Analysis of crew competence factor in the ship collisions (Case study: Collision accident in Indonesian waters)

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Abstract: Sea transportation has a vital role in the transportation system in many countries due to lower costs and higher accessibility. As in Indonesia, approximately 80% of the global trade occurs ships. This condition makes the shipping industry in Indonesia is growing, but this is not in line with improving shipping safety. Many accidents continue to occur, which pose a high risk to safety. One of the most common risks in terms of sea transportation is ship collision. Ship collisions can cause material losses, injuries, and fatalities. The International Maritime Organization (IMO) has issued various direction to prevent accidents, but in reality, collision accidents continue to occur. However, the failure to apply a solution to prevent ship collisions is not at the root cause of the accident. According to the juries of the Maritime Court and the National Transportation Safety Committee (NTSC), one of the factors causing the collision of ships in Indonesia is the human factors (the inadequate crew competencies). The purpose of this research is to analyze the human factors involved in ship collision. The method used in this research is the House of Risk (HOR) phase 1. The data used in this study was obtained through a chronological review of ship collisions, questionnaires, and interviews with shipping experts. The results of this research reveal than inadequate crew competencies only a direct cause, not the root cause of ship collisions. The root cause is that the crew recruitment process is not accountable, the harbormaster does not thoroughly check crew competency certificates, and that maritime education does not implement QSS, STCW 95 and the amendments. To prevent ship collisions, should take preventive action on the root cause of the accident and not on the direct cause.

Keywords: ship collision, human factors, risk, critical category

1. Introduction
Maritime transportation is essential for the development of the world economy, as it constitutes the primary means of transporting goods [1] author [2]. Currently, over 90% of the world's trade occurs through marine transportation [3]. Although marine transportation is the primary means of trade, it is a risk both when ships are undertaking voyage and when ships are in port [4]. The maritime industry, especially in the transportation sector is dangerous. Many risks can occur during the voyage. Therefore,
Marine safety is important in national shipping and international shipping. Indonesia, as an archipelagos country that has 18,000 islands. The sea area of 70% of Indonesia's territory, causing Indonesia to emphasize its transportation by using marine transport mode, where the ship as a means of transport. Marine Transportation has the potential to be developed because it can carry large quantities of cargo to encourage economic improvement and public welfare. In parallel with growing world trade, the ship has grown in term of the number of ship and volume (Figure 1, and 2)

![Source: Indonesian Ministry of Transportation, 2018](image1.png)

**Figure 1.** The number of the ship.

![Source: Indonesian Ministry of Transportation, 2018](image2.png)

**Figure 2.** Number of GT.

The number of vessels from 2014 to 2018 increased by 55.38% (Figure 1a). The increase in the number of vessels is in line with the increased Gross Tonnage (Figure 1b). The total volume of goods in 2014 was 11,551,642 increased to 64,924,083 in 2018. Indonesia is a country with a large population, so it affects the number of goods needed. Increasing the amount of cargo needed will increase the flow of cargo distribution.
Developments in the shipping industry have led to an increase in sea traffic, but this increase is not in line with increased safety, there is still a risk that occurs when the ship on the voyage, such as collision ships [5]. Efforts have been made to achieve safety in maritime transport, but there is still an increase in the ship accidents [6] author [3]. Ship accidents will eventually cause damage to the environment, human life, and cargo [4]. Besides, the indirect impact caused by accident will involve the victim's family [7].

In Indonesia, the number of ship collision is quite large. This is exacerbated by the varied sea conditions of Indonesia, the characteristics of cargo, and passengers who have low education [8]. Based on data from the Coast guard unit, the total of ship collision in Indonesia in 2010 until 2017 (see figure 3).

From figure 3, it can be seen that the number of ship collision in 2010 to 2017 was 139 cases. The number was huge and did not experience a significant decrease. It was indicated there was no accurate solution to prevent the ship collision. It is crucial to know the cause of the ship collision to take a fixed action.

[9] and [10] in their research stated the humans are a significant contributor to accidents. Previous research categorizes humans as the dominant cause is: the accidents are caused by the condition of Human Resources (HR) in the marine sector has various problems [11] and competence of ship crew is less due to the inadequate quality of education [8]. The crew has minimal competence, negligent and careless while working, and old age can make the crew make mistakes and caused an accident [3]. Crew's inability to use equipment is caused by the inadequate quality of education and lack of safety training [5]. Besides undisciplined, fatigue while working could be the cause of the accident [12]. Excessive workload and insufficient rest will cause fatigue. Fatigue will result in less physical, mental, energy, which eventually seafarers depressed and stressed while working [4]. People need 8 hours a day for sleep. Sleepless than can cause fatigue which impacts degraded performance and decreases cognitive skills, slowing reaction time, reducing vigilance, and adversely affecting decision making [12]. Also, the crew who lacked understanding and did not adjust to the ship condition will be the cause of the accident [13]. According to the juries of the Maritime Court, ship accidents are caused by mistakes and negligence of the crew, technical factor, and natural factors.
2. **Standard Training Certification Watchkeeping for Seafarers (STCW Manila 2010)**

The Manila STCW amendment adopted based on several studies on human factors as the cause of ship accidents. This rule emphasizes the competence of the Captain and other crew when operating the ship [3]. The STCW amendment 2010 is about the competency certificate of seafarers, seafarers' medical standards, time to rest on the ship, seafarers training methods and competencies as well as the curriculum of the Maritime Education [14]. In addition to technical training aspects, STCW includes for the non-technical training aspect, such as (a) Bridge Resources Management; (b) Engine-room Resources Management; (c) leadership and Managerial Skill; (d) Application of Leadership and team-working Skills [15]. The education and skills of the ship's crew when conducting vessel operations determine the safety conditions of the voyage. Seafarers with proper education and skills will be ready to undertake onboard and have the ability to respond to an accident to prevent the loss of ships and humans [16].

The Standard Training Certification and Watchkeeping (STCW) 1978 amendment 95 and other amendments stipulate standard qualifications for captains, officers, and watchkeeping officers in commercial vessels. The aim of applying the minimum standard of education and training for seafarers' qualifications is to support marine transportation and shipping safety. Seafarers who want to work on a ship as captains, officers, and watchkeeping officers on commercial vessels are required to have a certificate of competency for Nautical or Technical issued by the Indonesian Ministry of Transportation. The competence of Nautical is seafarers who work on the deck of the ship (navigation and loading), and Technical is seafarers who handle the machining of ships. The regulation not only applies to crew ship, but also to ship owners, and shipping companies [15].

3. **Method**

This research uses the House of Risk (HOR) phase 1 method. House of Risk phase 1 aims to identify the risk agent of ship collisions, which are a critical category and are priority risks that must be addressed first. The HOR phase 1 begins with the process identifying risks carried out by identifying risk events and identifying of risk agents. After the risk agent of the critical category is identified then a Root Cause Analysis is performed on the critical risk. Risk agents are factors that cause and encourage risk. Through actions to reduce risk agents, it can indirectly reduce the incidence of risk events [17]. House of Risk is the development of QFD (Quality Function Deployment) and FMEA (Failure Models and Effect Analysis) that are used to develop a framework for managing risk.

The data used in this study were obtained through chronological review of ship collisions, questionnaires, and interviews with shipping experts, includes the juries of the Maritime Court, investigators of the National Transportation Safety Committee (NTSC), Captain, Chief Officers, and Chief engineers, Marine Superintendents, Marine Inspector, Harbormaster, Lecturers of Maritime Education, and Maritime Educational Practitioners. The analysis follow the procedure:

a. **Chronological Review of Ship Collisions**
   The first step in this research is to review 46 chronological ship collisions which were the results of the decision from the juries of the Maritime Court, then make a list of the causes of ship collisions in each chronological.

b. **Identification of risk events and risk agents**
   Identification of risk events and risk agents through a list of causes of ship collisions that have been made in a chronological review of ship collisions, then make a root cause analysis of risk events and risk agents (Figure 4). Risk events are events that might lead directly to the accident, and risk agent which could potentially lead to a risk event.

c. **Severity Assessment of Risk Events**
   Severity is assessed based on the level of loss due to ship collisions. Severity assessment using a scale
of 1 to 4 (Table 1). If there is more than one respondent, used a geometric formula to get the average value.

| Value | Assessment criteria | Remarks |
|-------|---------------------|---------|
| 1     | Contribute to ship damage ≤ 50% | Low |
| 2     | Contribute to ship damage ≤ 50% and load damage ≤ 50% | Moderate |
| 3     | Contribute to ship damage ≥ 50% load damage ≥ 50% | High |
| 4     | Contribute to 100% loss of ship, 100% damage/loss of load, and fatalities | Very High |

Table 1. Criteria for evaluating the impact of risk events.

d. Occurrence Assessment of Risk Agents
Occurrence is the chance of a ship collision. To measure the level of occurrence, use a scale of 1 to 4 (Table 2).

| Value | Assessment Criteria | Remarks |
|-------|---------------------|---------|
| 1     | One time in a month | Rare |
| 2     | Twice in a month    | Moderate |
| 3     | Three-times until five times in a month | Often |
| 4     | More than five-times in a month | Very Often |

Table 2. Criteria for evaluating the probability of a ship accident.

e. Relationship Assessment Between Risk Events and Risk Agent
Relationship matrices are used to assess the relationship between risk events and risk agents. The relationship use \{0,1,3,9\}. To measure the relationship between risk events and risk agents based on assessment categories: 0 means no relationship, 1 is a weak relationship, 3 is a strong relationship, and 9 is a very strong relationship.

f. Aggregate Risk Potential (ARP) Calculation
Aggregate Risk Potential (ARP) describes the risk conditions of risk agents. Risk agents that have the highest ARP values are the biggest causes of risk. ARP values can be calculated using the formula:

\[
ARP_j = O_j \times \sum (S_i \times R_{ij})
\]

Description:
ARP<sub>j</sub> : Aggregate Risk Potentials of a risk agent.
O<sub>j</sub> : Occurrence of the risk agent.
S<sub>i</sub> : Severity of the risk agent.
R<sub>ij</sub> : Relationship between a risk event and a risk agent.

g. Identifying Critical Risk Agents
After assessing the Aggregate Risk Potential (ARP), then ranking the ARP values from the largest to the smallest. After ranking the ARP, identify the risk agent critical category using the Pareto Chart with the 80-20 rule. The rule has the understanding that about 80% of the effects caused by 20% of the problem causes.

4. Result and Discussion
From the chronological review of ship collisions, and interview with shipping experts was identified causes of ship collisions caused by crew factors are inadequate crew competence, and crew is unsure in navigating or maneuver. These two causes are only a direct cause/risk event for ship collisions, and not
the root of the problem yet, so it needs to be further investigated at the root of the problem a root cause analysis is carried out on each risk event to find the indirect cause/risk agent which is the root of the problem. Root cause analysis can be seen in Figure 4.

**Figure 4.** Root Cause Analysis of Risk Events and Risk Agents.

In Figure 4, There are several risk agents in the risk event of inadequate crew competence. The risk agent is crew competence less than required by regulation, the crew recruitment process is not accountable, and maritime education does not implement QSS and STCW 95 and their Amendments, and Harbormaster does not thoroughly check the crew competency certificates. Risk event the crew hesitate when navigating/maneuver have risk agents are the crew has less sailing experience, the crew is not familiar with shipping operations, traffic in the waterway is dense, the crew is not psychologically healthy, and the crew is in fatigue condition. From the risk agent, then analyzes to identify the risk agent critical category. Risk agent critical category is obtained by assessing the severity of risk events, assessing the occurrence of risk agents, evaluating the relationship between risk agents and risk events, and calculating Aggregate Risk Potential (ARP).

The severity of risk event assessment and the occurrence of risk agent assessment is carried out using a questionnaire provided by the respondents. The results of the severity of risk event assessment can be seen in Table 3, and the occurrence of risk agent assessment can be seen in Table 4.

| Code | Risk Event                              | Average |
|------|----------------------------------------|---------|
| E1   | Inadequate crew competence             | 2.7     |
| E2   | The crew hesitate when navigating/maneuver | 3.2     |

Based on the average severity of risk event given by 30 respondents presented in table 3, the risk event that has a higher value is the crew hesitate when navigating/ maneuver (E2) with an average value of 3.2. This means that the severity caused by the crew hesitate when navigating/maneuvering is included in the high criteria.
Table 4. The occurrence of risk agent.

| Code | Risk Agent                                                                 | Average |
|------|-----------------------------------------------------------------------------|---------|
| A1   | Harbormaster does not thoroughly check crew competency certificates          | 2.17    |
| A2   | The crew recruitment process is not accountable                              | 2.57    |
| A3   | The crew competence less than required by regulation                         | 3.27    |
| A4   | Maritime education does not implement QSS and STCW 95 and the Amendments      | 3.17    |
| A5   | The crew has less sailing experience                                          | 2.30    |
| A6   | The crew is not familiar with shipping operations                            | 2.40    |
| A7   | Traffic in the waterway is dense                                             | 2.93    |
| A8   | The crew is not psychologically healthy                                       | 2.47    |
| A9   | The crew is in a fatigue condition                                           | 2.43    |

Table 4 shows that the risk agent who has the highest occurrence is the crew competence less than required by regulation (A3) with an average value of 3.27. This means that ship collisions caused by crew competence are less than required by regulation often occur in Indonesian waters.

After evaluating the severity of the risk event and the occurrence of a risk agent, then assess the relationship between the risk event and the risk agent (Table 5).

Table 5. Relationship between the risk event and the risk agent.

| Risk Event Code | Risk Agent Code | Relationship value |
|-----------------|-----------------|--------------------|
| E1              | A1              | 9                  |
|                 | A2              | 9                  |
|                 | A3              | 9                  |
|                 | A4              | 3                  |
| E2              | A5              | 3                  |
|                 | A6              | 1                  |
|                 | A7              | 1                  |
|                 | A8              | 1                  |
|                 | A9              | 3                  |

In Table 5, there are three risk agents have a relationship value is nine, this means that the risk agent has a very strong relationship with risk events. The risk agents are: Harbormaster does not thoroughly check crew competency certificates (A1), the Crew recruitment process is not accountable (A2), and Crew competence less than required by regulation (A3).

From the assessment of the severity of risk events, the occurrence of risk agents, and the relationship between risk events and risk agents, the Aggregate Risk Potential (ARP) value is calculated. ARP calculation results can be seen in Table 6.

Table 6. Value of Aggregate Risk Potential (ARP).

| Code | Risk Agent                                                                 | ARP value |
|------|-----------------------------------------------------------------------------|-----------|
| A1   | Harbormaster does not thoroughly check crew competency certificates          | 52.65     |
| A2   | The crew recruitment process is not accountable                              | 62.37     |
| A3   | The crew competence less than required by regulation                         | 79.38     |
| A4   | Maritime education does not implement QSS and STCW 95 and the Amendments      | 25.65     |
| A5   | The crew has less sailing experience                                          | 22.08     |
| A6   | The crew is not familiar with shipping operations                            | 7.68      |
| A7   | Traffic in the waterway is dense                                             | 9.39      |
In the ARP calculation result (Table 6), the highest value is 79.38. The risk agent has the highest ARP value is crew competence less than required by regulation (A3). To find out the risk agents are included in the critical category, first rank the ARP value from highest to lowest then make a Pareto Chart. The rank of ARP values can be seen in Table 7.

### Table 7. Rank of ARP Value.

| Code | Risk Agent                                                                 | ARP value |
|------|----------------------------------------------------------------------------|-----------|
| A3   | The crew competence less than required by regulation                        | 79.38     |
| A2   | The crew recruitment process is not accountable                              | 62.37     |
| A1   | Harbormaster does not thoroughly check crew competency certificates         | 52.65     |
| A4   | Maritime education does not implement QSS and STCW 95 and the Amendments    | 25.65     |
| A9   | The crew is in a fatigue condition                                          | 23.36     |
| A5   | The crew has less sailing experience                                        | 22.08     |
| A7   | Traffic in the waterway is dense                                            | 9.39      |
| A8   | The crew is not psychologically healthy                                     | 7.89      |
| A6   | The crew is not familiar with shipping operations                           | 7.68      |

To identify risk agent critical category that is priority problems, used a Pareto Chart with 80-20 rules. The rule has the understanding that about 80% of the effects caused by 20% of the problem causes. The Pareto chart can be seen in Figure 5.

![Pareto Chart](image)

**Figure 5. Pareto Chart.**

From Figure 5 it can be seen the risk agent is crew competence less than required by regulation (A3) has a cumulative value of 79.38 and cumulative percentage of 27.33%, this means the percentage of the crew competence less than required by regulation as the cause of ship collision is 72.67%. The Crew recruitment process is not accountable (A2) has a cumulative value of 141.75 and a cumulative percentage of 48.80%, this means the percentage of risk agent as the cause of ship collision is 51.20%.
Harbormaster does not thoroughly check crew competency certificates (A1) has a cumulative value of 194.40 and cumulative percentage of 66.93; this means the percentage of risk agent as the cause of ship collision is 33.07%. Maritime education does not implement QSS, and STCW 95 and the Amendments (A4) has a cumulative value of 220.05 and cumulative percentage of 75.76%, this means the percentage of risk agent as the cause of ship collision is 24.24%. The Crew is in fatigue condition (A9) has a cumulative value of 243.41 and cumulative percentage of 83.80%; this means the percentage of risk agent as the cause of ship collision is 16.20%. The Crew has less sailing experience (A5) has a cumulative value of 265.49 and cumulative percentage of 91.41%; this means the percentage of risk agent as the cause of ship collision is 8.59%. Traffic in the waterway is dense (A7) has a cumulative value of 274.88 and cumulative percentage of 94.64%; this means the percentage of risk agent as the cause of ship collision is 5.36%. The Crew is not psychologically healthy (A8) has a cumulative value of 282.77 and cumulative percentage of 97.36%; this means the percentage of risk agent as the cause of ship collision is 2.64%. The Crew is not familiar with shipping operations (A6) has a cumulative value of 290.45 and cumulative percentage of 100%.

Based on the Pareto 80-20 rule, risk agents that are in the critical category are risk agents that have a cumulative percentage of ≤ 80%. The risk agents are the crew competence less than required by regulation (A3), the crew recruitment process is not accountable (A2), Harbormaster does not thoroughly check crew competency certificates (A1), and Maritime education does not implement QSS and STCW 95 and the Amendments (A4).

5. Conclusion

There are four critical risk agents, namely: A3, A2, A1, and A4. The four risk agents are priority problems that should be given preventive actions. The crew competence less than required by regulation, have an impact on the ability of the crew to work onboard. Crew's ability is limited in operating navigation equipment, teamwork and when in an emergency.

The crew competence less than required by regulation can occur if the shipping company does not thoroughly check crew competency certificates on the recruitment process and Harbormaster does not thoroughly check crew competency certificates on the clearance out process.

Shipping companies do not carry out the selection process in the recruitment crew, which will have an impact on companies not knowing the level of crew competency. So that is possible for companies to accept seafarers has minimal competence to work onboard. International Maritime Organization (IMO) in the STCW 95 and its Amendments, and Quality Standard System (QSS) have regulated minimum standards for learning facilities, Human Resource, maritime education curriculum, seafarers' competency requirements for working onboard, the crew healthy and crew rest hours. If maritime education does not implement the Quality Standard System (QSS) and STCW 95 and its Amendments will affect on alumnus competencies. They have minimal competence.

Inadequate crew competence not the root cause of ship collision, this is only the direct cause of the accident. The root cause is that maritime education does not implement QSS and STCW 95 and its Amendments to produce seafarers who have minimal competence. This condition will be worse when the shipping company does not conduct the selection process in the recruitment crew, and Harbormaster does not thoroughly check crew competency certificates on the clearance out process. For risk treatment should be done at the root cause and not on the direct cause. To prevent ship collisions, should take preventive action on the root cause of the accident.

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