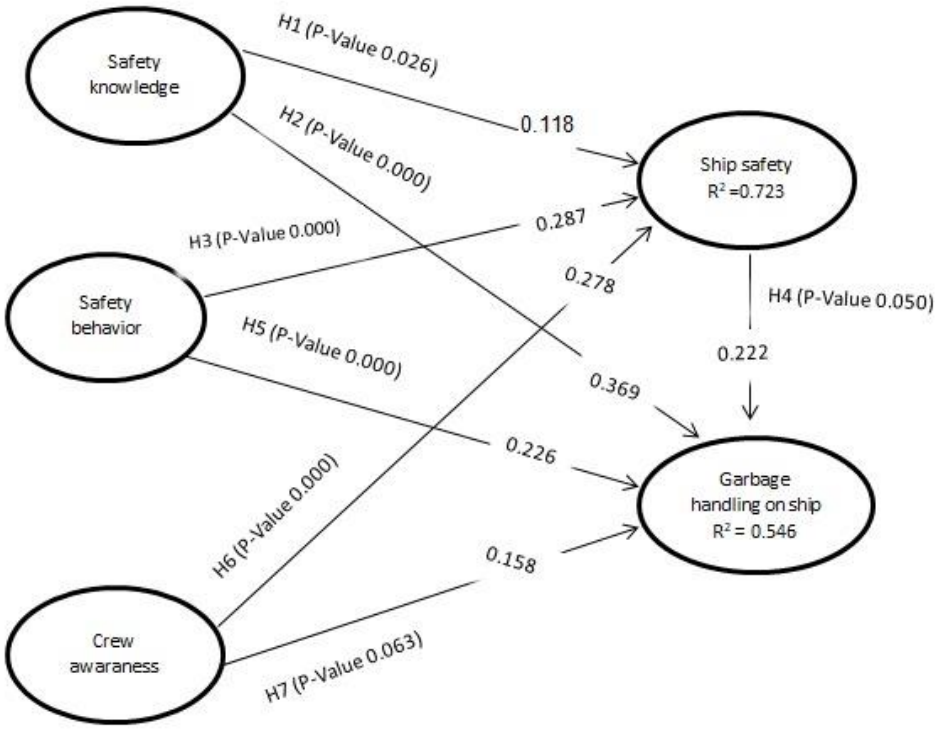


Fig. 1 Ship garbage handling model based on Container Ship's Crew Safety and Awareness at Tanjung Perak Port, Indonesia. Source: SmartPLS SEM Analysis Results, 2022

Figure 1 shows the waste handling model on ships based on crew safety behaviour and awareness at the Tanjung Perak Port. This model shows the magnitude of the coefficient of exogenous variables' influence on endogenous variables, as indicated by the p-value. In addition, based on the direct-effect path, there are relationships of influence on the entire construct of the research variables. The R-Square value in the model shows the value of ship safety of 0.723, while the R-Square value for handling garbage on the ship is 0.546. This means that the R-Square value is 0.50-0.75, which indicates moderate yet suitable. It can be further developed to overcome problems regarding ship safety, including accidents. Based on the data from the Indonesian National Transportation Accident Committee (2019), the waste from ships' discharges is visible on beaches and coasts [7][1][6]. This model can solve the such problem of illegal garbage disposal from ships to the sea [10].

4. Conclusion

Based on the results of the analysis of the waste handling model on ships in terms of safety (crew's safety knowledge and behaviour and ship safety) and crew awareness, it can be concluded that an efficient and practical waste disposal model can be created and developed to improve ship safety and protect the maritime environment. There is a positive and significant direct relationship between safety knowledge, safety behaviour, and crew awareness on ship safety, and a positive and significant relationship between safety knowledge, safety behaviour, and ship safety on garbage handling. However, crew awareness has no significant effect on waste handling on ships. Therefore, when

hiring a crew member, shipping companies should consider safety knowledge, behaviour, and crew awareness. This knowledge and competence can also be developed by training.

Ship management, such as leaders and owners of ships and shipping companies, can improve safety knowledge, behaviour, and safety to develop safety and waste handling on container ships at Tanjung Perak Port. Awareness among ship crew did not significantly affect waste handling on ships. They prioritise work on ships, such as navigation, engine operations, port guard services, cargo handling activities, and safety operations, over waste handling on ships. Therefore, the government must inspect and supervise waste handling on ships, which shall set sanctions if waste is not handled in compliance with Annex V MARPOL 1973/1978 and safety procedures.

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