Ship to Crane Allision Assessment

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Abstract. According to IMO, international trade 90% depends on seaborne trade. As demands continue to arise, ship’s size continues to increase simultaneously. As loading unloading occurs in port, safety issue regarding ship’s berthing is matters. This study aims to propose a process developing of safety factors in ship’s berthing, which might induce to an allision between ships and cranes. There are several risk factors such technical skills, communication issue, organizational gaps, port layout and facilities, and navigation. The identified risk events are ship’s maneuverability failure, ship’s machinery failure, and ship navigation failure, Meanwhile, the are six identified risk agents, there are lack of pilot competencies, insufficient tugboat power, climate condition, lack of competencies from crew on board, bad berthing procedures given by harbour master, and communication issue between port officer, boatmen, and tugboat pilots.

1. Introduction
International trade is highly dependent on seaborne trade. It is considered cheap and can carry large amounts of cargo at a time. As trade in the world continues to increase, shipping companies are triggered to build larger vessels [2]. Given the importance of this problem, accidents that occur in this trade cycle can have a significant impact on the global economy. Port is a workplace that has complex activities that would induce several risks [1]. The frequency and the density of vessels due to shipping activity at port to conduct its activity, making port as a susceptible object to accident or even business interruption. Indonesia as the largest archipelago country which should have exploit this abundance of maritime assets to support its logistic sectors.

Due to its geographical, port is a vulnerable object which is highly susceptible to many potential threats. Natural disaster is the first potential threat which might disrupt port’s activities and generates downtime and economic loss [10] [8] [11]. Operational failure risk and facilities shortage are another potential threats which often likely to occur [4]. Given the importance of this issue, many researches have been done in ensuring the safety operations at port with respect to operational, organizational, and economic point of view [7]. Risk is a measure of an uncertain event which might produce in terms of likelihood and the consequences. Likelihood or probability can be interpreted as a measure of a tendency for the risk to occur. Consequences is the impact that can emerge from the event. Based on the risk assessment concept, this study examines the process of developing a risk assessment of ship to crane allision using House of Risk Table Model. This study will assess the entities involved in the accident based on risk level acquired from House of Risk model.


2. Method

2.1. Literature Review

Figure 1 above is a procedure to entering port that any ships must follow. In the berthing process, there are 3 main stakeholders which responsible in the event of berthing. Those are port, ship owner, and harbourmaster. Port’s contribution to this event is depending on its management and facility. Port authorities should develop rules and procedures to ensure ship’s safety with the help of adequate layout and facility. From ship owner perspective, the shipping management should provide crews with adequate operational skills and work attitudes. Crew’s skills and attitudes could affect the ship’s safety, if all the equipment on board is not handled properly. Harbourmaster has the right to authorize ships to enter the port’s designated berth. In doing so, harbourmaster often sends marine pilot and tug to assist approaching vessels in safety manners. There are only limited available research regarding marine safety which specific in allision incident.

2.2. House of Risk Model

House of Risk is a risk assessment methodology which was developed from FMEA and House of Quality [3]. It is a qualitative assessment which the quantification involves experts to judge the risks. HOR is divided into two models, HOR I is used to identify the risks and calculate the Aggregate Risk Potential from the Risk Agent. It is a multiplication of occurrence from risk agent and severity from risk event. Since one risk agent may induces several risk events, therefore the ARP is necessary to be calculated. The listed risk will be presented in the HOR I table. Commonly, House of Risk model is used in supply chain activity. It is a risk management method used in supply chain industry. This model is used in this research to analyze allision event to enlist the safety factors and the entities involved in berthing procedure. Based on the ARP value after analyzing the collected data, the most responsible entity will be shown from the figure. The formula of calculating Aggregate Risk Potential is:

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

| Risk Event | A1  | A2  | A3  | A4  | A5  | A6  | Severity of Risk Event |
|------------|-----|-----|-----|-----|-----|-----|------------------------|
| E1         | R11 | R12 | R13 | R14 | .   | .   | S1                     |
| E2         | R21 | R22 | R23 | .   | .   | .   | S2                     |
| E3         | R31 | R32 | .   | .   | .   | .   | S3                     |
| E4         | .   | .   | .   | .   | .   | .   | S4                     |
| E5         | .   | .   | .   | .   | .   | .   | S5                     |

Occurrence of agent: O1, O2, O3, O4, O5, O6

Aggregate Risk Potential: ARP1, ARP2, ARP3, ARP4, ARP5, ARP6

Risk Agent Priority

Figure 2. House of Risk I
In the final stage of HOR I, a Pareto Diagram needs to be established based on the ARP value of each risk agents. Using the Pareto Diagram, the 80:20 principle will be used to determine the preventive actions for entire risk agent. The selected risk agents are agents with ARP value above 80%, with the assumption of the remaining 20% will be able to be prevented if those which are above 80% is given the priority to be prevented.

2.3 Risk Identification

HOR will be used to analyse risk causes added with entities in the risk. These causes will be categorized as risk event and the entities modelled with the risk factors will be the risk agent. Below are the potential risks collected from literature review.

| Potential Risk         | Explanations         | Source         |
|------------------------|----------------------|----------------|
| Pilotage Error         | Steering failure     | Hsu, 2014      |
| Machinery Failure      | Machinery failure    | Bouzaher, 2015 |
| Tugboat Error          | Insufficient tug power | Hsu, 2014     |
| Port Facility          | Failure of port facilities | Bouzaher, 2015 |
| Meteorology            | Climate condition    | Bouzaher, 2015 |
| Organizational gap     | Bad procedure        | Hsu, 2014      |

After the potential risks are gathered, entities involved in the event needs to be identified to model the risk agent. Table 2 below is the entities involved.

| Entities   | Functions                             |
|------------|---------------------------------------|
| Ship       | Request permission to berth           |
|            | Authorizes port entry                 |
| Harbourmaster | Sends a pilot to help navigation     |
| Pilot      | Leads ships to the port               |
| Tugboat    | Assist vessels                        |
| Ship crew  | Responsible for vessel’s operation     |

If the entities already collected, risk factors which might induce the potential risks to occurred need to be identified as well. When the potential risks are gathered, the potential risks and the identified entities are linked thus risk event and risk agent can be clustered.

| Risk Factors       |
|--------------------|
| Technical Skill    |
| Communication Issue|
| Port’s Infrastructure|
| Environment        |
| Navigation         |
| Machinery          |

2.4 Risk Event Identification

In this identification step, risk event and risk agent need to be listed to ease the correlation table making in the aggregate risk potential calculation where the likelihood times consequences times correlation value will result the aggregate value. Table 4 below is the identified risk event based on the risk identification.
Table 4. Risk Event

| Risk Event                  |
|----------------------------|
| Ship’s maneuverability failure |
| Ship's machinery failure    |
| Ship navigation failure     |

Identification of Risk Events above indicates the event possibility of collisions that may occur. This identification aims to solve the events that might occur due to collisions between ships and cranes. With the entities involved in the incident, risk agent must be identified and linked with the entities which might induce the risk event to occurs.

Table 5. Risk Agent

| Risk Agent                                                                 |
|---------------------------------------------------------------------------|
| Lack of Pilot competencies                                               |
| Insufficient Tugboat power                                               |
| Climate condition                                                        |
| Lack of crew competencies on board                                       |
| Bad procedures given by harbor master                                    |
| Communication issues between Port Officer, boatmen, and tugboat pilots   |

After collecting risk event and risk agent, a correlation table is needed in order to calculate the Aggregate Risk Potential. Using the correlation table, we might know how high or low some risk agents are affecting various risk events.

Table 6. Correlation Table

|   | E1        | E2        | E3        |
|---|-----------|-----------|-----------|
|   | Ship’s Maneuverability Failure | Ship’s Machinery Failure | Ship Navigation Failure |
| A1 | Lack of Pilot competencies   | Lack of Pilot competencies | Lack of Pilot competencies |
| A2 | Insufficient Tugboat power  | Insufficient Tugboat power | Insufficient Tugboat power |
| A3 | Climate condition            | Climate condition         | Climate condition         |
| A4 | Lack of crew competencies on board | Lack of crew competencies on board | Lack of crew competencies on board |
| A5 | Bad procedures given by harbor master | Bad procedures given by harbor master | Bad procedures given by harbor master |
| A6 | Communication issues between Port Officer, boatmen, and tugboat pilots | Communication issues between Port Officer, boatmen, and tugboat pilots | Communication issues between Port Officer, boatmen, and tugboat pilots |

3. Result and Discussion
3.1. Risk Event Result
After potential risk events are listed, the list is modified to questionnaire as an instrument to collect the qualitative data. Correspondents from various backgrounds such port operator, ship owner, insurance,
adjuster, and independent surveyor are chosen as they are entities involved in allision incident. Risk event is assessed based on its consequences. Risk events and risk agents measurement is using University Southern Cross Risk Management Policy standard.

| Code | Risk Event Result | Value |
|------|-------------------|-------|
| E1   | Ship’s maneuverability failure | 7     |
| E2   | Ship’s machinery failure       | 5     |
| E3   | Ship navigation failure        | 5     |

3.2. Risk Agent Result

Same correspondents were asked to fill the identified risk agent. Unlike risk event, risk agent value is assessed based on its occurrences. Table below is the result of risk agent values

| Code | Risk Agent Result | Value |
|------|-------------------|-------|
| A1   | Lack of Pilot competencies | 5     |
| A2   | Insufficient Tugboat power | 1     |
| A3   | Climate condition     | 3     |
| A4   | Lack of crew competencies on board | 5 |
| A5   | Bad procedures given by harbor master | 1 |
| A6   | Communication issues between Port Officer, boatmen, and tugboat pilots | 3 |

3.3. Correlation Result

Correlation value between risk event and risk agent will show how high or low is the correlation that occurs between any event that is induced by various risk agent. These correlation result will be used in the Aggregate Risk Potential calculation to measure the risk level of every risk agents listed.

| Event | Risk Agent | Correlation Value |
|-------|------------|-------------------|
| E1    | A1         | 9                 |
|       | A2         | 1                 |
|       | A3         | 3                 |
|       | A4         | 9                 |
|       | A5         | 1                 |
|       | A6         | 3                 |
| E2    | A1         | 9                 |
|       | A3         | 3                 |
|       | A4         | 3                 |
|       | A6         | 0                 |
3.4. ARP Calculation

Risk Agent is a factor that supports the probability of any major risks or it is called as risk event. Risk events will affect conditions that will increase the likelihood of allision between ships and cranes at port. To reduce its severity, port operator or any ship owner and other entities involved in this event, they have to reduce the occurrence level of Risk Agents so that ARP calculations need to be done.

\[
ARP_f = \sum_{j=1}^{n} i \cdot S_i 
\]

\[
ARP_f = 5 \left[ (9 \times 7) + (9 \times 5) + (1 \times 5) \right] 
\]

\[
ARP_f = 565 
\]

**Table 10. Aggregate Risk Potential Calculation Result**

| Code | Risk Agent | ARP |
|------|------------|-----|
| A1   | Lack of Pilot competencies | 565 |
| A2   | Insufficient Tugboat power | 7   |
| A3   | Climate condition | 108 |
| A4   | Lack of crew competencies on board | 465 |
| A5   | Bad procedures given by harbor master | 12  |
| A6   | Communication issues between Port Officer, boatmen, and tugboat pilots | 78  |

Important things to remember is that one risk agent may induce several risk events and it is shown in the aforementioned correlation table. ARP value may get a high result because it is involved in several risk event. House of Risk has its own matrix to present the risk level result. Below is the House of Risk 1 table and the result.

**Table 11. House of Risk Model 1 Result**

| House of Risk | Risk Agent | A1 | A2 | A3 | A4 | A5 | A6 | Severity |
|---------------|------------|----|----|----|----|----|----|---------|
| Risk Event    | E1         | 9  | 1  | 3  | 9  | 1  | 3  | 7       |
|               | E2         | 9  | 1  | 3  | 9  | 1  | 3  | 7       |
|               | E3         | 1  | 0  | 3  | 1  | 1  | 1  | 5       |
| Occurrence    | 5          | 1  | 3  | 5  | 1  | 3  |    |         |
| ARP           | 565        | 7  | 108| 465| 12 | 78 |       |
| ARP%          | 46%        | 100%| 92%| 83%| 99%| 98%|       |
| Rank          | 1          | 6  | 3  | 2  | 5  | 4  |       |
3.5. Pareto Diagram

![Pareto Diagram Result](image1)

**Figure 3. Pareto Diagram Result**

| Code | Risk Agent                                         | ARP | Rank | ARP % |
|------|----------------------------------------------------|-----|------|-------|
| A 1  | Lack of Pilot competencies                         | 565 | 1    | 46%   |
| A 4  | Lack of crew competencies on board                 | 465 | 2    | 83%   |
| A 3  | Climate condition                                  | 108 | 3    | 92%   |
| A 6  | Communication issues between Port Officer, boatmen, and tugboat pilots | 78  | 4    | 98%   |
| A 5  | Bad procedures given by harbor master              | 12  | 5    | 99%   |
| A 2  | Insufficient Tugboat power                         | 7   | 6    | 100%  |

![Pareto Diagram Result (80% Marker)](image2)

**Figure 4. Pareto Diagram Result (80% Marker)**
The Pareto Principle explains that of all the events, 80% of the effects are caused by 20% of the causes. The Pareto Diagram hold the law of 80:20, where it enables to prioritize risk agents which have the high rank of aggregate risk potential [6]. 80% chance of allision occurring at the dock is the result of the 20% of the available Risk Agent. This means that it only needs 20% of all Risk Agents which might cause an effect of 80% or more from the occurrence of allision. By using this Pareto principle, risk management is carried out by making mitigation actions against Risk Agents that have an ARP value below 80%. In this study, by analysing the Pareto principle, Risk Agent A 1 or the lack of pilot competencies on ship has the most influence on the occurrence of allision at the dock.

4. Future Research/Challenges
Due to the limited time given, there are some step ahead to finish the research. The next step is to decide preventive actions to tackle each risk agents based on the pareto diagram. Another future opportunity is that this study is continued by insurance analysis, where some of risk instrument is insurance, where insurance is a tool to decrease financial risk [5]. The insurance tools might be used as a business recovery tools from a major disruption event, where the whole process might lead to a business continuity management study.

5. Conclusion
There are several factors which may induce the allision between ship and crane at ports. A proper safety assessment needed to be done in order to establish a proper berthing procedure for any ships to follow. Factors such port layout, entities involved in this event, tugboat availability is a must consideration. Using House of Risk model modified with entities whose are involved in the risk agent, we may identify the potential risk and the real agent that may induce the risk event, in this case is Allision of ship to crane. There are 3 Risk Events and 6 Risk Agents which might induce the allision to incurred. Based on the analysis of Aggregate Risk Potential calculation, highest rank of risk agent is A 1 or lack of pilot competencies hence mitigation action needed to be done to reduce the risk of allision at port.

6. References
[1] A. Bouzaher, L. Bahmed, F. Masao, and M. Fedila “Designing a Risk Assessment Matrix for Algerian Port Operations,” Springer, 2015.
[2] W. K. Hsu, “Assessing the Safety Factors of Ship Berthing Operations,” The Journal of Navigation, pp. 576–588, 2014.
[3] I. N. Pujawan and L. H. Geraldin, “A Model for Proactive Supply Chain Risk Management,” EmeraldInsight, 2009
[4] Loh, H. S. et al., 2016. Fuzzy comprehensive evaluation of port-centric supply chain disruption threats. Ocean & Coastal Management, Volume 148
[5] S. Snedaker, C. Rima, “Business Continuity and Disaster Recovery Planning for IT Professionals,” ISBN 978-0-12-410526-3 (pbk.)
[6] K. A. Basara, R. O. S., Gurning, K. B., Artana, "Problem Analysis of Misdeclared Container Weight Using House of Risk Approach in Teluk Lamong Terminal," Surabaya, Institut Teknologi Sepuluh Nopember 2019
[7] University Southern Cross Risk Management Policy [Journal]. - Australia : Southern Cross University, 2010. - Vol. 1
[8] Lam, J. S. L. & Su, S., 2015. Disruption risks and mitigation strategies: an analysis of Asian ports. Maritime Policy and Management, 42(5).
[9] H. Alyami, P. T. Lee, Z. Yang, R. Riahi, S. Bonsall, J. Wang, “An Advanced Risk Analysis Approach for Container Port Safety Evaluation,”, Maritime Policy & Management, 41:7, 634-650
[10] Cao, X. & Lam, S. L., 2019. Simulation-based severe weather-induced container terminal economic loss estimation. Maritime Policy & Management.
[11] Lam, J. S. L. & Lassa, J., 2017. Risk assessment framework for exposure of cargo and ports to natural hazards and climate extremes. Maritime Policy & Management.