

Tuesday, December 22, 2020

Letter of Appreciation

Dear Dr. Daeng Paroka

On behalf of the Editorial Board, I would like to thank you for your contribution in reviewing the following paper submitted to our journal.

RISK ANALYSIS OF SHIP COLLISION IN INDONESIAN WATER USING HOUSE OF RISK

I am confident that with your continuous support and commitment, we will be able to maintain the quality and value of JESTEC.

With best regards

Yours sincerely

Associate Professor Dr. Abdulkareem Sh. Mahdi Al-Obaidi, CEng MIMechE
Executive Editor, Journal of Engineering Science & Technology
<http://jestec.taylors.edu.my/>

REVIEW FORM

Title of paper: RISK ANALYSIS OF SHIP COLLISION IN INDONESIAN WATER USING HOUSE OF RISK

For sections A & B, please tick a number from 0 to 5, where 0 = strongly disagree and 5 = strongly agree.

A. Technical aspects

- | | | | | | | |
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| 1. The paper is within the scope of the Journal. | <input type="checkbox"/> 0 | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input checked="" type="checkbox"/> 3 | <input type="checkbox"/> 4 | <input type="checkbox"/> 5 |
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B. Communications aspects

- | | | | | | | |
|--|----------------------------|----------------------------|---------------------------------------|---------------------------------------|----------------------------|----------------------------|
| 1. The paper is clearly readable. | <input type="checkbox"/> 0 | <input type="checkbox"/> 1 | <input checked="" type="checkbox"/> 2 | <input type="checkbox"/> 3 | <input type="checkbox"/> 4 | <input type="checkbox"/> 5 |
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C. Comments to the authors (You may use another sheet of paper.)

D. Recommendation (Tick one)

- | | |
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| 1. Accepted without modifications. | <input type="checkbox"/> |
| 2. Accepted with minor corrections. | <input type="checkbox"/> |
| 3. Accepted with major modification. | <input checked="" type="checkbox"/> |
| 4. Rejected. | <input type="checkbox"/> |

E. Comments to the editors (These comments will not be sent to the authors)

Comments to the authors

1. The English should be improved to be easily understood by the readers.
2. The abstract should be consists of introduction, methodology, results and conclusion. The conclusion was not found in the abstract.
3. The introduction has been well described by presenting enough references to show the originality of the paper.
4. The authors explained the methodology clearly. In order to easily be used by the other researchers in interested in the same subject, the authors should explained how to determine the number total response as well as the number of response for different ship experts profession, how to validate and test reliability of the questionnaire used in this paper.
5. Results should be discussed correspond to results of the others papers/research or compared to the recently available system. How is different between the preventive action recommended in this paper with the applied system or regulation correspond to ship crew, equipments maintenance as well as ship clearance in departure and arrival ports. The authors should also explained the gap between the existing applied method and the finding of this research.

RISK ANALYSIS OF SHIP COLLISION IN INDONESIAN WATER USING HOUSE OF RISK

Abstract

Marine transportation is the workhorse of the world trade. In spite of the implementation of an array of regulations, marine transport still entails risk in their voyages. One of the safety risks are the collisions. The paper outlines the efforts to identify the root causes of ship collisions in Indonesian waters, occurring between 2010 ~~and~~ 2018, and identify preventive action to reduce the ship collision. The study is conducted based upon forty six collision cases published by the National Transportation Safety Committee (NTSC). This study uses House of Risk Method. The House of Risk (HOR) consists of two phases. The House of Risk Phase 1 is deployed to reveal the risks agent critical category of the accidents, and the analysis has found the following risk agents which are viewed as the primary trigger of the accidents. The risks agent critical category is the root cause of the accident. The House of Risk Phase 2 developing measures to mitigate the risk agent critical category. The risk agent critical category ~~in this study~~ are limited crew competence, is the one with the highest ARP score. Other major risk causes are unaccountability of crew recruitment process, not well-functioning of navigation equipment, uncalibrated radar, undisciplined crew competency certificate check, incomplete navigation equipment and irregular check on navigation and safety equipment, inaccurate information on cargo quantity and bad weather. ~~Those critical category of risk agents e-above~~ affect the critical risk events, namely incompleteness and not-well functioning navigation equipment and inadequate crew competency. ~~Stage~~ are crew preparation, and voyage preparations are the most critical stages to be aware of, in order to reduce of ship collision should be to create a system in the crew recruitment procedure at the crew preparation stage and create a system in the clearance out procedure at the sailing preparation stage.

Keywords: Risk agent, risk event, House of Risk, ship collision.

Comment [Z1]: The word of "stage" should be defined clearly.

Comment [Z2]: The meaning of this sentence was not clear.

analysis can provide information on the root causes of ship accidents. By doing so, we could identify ways to control risks [6]. Weng [7] categorize the causes of ship accidents into: (i) human error, (ii) technical and mechanical failure, and (iii) environmental factors.

Comment [Z6]: categorized

A number of studies on ship accidents shows various factors which have caused shipping accidents [8,18]. Most of the collisions accidents are caused by bad visibility (environmental factors), wrong decision making, poor communication between ships or between bridge crew (Bridge Resource Management), the crew does not focus during watch keeping and does not comply with the Safety Management System [9,19]

Sotrialis [10] developed a Bayesian Network model to identify the most important factors in collision probabilities. He concluded that collisions depend strongly on human factors. The main source of human error leading mostly to a collision accident is the poor monitoring and control of traffic conditions while on watch keeping. Yildirim [11] ~~in their study~~ found that the most important causes of accidents are unsafe actions and their triggers. The undisciplined crew on watch keeping, poor communication, and poor bridge resource management are the main causes of the collision accidents. The framework for assessing ship accidents was developed by considering two main consequences of ship accidents, namely human losses and environmental pollution [12]. Kim [13] studied on the MV SEWOL accident showed that accidents could occur if the organization failed to identify the ability of the crew and placed the crew that could not to handle dangerous situations onboard. Graziano [14] apply Technique for the Retrospective and Predictive Analysis of Cognitive Errors (TRACER) to identify the human error in collisions. He delivers a procedure to identify the human errors by measuring the performance of ship operations. Furthermore, ship safety encompasses aspects from design state to the operations. Inappropriate design, construction which are typical in traditional shipbuilding, poor implementation of regulations and operations of ships are exposed to the safety risks which might lead to ship accidents [15,17]. The National Transportation Safety Committee of Indonesia states that the causes of ship accidents are bad weather, fires due to dangerous loads, overload, shifting loads, imperfect ship design and human error.

Comment [Z7]: The reference should be showed here.

The above studies mostly presented the “upper level” causes of accidents. In order to make the risk analysis practically useful, a government authority or a shipping company prefers a list actionable activities, as a set of measure to reduce ship accidents. Unfortunately, the above findings are less adequate to be immediately translated into steps of actions. It remains unclear the direct and indirect causes of accidents. This paper aims to identify the root causes or risk agent critical category of ship collisions, and identify preventive action to reduce the root cause, by using the House of Risk.

2.Method

The House of Risk method involves the process of identifying, assessing, planning and implementing solutions. This method is innovative, integrated and simple. The House of Risks (HOR) consists of two phases, namely, to identify, analyse and measure potential risk by prioritizing critical risk agents, which called HOR Phase 1. Then, developing measures to minimize or mitigate the root cause

accident is called HOR Phase 2. A risk agent is defined a factor ~~that is~~ viewed as the root cause of triggering a risk event. ~~This is~~ in many cases an indirect cause of an accident. A risk event is a situation ~~which is~~ viewed as a direct cause of an accident [16.]

The House of Risk modifies FMEA (*Failure Models and Effect Analysis*) model for risk quantification. It adapts the home quality model (HOQ) to prioritize risk agents that have to handle first and to choose the most effective actions to reduce the risks that potentially arise from risk agents. The House of Risk Phase 1 method evaluates the occurrence and severity. Severity shows the level of disruption or damage which could be caused by a risk event. Occurrence is a probability a risk agent ~~might occur~~. In order to obtain the critical risk agents, a correlation between the severity of risk events and the occurrence of risk agents are ~~to be~~ computed. This method also evaluates the Aggregate Risk Potential (ARP). ARP is obtained through the value of severity of risk events, the probability of occurrence of risk agents, and the level of relationship between risk agents and risk events. The House of Risk phase 2 is used for risk treatment which gives priority to practical preventive actions to reduce the root cause. Preventive action requires consideration of choices and creative design. Preparation of preventive action should consider resources that include funds, people, time, facilities and infrastructure. The analysis follows the following procedure [16]:

2.1. House of Risk Phase 1

2.1.1. Identification of risk events dan riskagents

It starts with selecting an accident case, namely a ship collision. From every accident, ~~it is to be identified~~the events ~~which might~~ lead directly to the ~~selected~~above accident, ~~which are~~ called risk events ~~are identified~~. ~~Then~~ ~~From every~~the risk event, ~~it is to be identified~~ situations or objects potentially lead to a risk event called risk agents are identified. ~~called risk agents, which could potentially lead to a risk event.~~

2.1.2. Severity assessment of risk events

The criteria involve the assessments on the damage of the ship, cargo and human lives. The degree of severity obtained from the questionnaire and interviews is qualitative and converted into a numerical scale from 1 ~~to~~ 4. The ship collision contribute to ship damage $\leq 50\%$ are given value 1, and include in low category, the ship collision contribute to ship damage $\leq 50\%$ and load damage $\leq 50\%$ are given the value of 2, and include in moderate criteria, the ship collision contribute to ship damage $\geq 50\%$ load damage $\geq 50\%$ are given value of 3, and include in category of high, ship collision contribute to 100% loss of ship, 100% damage/loss of load, and fatalities are given value of 4, and include in very high category. Severity assessment criteria obtained from 30 shipping experts as respondents.

2.1.3. Occurrence assessments of risk agents

Similar to the above, the information obtained the respondents are qualitative. A conversion to a numerical scale from 1 to 4. The occurrence assessment is based on the number of ships collision within one month. The assessment level is

Comment [Z8]: The reasons to determine the number of sample should ne explained in this paragraph. What cetagories of shipping experts was choosen as sample should also be explained here.

Comment [Z9]: The meaning of these words are not clear.

Comment [Z10]: The meaning of this sentence is not clear.

Comment [Z11]: This sentence is not complete

categorized into four levels, rare is ship collision occurred one time in a month, and given value of 1, moderate is ship collision occurred twice in a month, and given value of 2, often is ship collision occurred three times until five times in a month, and given value of 3, very often is ship collision occurred more than five times in a month, and given value of 4. 30 shipping experts as respondents gave an assessment and grouping the criteria of occurrence.

2.1.4. Relationship assessment between risk events and risk agent.

They are building a relationship matrix between risk events and risk agents with a value of {0,1,3,9}. It aims to measure the level of relationship between risk events and risk agents. The relationships between risk events and agents may vary on a numerical scale from 0 to 9. The relationship assessment categorized into four levels ~~of relationship~~, no relationship is given a value of 0, weak relationships are given a value of 1, the moderate relationships is given the value of 3 and strong relationships are given a value of 9. No relationship means that a risk agent does not cause a risk event.

Comment [Z12]: What is represent by "they" in this sentence.

2.1.5. Aggregate Risk Potential (ARP) calculation

Aggregate Risk Potential (ARP) value describes the level of consequences caused by a risk agent. The value of the ARP is computed using the following formula:

$$ARP_j = O_j \sum (S_i R_{ij}) \quad (1)$$

Comment [Z13]: Please use equation in MS Word.

where ARP_j is the Aggregate Risk Potentials of a risk agent, O_j is occurrence of the risk agent, S_i is severity of the risk agent, and R_{ij} is relationship between a risk event and a risk agent.

Risk agents ~~having a with~~ high ARP value are very likely the ones which might cause a risk event. Ranking the risks agents from those with the highest ARP value to the lowest one is helpful, to the order of priorities.

2.1.6. Identifying critical risk agents

For practical purposes, most risk events are very likely triggered by only a very few risk agents. Attention at these very few agents causing most risk events is conducted by using the Pareto chart. The Pareto Chart is applied to identify risk agent of critical categories that are priority problems. In use, the Pareto Chart has 80-20 rules ~~mean. The rule has the understanding that~~ about 80% of the effects caused by 20% of the problem causes.

Comment [Z14]: The meaning if this sentence is unclear

2.2. House of Risk Phase 2

2.2.1. Identification of preventive action

The purpose of identifying preventive action is to reduce the ship collision. Identification of preventive action in this study from the questionnaire and interviews with shipping experts such as the Captain of the ship, Marine Superintendent, Harbour master, Marine Inspector officers, investigators of National Transportation Safety Committee (NTSC), juries of the Maritime Court, lecturers of maritime polytechnics, and Practitioners in the shipping education.

Comment [Z15]: Are the shipping experts the same as those previously mentioned. How to determined the number of each expert category to be interview as sample.

2.2.2. Relationship Assessment between root cause of the accident and preventive action.

Identification of preventive action based on the relationship between the classification of the risk agent critical category or the other name root cause of the accident and the preventive action. Assessment of the relationship between the root cause of the accident and preventive action using a numerical scale 0,1,3,9. The relationship assessment categorized into four levels of relationship, no relationship is given a value of 0, weak relationships are given a value of 1, the moderate relationship is given the value of 3 and strong relationships are given a value of 9 [16].

Comment [Z16]: These sentences have been mentioned previously

2.2.3. Level of difficulty to implement preventive actions

Assessment is given by shipping experts using a numerical scale 3,4,5. The category into three levels, very easy to implement is given a value of 3, easy to implement given a value of 4, and difficult to implement is given a value of 5 [16].

2.2.4. Effectiveness to difficulty ratio

Effectiveness to Difficulty Ratio (ETD) is an evaluation of preventive actions that are classified as useful to overcome some of the root causes that can arise. To calculate the value of ETD begins by calculating the value of total effectiveness. The value of the total Effectiveness is computed using the following formula [16]:

$$TE_k = \sum ARP_j \cdot E_{jk} \quad (2)$$

Comment [Z17]: Do the authors mean effectiveness.

Comment [Z18]: The meaning of j and k in this equation have not been explained

After obtaining the value of total effectiveness, then calculate the value of effectiveness to difficulty using a formula:

$$ETD_k = TE_k / D_k \quad (3)$$

where ETD_k is effectiveness to difficulty ratio, TE_k is total effectiveness of preventive action, E_{jk} is relationship between classification of risk agent critical category and the preventive action, and D_k is the level of difficulty to implement preventive action.

2.2.5. Evaluation the most effective preventive action

In this step, ranking ETD values from the largest to the smallest and calculating the cumulative value and cumulative percentage on each ETD value. Then determine the most effective preventive action using the Pareto Chart. The Pareto Chart is applied to identify the most effective preventive action. In use, the Pareto Chart has 80-20 rules. The rule has the understanding that about 80% of the effect can prevent 20% of the problem.

Comment [Z19]: This sentence seems to be redundant

3. Results and Discussion

3.1. Stages in ship operations

The whole ship operations are described as processes which grouped into stages. The operation stages are crew preparation, ship maintenance, cargo handling, voyage preparation and voyage/sailing processes. Each group of processes consists of situations or processes which are titled as risk agents. The first stage, crew preparation, contains processes starting from crew recruitment process till and the state of crew competence. The sea retitled as risk agents. The second

stage focuses on the treatment on the ship, namely maintenance. How well the shipping company organization manages the ship maintenance. The third stage, cargo handling, consists of activities to ensure a proper loading process including the measures to ensure that the ship possesses a sufficient stability. The fourth stage is a preparatory stage prior to the ship departure. This stage includes the activities carried out by the shipping company, the captain, the crew, and the inspection of the harbour master to ensure the seaworthiness. The analysis is made, based upon 46 ship collision cases in Indonesian waters in the period from 2010 till 2018. Most of ship collisions occurred in western part of Indonesian waters (see figure 1), where the shipping traffic is denser than the eastern part. A questionnaire is distributed to 30 respondents, who are captains, chief officers, chief engineers, marine superintendents, port captains, marine inspector officers, investigators of the NTSC, juries of the Maritime Court and lecturers of maritime polytechnics.

Comment [Z20]: These sentence should be in Methodology with explanation how to determine the composition of shipping experts as responses of this research.

3.2. House of Risk Phase 1

3.2.1. Identification of risk events and riskagents

Risk Events (RE) and Risk Agents (RA) identified from 46 chronological collision. Each chronological collision analysed the accident process, then identify the risk event and risk agents. The risk events and risk agents can be seen in Table 1.

Table 1. Identification of risk events and their relevant risk agents

Remarks on Risk Events	RA Code	Remarks on Risk Agents
Ship is sailing in an overloaded condition	A1	Crew and harbour master do not have accurate information on quantity of cargo
	A2	Crew does not make stability calculation after loading.
Number and condition of navigation equipment are inadequate	A3	Navigation equipment does not work well
	A4	Map is not updated.
	A5	Radar is not calibrated.
	A6	Navigation equipment is incomplete and inadequate.
	A7	Crew and harbour master do not check the crew Certificate of Competency
	A8	Communication equipment does not work well.
	A9	Shipping company does not implement appropriate maintenance plan.
Crew competence is inadequate	A10	Harbour master does not thoroughly check crew Certificate of Competency
	A11	Crew recruitment process is not accountable
Visibility is limited	A12	Weather is bad

3.2.2. Severity of risk events

This assessment involves thirty shipping experts as respondents. The assessment addresses their valuation on how harmful or severe a particular risk event is. The scores provided by respondent at the Severity value is shown in Table 2.

Table 2. Result of severity assessment

Code	Risk Event	Severity
E1	Overload condition	3.10
E2	The number and condition of Navigation equipment is not optimal	2.77
E3	The crew has minimal competence	3.27
E4	Visibility is limited	3.03
E5	Crew doubt in navigating	3.20
E6	The careless crew in watch keeping	2.73

Assessment severity of risk event (shown in Table 2) from the interview and questionnaire with thirty respondents. All risk events have a severity value around of three, indicating that the risk event has a high level.

3.2.3. Occurrence of risk agents

This assessment involves thirty shipping experts as respondents. Occurrence of risk agents is fairly of the same level. The scores provided by respondent at the occurrence of risk agent value is shown in Table 3.

Table 3. Occurrence of risk agents

Code	Risk Agent	Occurrence
A1	Crew and harbour master do not have accurate information on quantity of cargo	2,70
A2	Crew does not make stability calculation after loading.	2,53
A3	Navigation equipment does not work well.	2,63
A4	Map is not updated.	2,33
A5	Radar is not calibrated.	2,55
A6	Navigation equipment is incomplete and inadequate.	2,50
A7	Crew and harbour master do not check the condition of navigation and ship safety equipment.	2.33
A8	Communication equipment does not work well	2.57
A9	Shipping company does not implement appropriate maintenance plan.	2,73
A10	Harbour master does not thoroughly check crew Certificates of Competency.	2.17
A11	Crew recruitment process is not accountable	2,57

Comment [Z21]: It is enough to mention the number of response in Methodology. No need to be repeated in each sub title.

Code	Risk Agent	Occurrence
A12	Weather is bad	2,63
A13	Environment is dark	2,40
A14	Crew competence is limited	2,70
A15	Crew has less sailing experience	2,30
A16	Crew is not familiar with shipping operations	2,40
A17	Port is a congested	2,93
A18	Crew is in fatigue condition	2,43
A19	Crew number is less than required by regulation	2,17

Table 3 show the assessment of occurrence of risk agents between 2.17 to 2.93. The value indicated the risk agent in the moderate criteria to often criteria.

3.2.4. Relationship between risk events and risk agents

Relationship assessment between risk events and risk agents is carried out after the risk agent and risk event are identified. This is to assess the level of relationship between risk events and risk agents. The assessment results obtained interviews from 10 shipping experts. The results of the relationship assessment are in Table 4.

Comment [Z22]: Why in this stage the number of response is changed to be 10. This should be explained in the methodology.

Table 4a. Relationship assessment A1 to A10

RE code	RA code	Relationship value
E1	A1	3
	A2	3
	A3	9
	A4	3
	A5	9
E2	A6	9
	A7	9
	A8	1
E3	A9	3
	A10	9

Table 4b. Relationship assessment A11 to A19

RE code	RA code	Relationship value
E3	A11	9
E4	A12	3
	A13	1
	A14	9
E5	A15	3
	A16	1
	A17	1
E6	A18	3
	A19	1

Base on assessment of relationship between risk agent and risk event shown in Tables 4a and 4b, there was seven risk agents have strong relationship to risk events. WeIt notice that problems in checking the navigation equipment and crew competency issues are highly related to a ship collision.

3.2.5. Aggregate Risk Potential assessment

Aggregate Risk Potential (ARP) assessment comes from severity assessment, occurrence assessment, and relationship assessment. ARP value describes the level of consequences caused by risk. The value of ARP illustrates a risk agent condition. The result of ARP calculation shown in Tables 5a and 5b. From the ARP calculation, the highest value is 77.76 and the lowest value is 5.92. Risk agents that have the highest value is crew competence is minimal, and the risk agent in lowest value is crew number is less than required by regulation.

Table 5a. Value of ARP

A1 to A9	
RA Code	ARP Value
A1	25.11
A2	19.90
A3	65.57
A4	19.37
A5	63.91
A6	62.25
A7	58.10
A8	7.10
A9	22.69
A10	63.70

Table 5b. Value of ARP

A11 to A19	
RA Code	ARP Value
A11	75.46
A12	23.96
A13	7.28
A14	77.76
A15	22.08
A16	7.68
A17	9.39
A18	19.95
A19	5.92

3.2.6. Ranked ARP values

The **previous table** is then ranked according to their ARP values, starting with the risk agent with highest ARP value. The above analysis shows that the following factors contribute most to the collision risk of a ship, **namely the namely** the not well-functioning of navigation equipment including radar, and the role of human, especially crew and harbour master who do not **supervise** the conditions of equipment, crew certificates, and inadequate crew qualification due to unaccountable recruitment process. The result is shown in Tables 6a and 6b.

Comment [Z23]: Which tables. It is better to mention the table address directly.

Comment [Z24]: Word namely was double.

Comment [Z25]: The authors mean checking

Table 6a. Ranked ARP

From 1 to 10		
Rank	RA code	ARP value
1	A14	77.76
2	A11	75.46
3	A3	65.57
4	A5	63.91
5	A10	63.70
6	A6	62.25
7	A7	58.10
8	A1	25.11
9	A12	23.96
10	A9	22.69

Table 6. Ranked ARP

From 11 to 19		
Rank	RA code	ARP value
11	A15	22.08
12	A18	19.95
13	A2	19.90
14	A4	19.37
15	A17	9.39
16	A16	7.68
17	A13	7.28
18	A8	7.10
19	A19	5.92

3.2.7. Identifying critical risk agents

The fact shows that very few risk agents might trigger risk events which might lead to an accident. In short, a small number of risk agents are dominating the ship's exposure to risk for a collision. This resembles the Pareto principle, also known as 80/20 principle, where some 80% of accidents might be caused by some 20% of risk agents. ~~We define~~ ~~The~~ critical risk agents are a set of risk agents having a cumulative percentage of ARP value $\leq 80\%$.

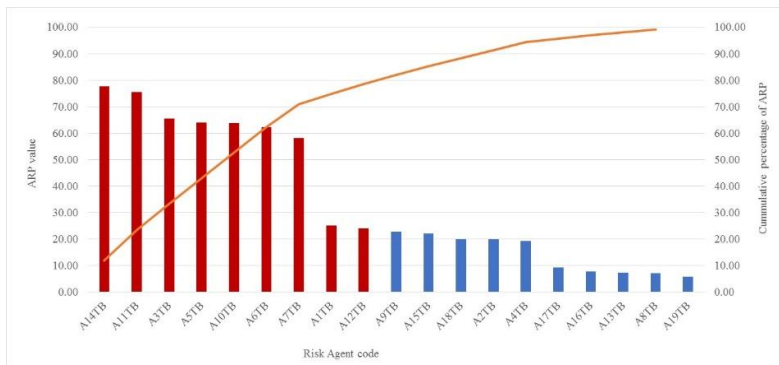


Fig.2. Pareto chart of preventive action

Based on the Pareto chart (as shown in Fig. 2), the following nine risk agents, namely A14, A11, A3, A5, A10, A6, A7, A1 and A12, cumulatively have a total ARP score of under 80%. A risk agent A14, a limited crew competence, is the one with the highest ARP score. Other major risk causes are unaccountability of crew recruitment process (A11), not well functioning of navigation equipment (A3), uncalibrated radar (A5), undisciplined crew competency certificate check (A10), incomplete navigation equipment (A6) and irregular check on navigation and safety equipment (A7), inaccurate information on cargo quantity (A1), and weather is bad (A12).

After obtaining a critical category of risk agents, they are classification according to the kinds of problem. Classification 1 namely crew recruitment process is not accountable. The risk agent critical category of risk agents included in the classification 1 are A14, A11, and A10. Unaccountability of crew recruitment process causing the shipping company do not know the level of crew's competence. So that has as results the risk of ship crews recruited by shipping companies may haveing limited competence. Other than the Harbour master does not thoroughly check crew competency certificates causing the crew have competence is lower than regulation, this has an impact on the crew's limited competence.

Classification 2 namely shipping company does not implement maintenance plan. The risk agent critical category included in the classification 2 are A3, and A5. Not well functioning of navigation equipment, and uncalibrated radar due to the shipping company does not implement maintenance plans of the ship. Undisciplined of the shipping company in the maintenance of the ship causes the shipping in the critical risk.

Classification 3 namely Clearance out letter approved without inspection to the ship (checking the ship stability, navigation equipment, safety equipment, and firefighting). The risk agent critical category included in the classification 3 are A6, A7, and A1. During the application process for Port Clearance, the Harbour master only carries out an administrative check, Harbour master do not inspection to the ship regularly, which affected the ship sailing in the incomplete navigation and safety equipment, and inaccurate information on cargo quantity.

3.3. House of Risk Phase 2

Comment [Z26]: Do the authors mean "the obtained critical category of risk agents are classified according to three groups" in this sentence.

Comment [Z27]: The meaning of this sentence is not clear

Comment [Z28]: It could be better if the risk agents directly mentioned than using code of the risk agents.

Comment [Z29]: Directly mentioned the risk agents are better than use code correspond to the risk agents

House of Risk Phase 2 is a step for preventive action. The first stage is identification of preventive action (as shown in Table 7).

Table 7. Identification of preventive action

Classification	Preventive action code	Preventive action
Crew recruitment process is not accountable	1PA	Create a system to ensure shipping companies carry out the selection in the crew recruitment process.
	2PA	Create a system to ensure shipping companies conduct competency tests on crew recruitment.
	3PA	Using technology in the crew selection process.
Shipping company does not implement maintenance plan.	4PA	Create a system to ensure that shipping companies carry out ship maintenance plans.
Shipping company does not implement maintenance plan	5PA	Create a system to ensure that surveys for ship maintenance scheduled, and survey reports make correctly.
	6PA	Provide penalties for shipping companies that do not carry out ship maintenance.
Clearance out letter approved without inspection to the ship (checking the ship stability, navigation equipment, safety equipment, and fire fighting)	7PA	Create a system so that the crew can report to the harbour master when they find deficiencies or damage to the ship and the equipment especially for items classified as critical equipment.
	8PA	Create a system to ensure the crew on board have appropriate competence.
	9PA	Create a system and use technology in assessing sea-worthy requirements.
	10PA	Create systems and using technology to ensure shipping companies provide up-to-date information about the ship's condition.

Preventive action is identified through observation, questionnaires, and interviews. From Table 7, there are ten preventive actions from three classification of risk agent critical category. The classification 1 is crew recruitment process is not accountable has three preventive action, namely 1PA, 2PA, and 3PA. The classification 2 is shipping company does not implement appropriate maintenance plan has three preventive action, namely 4PA, 5PA, and 6PA. The classification 3 is clearance out letter approved without inspection to the ship (checking the ship stability, navigation equipment, safety equipment, and fire fighting) has four preventive actions, namely 7PA, 8PA, 9PA, and 10PA.

3.3.1. Assessment of relationship between classification of risk agent critical category and preventive action

The assessment of relationship obtained interviews from 15 shipping experts. The assessment shown in Table 8.

Table 8. The assessment result of the relationship

Classification of risk agent critical category	Preventive action code	Average value
Crew recruitment process is not accountable.	1PA	4.79
	2PA	4.95
	3PA	5.42
Shipping company does not implement appropriate maintenance plan.	4PA	5.42
	5PA	6.88
	6PA	4.79
Clearance out letter is approved without inspection	7PA	7.00
	8PA	5.95
to the ship (checking the ship stability, navigation equipment, safety equipment, firefighting, and the crew competence).	9PA	6.47
	10PA	5.63

From the assessment (~~as shown in~~ Table 8), the highest relationship value is 7.0. The preventive action has the highest value is to create a system so that the crew can report to the harbour master when the crew finds deficiencies or damage to the ship and equipment, especially for items classified as critical equipment. The value indicated the preventive action have strong relationship to the classification of risk agent critical category.

3.3.2. Assessment level of difficulty

Assessment of the level of difficulty (D_k) to implement preventive actions provide by 17 shipping experts based on assessment criteria. The assessment results obtained (~~shown in~~ Table 9).

Table 9. The assessment result of the level of difficulty to implement preventive action

Classification of risk agent critical category	Preventive action code	D_k value
Crew recruitment process is not accountable.	1PA	3.47
	2PA	3.58
	3PA	3.58
Shipping company does not implement appropriate maintenance plan.	4PA	3.95
	5PA	3.89
	6PA	3.79
Clearance out letter is approved without inspection	7PA	4.37
	8PA	3.74
to the ship (checking the ship stability, navigation equipment, safety equipment, firefighting, and the crew competence).	9PA	4.11
	10PA	4.11

Table 9 show~~ed~~, the average value the level of difficulty to implement preventive action ~~is in~~ ranges between 3.47 to 4.37. The majority of respondents gave a preventive action assessment as easy to implement.

3.3.3. Calculation of Effectiveness to Difficulty Ratio

Effectiveness to Difficulty Ratio (ETD) is a value ~~describes that prescribes~~ practical preventive actions to prevent accidents. Before calculating Effectiveness to Difficulty Ratio value, ~~the calculate the~~ value of Total Effectiveness (TE) ~~is calculated by using the equation formula (2)~~. The results of the calculation of the total effectiveness of preventive action can be seen in Tables 10a and 10b, ~~respectively~~.

Comment [Z30]: The authors should consistence in writing Total Effectiveness

Table 10a. The total effectiveness of preventive action 1PA to 5PA

Preventive action code	Total Effectiveness (TE)
1PA	117.34
2PA	121.21
3PA	132.82
4PA	55.40
5PA	68.31

Table 10b. The total effectiveness of preventive action 6PA to 10PA

Preventive action code	Total Effectiveness (TE)
6PA	48.95
7PA	116.47
8PA	98.96
9PA	107.72
10PA	93.70

Tables 10a and 10b shown, the preventive action with the highest total effectiveness is using technology in the crew selection process (3PA). This preventive action is a solution to prevent the crew recruitment process ~~to be is not~~ accountable. The next step is to calculate the Effectiveness of the Difficulty Ratio (ETD) using formula 3. Calculation results can be seen in Tables 11a and 11b.

Table 11a. ETD ratio code 1PA to 5PA

Preventive action code	ETD Ratio
1PA	104.04
2PA	104.31
3PA	114.30
4PA	18.70
5PA	23.36

Table 11b. ETD Ratio code 6PA to 10PA

Preventive action code	ETD Ratio
6PA	17.21
7PA	74.79
8PA	74.28
9PA	73.60
10PA	64.03

From the calculation of ETD Ratio (~~shown in~~ Tables 11a and 11b), the highest value is 104.31 and the lowest value is 17.21. The highest value of ETD calculation is create a system to ensure shipping companies conduct competency test on crew recruitment (2PA), and the lowest value is provide penalties for shipping companies do not carry out ship maintenance (6PA).

3.3.4. Evaluation the most effective preventive action

For the evaluation, the most effective preventive actions start from the highest ETD ratio to lowest ETD ratio then making a Pareto Chart (~~shown in~~ Fig. 3).

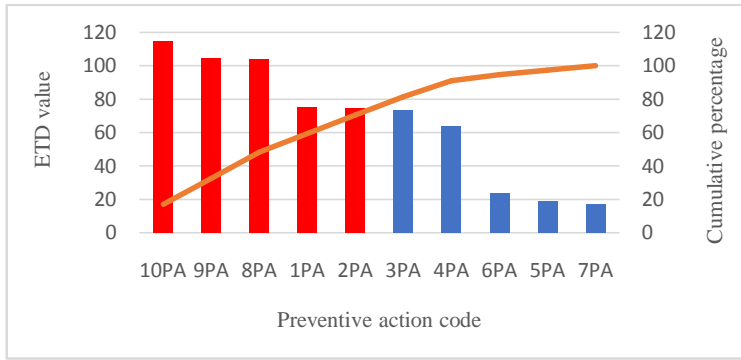


Fig. 3. Pareto chart of preventive action

From Pareto chart (shown in Fig.3), the most effective preventive action has a cumulative percentage of $\leq 80\%$. The preventive action are create a system and using technology to ensure shipping companies provide up-to-date information about the ship's condition (10PA), create a system and use technology in assessing sea-worthy requirements (9PA), create a system to ensure the crew on board have appropriate competence (8PA), create a system to ensure shipping companies carry out the selection process in crew recruitment (1PA), and create a system to ensure shipping companies conduct competency tests on crew recruitment (2PA).

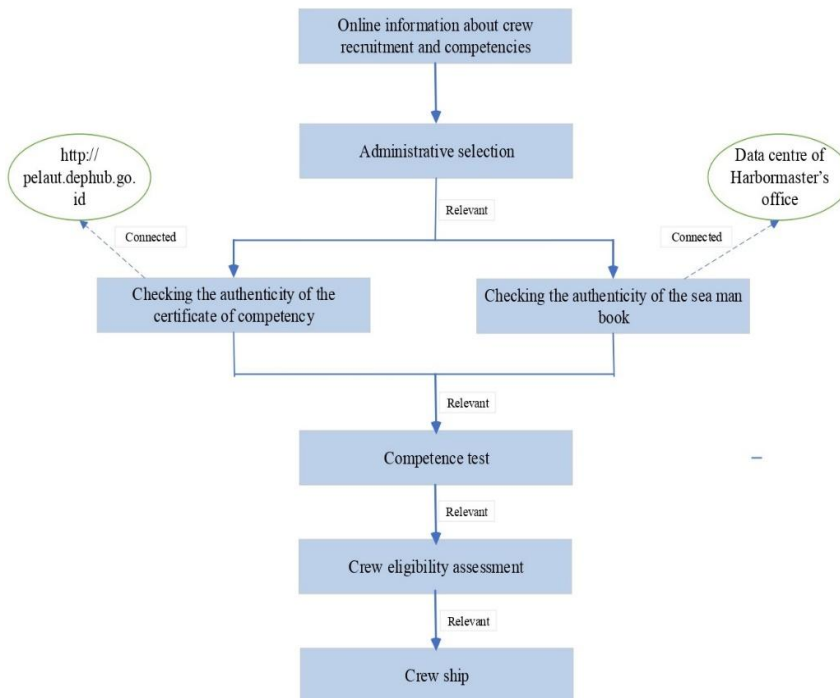


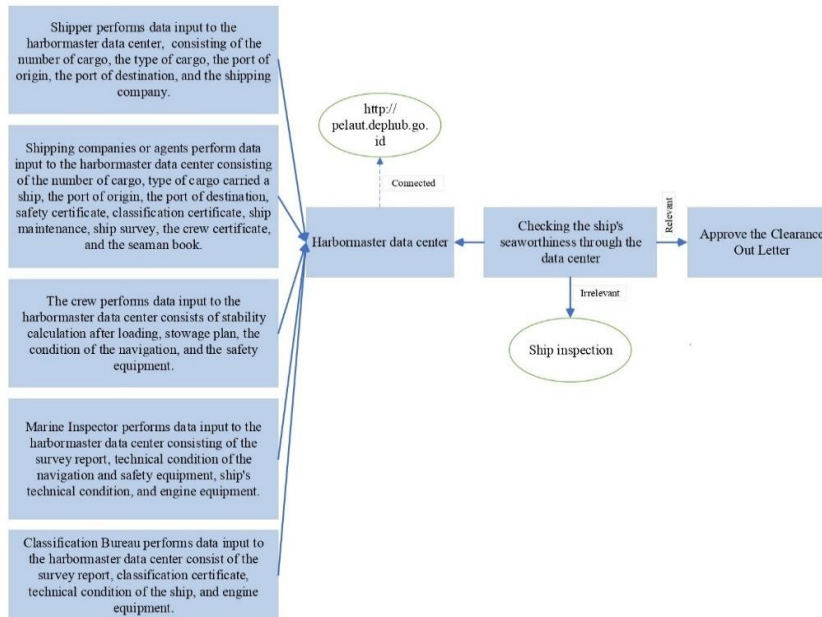
Fig. 4. Crew recruitment system**Fig. 5. Clearance out system**

Figure 4 show the all processes in the ship crew recruitment system are carried out online and can be accessed by shipping companies, seafarers, Harbormaster, Shipping Education, Department of Marine Transportation Human Resource Development, and the Directorate of Sea Transportation. Shipping companies provide information about the needs of the ship's crew through the system. Seafarers can access and view this information and its requirements and can register for selection to become a ship crew. The system is connected to the site <http://pelaut.dephub.go.id> and connected to the harbormaster data center, to check the authenticity of seafarers' documents (Certificate of Competency, and seaman book). Testing seafarers' competence is carried out through the system, and online, the system verifies a seafarer's eligibility to become a crew. If the sailor is reliable, the system will approve the eligibility to become a ship crew.

Figure 5 show all parties in the shipping business input data into the Harbormaster data center. The shipper enters data on the quantity and type of the cargo, the port of origin, the port of destination, and the shipping company. Shipping companies/agents input data on the number and types of cargo transported by each ship, port of origin, and port of destination. Besides, the shipping company/agent regularly enters class certificate data, ship safety certificates, ship maintenance implementation schedules, survey schedules, survey report from the Classification Bureau, survey report from the Marine Inspector, and the ship crew documents. Crew input data before the ship departs for the port of destination consisting of calculations of ship stability, stowage plan, conditions of navigation equipment, conditions of safety equipment, and conditions of firefighting equipment. Marine Inspector and Classification Bureau input data on survey reports, the ship's condition and its equipment, and the

condition of the ship's machinery. The data is stored in the harbormaster data center. The harbormaster data center is linked to the seafarer's website (<http://pelaut.dephub.go.id>) to facilitate checking crew competency certificates. Every shipping company/agent submits a clearance out a letter; then, the harbormaster officer checks the ship's condition, and the crew competency in the database. If all the data in the harbormaster data center is under the ship's seaworthiness, then the harbormaster approves the clearance out letter, but suppose there is no input of one of the data into the harbor master data center or there is a discrepancy in the data. In that case, the Harbormaster officer performs a physical inspection of the ship and its equipment. The system carries out seaworthy vessel assessment; each person or shipping company have to input data related to the evaluation. Harbormaster, shipping company, Classification Bureau, Marine Inspector, Directorate of Sea Transportation, Master, and the shipper can access the database.

4. Conclusions

House of Rik is an integrated method. This method can be used to identify the root cause of ship collisions, and identify preventive action. The method has successfully revealed deeper factors which might cause ship accident and the preventive action to prevent ship accidents. These are risk events which are viewed the direct cause of an accident, and a risk agent which is a direct cause of a risk event, ~~or in other words~~, and indirect cause as a root cause of ship collision. Having this at hand, the availability of both risk agents and risk events, a translation into a list of actions or policies is enabled. A careful identification of risk agents and risk events is a pre-requisite for delivering a correct result. The root cause of ship collision is a limited crew competence, unaccountability of crew recruitment process, not well functioning of navigation equipment, uncalibrated radar, undisciplined crew competency certificate check, incomplete navigation equipment, irregular check on navigation and safety equipment, inaccurate information on cargo quantity, and weather is bad. The cause of the ship collision occurred during the crew preparation stage and the sailing preparation stage. Therefore, preventive action should apply at this stage. To reduce ~~of~~ ship collision, ~~should be to create~~ a system in the crew recruitment procedure at the crew preparation stage should be created and create a system in the clearance out procedure at the sailing preparation stage.

Nomenclatures

ARP _i	Aggregate Risk Potentials
O _j	Occurrence of the riskagent
S _i	Severity of the riskevent
R _i	Relationship between a risk event and a riskagent
TE	Total effectiveness of preventive action
E _{jk}	Evaluation of the relationship between root causes and preventive action.
ETD _k	Effectiveness to difficulty ratio
TE _k	Total effectiveness of preventive action
D _k	Level of difficulty to implement preventive action

Abbreviations

NTSC	National Transportation Safety Committee
JESTEC	Journal of Engineering Science and Technology
HOR	House of Risk
COLREG	Collision Regulation

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