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Analysis of Ship Collision Risk with Jetty at River Current Speed 2 Knot

Mochamad Junaidi, Dewi Kurniasih, I Putu Sindhu Asmara, Suratno
Shipbuilding Institute of Polytechnic Surabaya
Surabaya, Indonesia

Abstract:- River ports have a major role in the export, import and national trade activities of sea lanes. With these conditions, it causes a heavy flow of ship traffic in the River Shipping Channel. The density of ship traffic makes it possible for ship accidents to occur at the River Port.

The study in this study is to determine the level of risk from the consequences of a ship accident with a Jetty based on a river current that has a speed of 2.0 knots. So that the possible speed of the ship when there was a loss of control that hit Jetty was 2.0 knots.

In this study, the analysis of the risk of ship collisions at the Sungai Harbor uses the DNV GL 2015 Risk Matrix standard. Hazard identification uses the brainstorming method from the DNV and KNKT investigations. Frequency analysis using Bayesian Network model which is applied to Hugin Expert software. The effect analysis is calculated by modeling the ship and Jetty due to the collision using the Ansys software.

The value of the frequency of ship collisions using 3 (three) scenarios with the results of the frequency of each scenario is 0.0638, 0.0285, and 0.0285, respectively. Consequences are calculated by simulation using Ansys software by modeling ship and jetty collisions. The simulation results show that there is damage to the hull of the ship. The estimated cost of repairing the hull is IDR. 587.612.250,00. The risk matrix used is the 2015 DNV GL standard so that the risk level after the analysis is in the Tolerable category.

Keywords:- *Bayesian Network, Ansys, Ships Collision.*

I. INTRODUCTION

Sea transportation facilities play a very important role in the success of development and in efforts to connect between regions of Indonesia. This is because Indonesia is an archipelagic country consisting of many islands so that modes of transportation, especially sea transportation, are very important to support development which includes aspects of life (political, economic, socio-cultural, defense-security) of a nation. The use of sea transportation services is increasing and promising for the future, it needs to be accompanied by better service quality. In this case, the safety of sea transportation is very important in order to reduce the dangers that can cause damage to assets or avoid the death of the crew or ship passengers.

The impact of losses caused by sea transportation accidents is very large which includes material, energy and time. Safety is the most important factor in all activities related to humans. The safety of sea transportation in the maritime world, such as ships or ports, is very important to be a concern.

The number of cases of ship accidents is one indication of the need for improvements in the marine transportation system. Based on reports from the KNKT investigations for the period 2007 to 2014 in Indonesian waters, ship accidents occurred with various types of events such as sinking, overturning, running aground and collisions [1]. Ship accidents that almost increase every year are caused by various errors, including technical factors and human factors such as fatigue, boredom, and carelessness. The comparison of errors caused by technical factors is 51% while the human factor is 49% [2]. From the results of the KNKT investigation, conclusions were drawn regarding the causative factors and contributing factors including human, technical, and weather errors that resulted in accidents such as collisions, equipment failures, explosions, fires, leaks, ran aground, overturned and sinking [2].

River ports have a major role in the export, import and national trade activities of sea lanes. With these conditions, it causes a heavy flow of ship traffic in the River Shipping Channel. According to the Pelindo Annual Report in April 2013, the River has a length of ± 750 km with a width of ± 540 meters, is one of the main gates of the international port network and serves as a consolidation/distribution route for goods from/to the Western Region of Indonesia , with a movement reaching around 27.000 ships in 2008. In 2012 it even reached 41.000 movements [3]. Heavy traffic in river waters causes frequent ship collisions with Jetty. Departing from these reasons, a risk analysis is carried out in the case of ship accidents which includes factors in the ship's work system. The analysis is carried out by taking into account various factors, namely subjectivity when the ship is leaning on the river port.

II. METHODS

The risk analysis includes an analysis of the causes and sources of risk, the positive or negative impact of a risk, and the possibility that a risk may occur. Factors that influence the impact and likelihood of risk events must be identified [4]. The purpose of risk analysis is to separate acceptable minor risks from major risks, and to provide data to assist in evaluating and mitigating risks. Risk is analyzed by combining the estimated consequences and likelihood of risk events in the context of existing control measures [5].

A. *Hazard Identification*

Hazard identification is the first stage of risk analysis. Hazard Identification itself is the stage of identifying all possible hazards.

B. Frequence Analysis

Frequency analysis is the stage of determining the cause of ship accidents and how often these accidents occur within a certain period of time. To calculate the frequency value in this study using the Bayesian Network (BN) method. The software to analyze the frequency value is Hugin Expert software. Hugin Expert is an analysis software that adopts Bayesian Network method to calculate conditional network probability from Bayesian Network structure. Bayesian Network (BN) or more abbreviated Bayesian Nets is a directed acyclic graph (Directed Acyclyc Graph) and belongs to the family of graphic models (Graphical Models). Usually Bayesian Network is used to analyze the probability of events using conditional probability as a basis. The value of the probability of occurrence is obtained by combining the probability distribution or function of different parameters and changing the probability value if there is a new data change. The Bayesian Network (BN) structure classically consists of nodes and arcs. The value of the node can be discrete or continuous, and the most widely used is the discrete node [9].

The basic formula for the equation of Bayes' theorem is :

$$P(A/B) = \frac{P(B/A)xP(A)}{P(B)}$$

Or

$$P(A/B) = \frac{P(A)P(B/A)}{P(B/A)P(A) + P(B/A^c)P(A^c)}$$

where:
P(A|B) is the probability of A occurring if the value of B is known.
P(B|A) is the probability of B occurring if the value of A is known.
P(A) is the value of the probability of A
P(B) is the value of the probability of B.

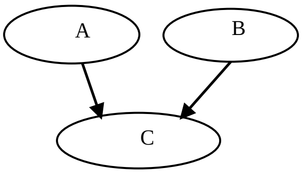

Fig. 1: Exemple Bayesian Network

Bayesian Network consisting of nodes A, B, and C is considered as a random variable. Node C is affected by node A & node B. Node C is the parent while node A & B is the child.

C. Consequence Analysis

Consequence Analysis is the stage of determining the impact or consequences that occur due to ship accidents. There are many methods that can be used to calculate the consequences of a ships collision. In this study using ANSYS Explicit Dynamics software to analyze the damage to the hull due to a collision with the Jetty through the Finite Element Method (FEM) approach. ANSYS Explicit Dynamics is a software that can simulate the response of structures to loading in a short duration such as collisions and others.

Because the river current has a speed of 2.0 knots towards the east, so the possible speed of the ship when it lost control that hit Jetty is 2.0 knots [18]. Then the ship's impact energy uses a speed of 2.0 knots. The combination of frequency and consequences to be applied to the DNV GL Risk Matrix (2015) uses the frequency value of 3 (three) scenarios and the consequence value with a ship speed of 2.0 knots. To calculate the magnitude of the deformation of the hull plate due to hitting the Jetty by using the collision energy formula between the ship and the Jetty. The equation for the ship's impact energy formula based on the size of the ship leaning on the dock is as follows [8][17][19]:

$$E_n = \frac{WV^2}{2g} C_m C_e C_s C_c$$

Where:

E_n = normal impact energy (tonm).
W = ship weight (ton).
V = speed of the ship docking in the perpendicular direction (m/s).
g = gravity (m/s^2).
C_m = mass coefficient.
C_e = eccentricity coefficient.
C_s = roughness coefficient.
C_c = shape coefficient of mooring.

Oil Tanker Ships	
LoA	: 160m
LPP	: 154m
Breadth	: 27m
Depth	: 11,5m
Draught	: 5,2m
Speed	: 13 knots
Engine	: MAN B & W 6.650 HP
Deadweight	: 17500 ton
Gros tonnage	: 13964 ton
Crew	: 37

Table. 1: Ships Dimension

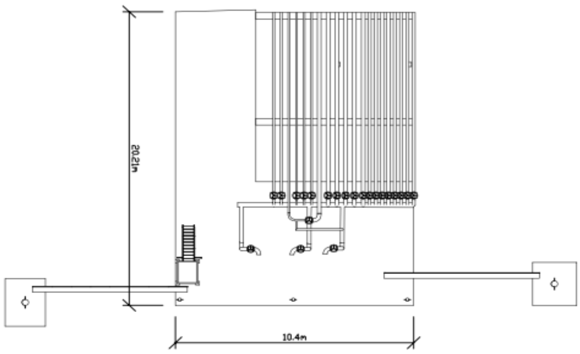

Fig. 2: Jetty Dimension

D. Risk Analysis

Risk analysis is a stage in determining the risks that occur due to ship accidents. The known risks are then displayed in the form of a risk matrix. Assessment of the risk level of the identified activities in relation to the level of likelihood and severity can be seen in the risk table below. In this study, the

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risk matrix reference standard used is the risk matrix standard from Det Norske Veritas GL (DNV GL 2015) [10].

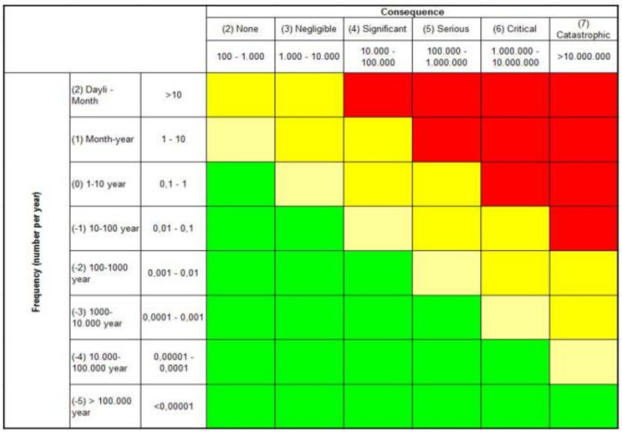

Fig. 3: Risk Matriks

Color	Risk Category
(green)	Negligible
(light yellow)	Tolerable
(yellow)	Unwanted
(red)	Unacceptable

Table. 2: Risk Category

E. *Risk Summation*

The summation of risk is the stage of determining the level of risk of a system into a risk matrix. The risk matrix used is the DNV GL risk matrix (2015) [10]. The level of risk that may occur is at risk level 1 to risk level 4.

III. RESULT

A. *Hazard Identification*

The purpose of hazard identification is to identify sources of hazards that can result in ship accidents. Hazard identification can use historical data or expert judgment. Based on research from the DNV report 2003 and investigations that have been carried out by KNKT in general, the sources of danger that result in ship accidents are [2] [11]:

- There is a disturbance when the officer is at work.
- (Human Factor).
- Failure of INS/IBS (Integrated Navigational System /Integrated Bridge System, including software)(Navigasi failure)
- Bridge and poor physical working conditions. (Engine failure)
- Wrong in predicting the traffic situation. (Weather, visibility)
- Officers who are not familiar or do not quite understand properly about the ship. (Human Factor)

B. *Frequence Analysis*

The Bayesian Network structure model in this study refers to the Bayesian Network structure research conducted by DNV report (2003), Aldara (2020) [6] [7]. For the calculation of frequency analysis using 3 (three) scenarios that allow a ship to collide with a Jetty.

The Bayesian Network structure model that can cause ship collisions can be seen as shown in Figure 4.

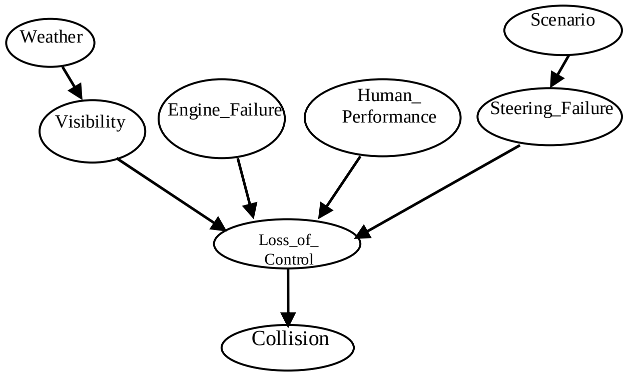

Fig. 4: Bayesian Network Structure of Collision Ships

These three scenarios are adopted from research conducted by DNV (2003) regarding the process of ship collision [6]. The 3 scenarios can be explained in Figure 5.

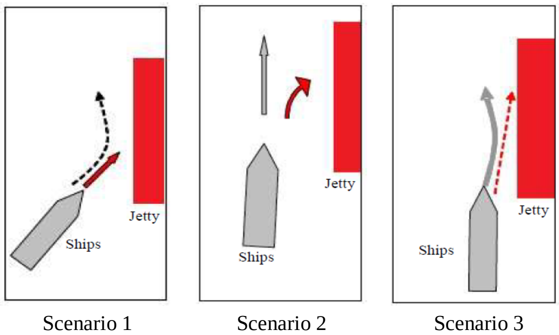

Fig. 5: Scenario Ships Collision

- Scenario 1: The ship was supposed to change course to dock but the ship collided with Jetty.
- Scenario 2: The ship was on track to dock but the ship ended up crashing into Jetty.
- Scenario 3: The ship changes course with a suitable course to dock but the ship ends up crashing into Jetty.

To calculate the frequency value using the Bayesian Network based on the results of the previous hazard identification, it is necessary to enter the value of each node. The occurrence of ship accidents due to loss of control because it is influenced by several factors, namely: weather, human performance, engine failure, or failure of the steering system.

The first step is to determine the probability of each node that has been created in the Hugin Expert software. The following is an explanation of each node along with the probabilities of these nodes:

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a) Scenario .
The scenario node explains the occurrence of ship deviations from the proper path in a narrow area trajectory. The probability value of deviation occurs [6].
Scenario 1 : 0.669
Scenario 2 : 0.003
Scenario 3 : 0.002

b) Weather.
The *Weather* node defines a description of the weather conditions [12].
- *Good Weather* : 0.993
- Bad Weather/Heavy Rain : 0.007.

c) Visibility.
The Visibility node describes the ship's visibility around the pier area related to the weather [6].
- < 1 nm.
- > 1 nm.

d) Engine Failure.
The Engine Failure node explains the probability of damage to the ship's propulsion engine [13].
- Engine Failure : 0.000014
- No Engine Failure. : 0.999986

e) Human Performance.
The Human performance node explains the influence of human factors on its performance which can result in ship accidents [14].
- Good Human Performance : 0.9950902
- Bad Human Performance : 0.0049098

f) Steering Failure.
The steering failure node explains the reliability of the steering system which functions as the ship's bow [15].
- Steering Failure : 0.0000343
- No Steering Failure : 0.9999657

g) Loss of Control.
The Node loss of control explains the possibility of the ship losing control due to engine failure, steering system failure, human factors, or weather conditions. The loss of control node states that the ship is in two possible conditions, namely [6].
- Loss of Control
- No Loss of Control

At this node the probability value is 1 if the ship loses control, resulting in a ship accident. The probability value is 0 when visibility is good, there is no engine failure, no control system failure occurs, and workers have good performance so that the ship is under control.

h) Collision
The Node collision explains the occurrence of a ship collision with a Jetty in the Ship in Cross Area because it is not in the actual traffic lane. The probability of a ship colliding with a Jetty at Ship in Cross Area using the 1999 Spouge formula is : 0.0813 [16].

The next step is to apply the Bayesian Network structure based on the nodes and the probability that has been planned on the Hugin Expert software to obtain the frequency value of ship accidents or collisions.

The results of the simulation frequency values from the Hugin Expert software that have been applied to the Bayesian Network (BN) structure for ship collisions are as shown in table 3.

Oil Tanker Ships	
	Frekuensi
Scenario $1_{(BN)}$	0.0638
Scenario $2_{(BN)}$	0.0285
Scenario $3_{(BN)}$	0.0285

Table 3: Frekuensi $\text{Scenario}_{(BN)}$

C. Consequence Analysis

Consequences that occur as a result of ship accidents using ANSYS Explicit Dynamics software. Analysis of damage to the hull with the Finite Element Method (FEM) approach. The process and result of consequence analysis using Ansys software on a ship collision with a speed of 2.0 knots as shown in Figures 6 & 7 . The ship's impact energy at a speed of 2.0 knots is (E_n)= 3.147,063 kNm.

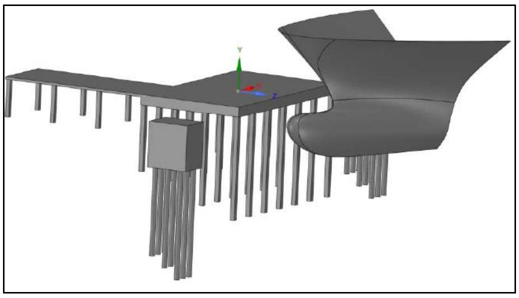

Fig. 6:- Collision Ships Process

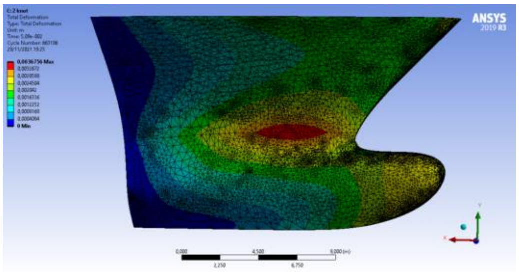

Fig. 7: Hull deformation

After running on the ANSYS Explicit Dynamics software, the results are as shown in table 4 below :

Speed	Deformation Area (m^2)	Normal Stress (Mpa)	Shear Stress (Mpa)
2.0 knot	171,131	14,159	16,91

Table 4: Deformation Area

With a deformation area of 171,131 m^2, then the cost of repairing the deformed hull plate is calculated. The calculation of repair costs in the 171,131 m^2 deformation area can be seen in table 5.

No	Plate thicknesst (mm)	Plate size (mm)	Qty	Weight /sheet (kg)	Total Weight (kg)	Price/kg	Total price
1	Plate 10	1524 x 12192	10	1.459	14.590,00	IDR.7.875,00	IDR.114.896.250,00
2	New plate repair cost				14.590,00	IDR..32.400,00	IDR.472.716.000,00
Amount of Expenditure for hull deformation repair							IDR.587.612.250,00
							€.36.138,18

Table 5: Cost of repairs

The total cost needed to repair a ship that had a collision with a hull deformation of 171,131 m^2 was IDR 587.612.250,00 or € 36.138,18 That number could be even greater if the finishing work stage is needed.

D. Risk Matrik Assessment

From the data obtained from the Bayesian Network after being applied to the Hugin Expert software, the frequency of ship collisions with Jetty is as in table 3, so that the frequency lies at level -1 (1 - 10 years = 1 time an accident occurs)[10].

Consequence data obtained from the ANSYS software application with a deformation area of 171,131 m^2 if repairs are carried out, the costs for consequences are €.36.138,18. This means that the consequences are located at level 4 (Significant)[10].

Furthermore, mapping the frequency value and consequence value on the Risk Matrix based on the DNV GL (2015) standard to determine the risk profile of the dangers that may occur in the event of a ship collision with a Jetty which is described in Figure 8.

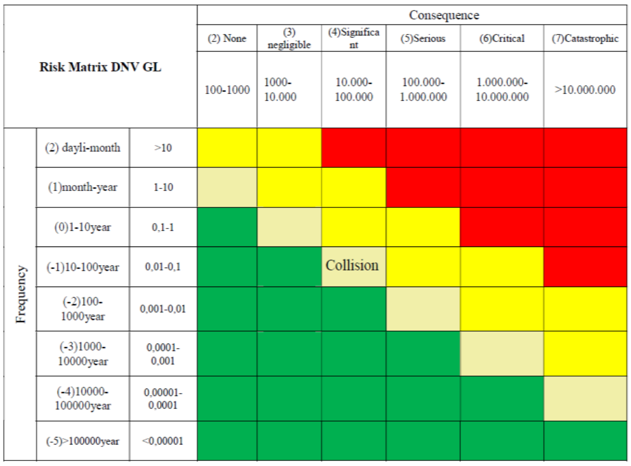

Fig. 8: Risk Matrik Collision

The final result of this risk assessment is that the frequency is at level -1 and the consequences are at level 4, so the risk level for this case is in the Tolerable category.

IV. CONCLUSIONS

From the results of processing and analyzing data related to the formulation of the problem and objectives in this study, the following conclusions can be drawn:

- Based on the results of investigations from competent and experienced parties, the general causal factors that contribute to ship accidents include human error, technical, and weather.
- Based on the results of running on the Hugin Expert software using the Bayesian Network method from the previous hazard identification, the frequency results in 3 (three) scenarios are 0.0638, 0.0285, and 0.0285.
- Based on the results of running the Ansys software, the consequences due to deformation if the repair is carried out will cost IDR 587.612.250,00 or € 36.138,18
- Based on the results of the combination of frequency and consequences applied to the 2015 DNV GL Risk Matrix, the risk level is in the Tolerable category.

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